The AFNETA
Alley Farming Training Manual

VOLUME 1

Core Course in Alley Farming

The AFNETA

ALLEY FARMING TRAINING MANUAL

Volume 1: Core Course in Alley Farming

Alley Farming Network for Tropical Africa - Ibadan 1992

Network Coordinator: Kwesi (A.N.) Atta-Krah
Assistant Coordinator: N. Sanginga

Editors: Bansh R. Tripathi and Paul J. Psychas

About AFNETA

The Alley Farming Network for Tropical Africa (AFNETA) was established in 1989 to promote and coordinate alley farming research and development within the national agricultural research systems (NARS) of the region. Network activities include collaborative research, individual and group training, and information dissemination and exchange.

AFNETA/NARS collaborative research projects are found in 20 different countries and in all major agroecological zones. The main topics of research are screening of multipurpose trees, alley farming management trials, livestock integration in alley farming, and on-farm R & D and socioeconomic investigation. AFNETA collaborates with several other networks, institutions and organisations in the implementation of its programs.

Three international research centers founded AFNETA and now provide technical backstopping: the International Institute of Tropical Agriculture (IITA), the International Livestock Centre for Africa (ILCA), and the International Centre for Research in Agroforestry (ICRAF). IITA, which houses the network's coordination unit, also provides administrative support.

Financial support for coordinating activities has been provided by the International Development Research Cente (IDRC) and the Canadian Agency for International Development (CIDA). Major funding for national research activities has been provided by the International Fund for Agricultural Development (IFAD), with additional support from the Danish International Development Agency (DANIDA). The United States Agency for International Development (USAID) has supported the collaborative research projects at U.S. universities.

Printed at the International Livestock Centre for Africa, Addis Ababa

ISBN 978-131-074-X (Volume 1)
ISBN 978-131-075-8 (Volume 2)

Address any inquiries or suggestions to:

The Coordinator, AFNETA, International Institute of Tropical Agriculture, PMB 5320, Oyo Rd., Ibadan, Nigeria

Telephone: (022) 400300-400314. Telex: TROPIB NG 31417
Cable: TROPFOUND IKEJA

Preface

Training is one of AFNETA's most important activities. In order to participate fully in AFNETA's collaborative research program, scientists and technicians of national agricultural research institutions require training on the concepts and principles of alley farming as well as on the research methodologies for studying different aspects of the system.

AFNETA employs a train-the-trainer strategy in its training program. Regional training courses are organized at four centers in Africa, in collaboration with national institutions. A core group of trainers from each center has undergone trainer-training to enable them to plan, implement, and evaluate the regional courses. Two regional course, one anglophone, and one francophone, are held each year. In addition, a central training workshop, focusing on a strategically important aspect of alley farming, is held each year at the International Institute of Tropical Agriculture (IITA), Ibadan. It is principally for these training courses that the AFNETA Alley Farming Training Manual has been developed.

This training manual is a collaborative project of the three International Agricultural Centres affiliated to the network: the International Institute of Tropical Agriculture (IITA), the International Livestock Center for Africa (ILCA), and the International Centre for Research in Agroforestry (ICRAF). The manual draws on articles, training materials, and illustrations prepared by scientists and support staff from the three institutions.

The manual has been written with two readerships in mind. First, it is intended for use in AFNETA's training courses, at which African scientists learn how to carry out alley farming research within the framework of AFNETA's collaborative research programs. Most of these scientists have backgrounds in agriculture, forestry, or animal husbandry, and are employed within national research systems.

Secondly, it is intended for any person interested in practicing or experimenting with alley farming. Interest in alley farming is increasing, not only in national research systems, but in non-governmental organizations, development agencies, and among private farmers. Extension agents in many parts of Africa are beginning to be asked to promote the technology. The manual addresses the growing need for readily accessible, technical information on alley farming.

The manual is published in two volumes. Volume 1, the *Core Course in Alley Farming*, has been designed as a basic, six-unit curriculum for short training courses. The Core Course introduces the theory and practice of alley farming, and acquaints the trainee with the major research topics. Volume 2, the *Source Book for Alley Farming Research* is a collection of technical papers for reference and for further study. Each unit and technical paper includes a set of "feedback exercises" as an aide to self-teaching. Those scientists who will go on to conduct field experiments will want to make use of AFNETA's documentation on research guidelines and data collection requirements (available from the Coordination Unit).

In its present form, the manual is presented as a test draft, for use and review in a number of training programs. Any suggestions for improvements from readers are welcome.

Kwesi Atta-Krah

Coordinator, AFNETA
Ibadan, 1992

Acknowledgement

This training manual has been made possible through support and contribution from several institutions and individuals.

AFNETA would like to thank the directors general of IITA, ILCA and ICRAF, who made it possible for their institutions to be involved in the development and production of this manual. We would also like to acknowledge the support and input of Drs. Jim Gulley (IITA), Esther Zulberti (ICRAF), Bansh Tripathi (ILCA) and Michael Smalley (ILCA).

Several scientists from IITA, ILCA and ICRAF prepared technical papers for this manual, and we are grateful to all of them. Our thanks also go to the secretaries and other technical and support staff who contributed in various ways towards the development of this manual. A full list of contributors is given on the following page.

List of Contributors

AFNETA Secretariat

Dr. A.N. Atta-Krah, agroforester and AFNETA Coordinator,
Dr. N. Sanginga, microbiologist and AFNETA Assist. Coordinator
Mr. Paul Psychas, science writer/editor
Mr. Yinusa Aiwinni, secretary
Mr. Abel Iyun, typist
Miss Shade Oyebanji, secretary

International Institute of Tropical Agriculture (IITA)

Dr. B.T. Kang, soil scientist/agronomist
Dr. Karen Dvorak, agricultural economist
Dr. K. Mulongoy, soil microbiologist
Mrs. Rose Umelo, editor
Miss Charity Nnaji, typist
Mrs. Adeola Ala, illustrator
Mr. Jide Ojurongbe, graphics production manager
Mr. Hendrick Pleysier, illustrator
Mr. Simeon Ughiekai, illustrator

International Livestock Centre for Africa (ILCA)

Dr. J. Cobbina, agronomist
Dr. P.A. Francis, socioeconomist
Dr. M.A. Jabbar, agricultural economist
Dr. L. Reynolds, animal scientist
Dr. B.R. Tripathi, agricultural educator
Mr. Mandefro H. Giorgis, audio-visual assistant
Mrs. Sosena Tilahun, secretary

International Centre for Research in Agroforestry (ICRAF)

Dr. M. Avila, principal scientist/agricultural economist
Ms. Damary Odanga, graphics manager
Dr. F. Owino, senior scientist/tree breeder
Hirst Studio Productions (illustrations)

International Centre of Insect Physiology and Ecology (ICIPE)

Dr. Sagary Nokoe, biometrician

AFNETA's Alley Farming Training Manual, 1992

VOLUME 1: Core Course in Alley Farming

VOLUME 2: Source Book for Alley Farming Research

Table of Contents

VOLUME 1:

CORE COURSE IN ALLEY FARMING

UNIT 1

Introduction to Alley Farming

Unit 1: Introduction to Alley Farming

***Main contributor:* B.T. Kang**

1.0 PERFORMANCE OBJECTIVES

Unit 1 is intended to enable you to:

1. Discuss the importance of alley farming in sub-Saharan Africa in the context of declining agricultural productivity in the region.
2. Discuss the potential of agroforestry technologies for addressing the ecological and economic constraints of small-scale farming.
3. Describe the essential characteristics of an alley farming system.
4. Compare and contrast alley farming with the bush-fallow system.
5. List major benefits of alley farming.
6. Recall major stages in the development of the alley farming concept in tropics.
7. Demonstrate your familiarity with recent research concerning alley farming's effects on soil properties and crop production.
8. Describe the priority areas for applied and basic research in alley farming.
9. Explain the functions and strategy of the Alley Farming Network for Tropical Africa (AFNETA).

1.1 THE RATIONALE FOR ALLEY FARMING IN TROPICAL AFRICA

Alley farming integrates modern science with the art and wisdom of traditional bush-fallow cultivation (slash-and-burn agriculture). Alley farming is a low-input system that has great potential for increasing food production in the humid and subhumid tropics. Its methods are more intensive and productive than the cyclic cropping practices which characterize Africa's traditional farming systems. At the same time, alley farming provides a way to sustain agricultural production in the face of rising land pressure and worsening soil degradation.

1.1.1 Africa's Agricultural and Environmental Crisis

Much of the uplands in the humid and subhumid tropics is used for traditional shifting cultivation farming. This is particularly the case in sub-Saharan Africa, which is dominated by low activity clays soils that are less suitable for conventional mechanized and high-chemical-input farming. Such traditional farming, because of rapidly increasing human population and subsequent land use pressure, cannot feasibly be practiced on a sustainable basis. Conversely, capital-intensive agricultural technologies, though agronomically feasible in selected areas, are not affordable for the small-scale family farmers who comprise the majority of the agricultural population in tropical Africa. Farmers are faced with progressively degrading soil, decreasing crop yields, and limited access to commercial inputs. There is an urgent need to provide them with technologies that have significant returns and long-term sustainability.

During the past two decades sub-Saharan Africa has witnessed a steady decline in its agricultural productive capacity (Figure 1-1). The cumulative result is that the region, which in the 1950s and 1960s was virtually self sufficient in food, has become a net importer of food. In 1985 twenty percent of Africans depended for their food supplies on food imports and food aids.

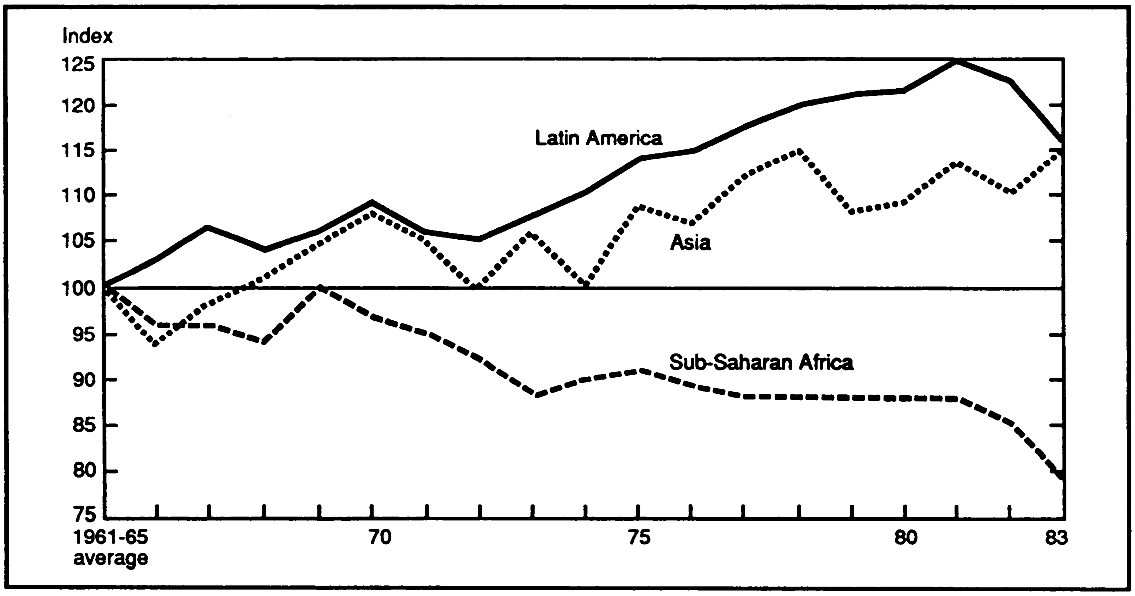

Figure 1-1. Per-capita food production in sub-Saharan Africa declined steadily during the 1970s and early 1980s. This alarming trend stimulated investigations into the suitability of alley farming in tropical Africa.

(Source: data from US Dept of Agriculture, as adopted in World Bank (1984) Toward Sustainable Development in Sub-Saharan Africa)

This agrarian decline coincides with increasing environmental degradation. The land use patterns associated with traditional cultivation systems are extensive (rather than intensive), and disturb more land than actually required for farming. In many areas, the current high rate of population growth and the resultant land pressure have sharply reduced restorative fallow periods. The land is no longer allowed to rest adequately. These factors, in combination with inappropriate "modern" farming methods, have resulted in increased rates of deforestation, soil erosion, and land degradation. It has been estimated that tropical Africa is losing annually more than 3.7 million hectares of forest cover. Of this, almost 70 percent is due to shifting cultivation involving clearing of forest in the humid zone or patches of grasses and trees in the subhumid zone.

The practice of repeated and frequent burning in the traditional systems further adds to the problem of land degradation. There is considerable evidence that repeated flash burning of vegetation causes increased "grassification". Since, in the majority of cases in the humid and sub-humid tropics, the grasses are less effective in soil rejuvenation than the original vegetation, land degradation is a common phenomenon. The degradation of land is one of the most alarming features of the African food and environmental crisis.

1.1.2 Bush-Fallow Systems no longer Viable

In many parts of the humid and sub-humid tropics, particularly in Africa, the dominant food crop production pattern is the bush-fallow system, also called shifting cultivation or "slash-and-burn". In this system, short cropping periods (1-3 years) alternate with long fallow periods (6 or more years).

The restorative power of fallows is linked to the regrowth of deep rooted trees and shrubs that recycle plant nutrients and build up soil organic matter (Figure 1-2). During the fallow period, plant cover and leaf litter protect the soil from the impact of high intensity rain, and roots help to bind the soil, increase water infiltration, and reduce run-off and soil erosion. In addition, the mulch and the shade provided by tree and shrub canopies reduce soil temperature and maintain soil moisture conditions that are favorable for beneficial soil organisms. Shading also reduces weeds.

As well as restoring soil fertility, the bush-fallow system provides food, livestock feed, staking and building materials, firewood, and herbal medicines. Where land is abundant, the bush fallow system has proved to be a stable and efficient method

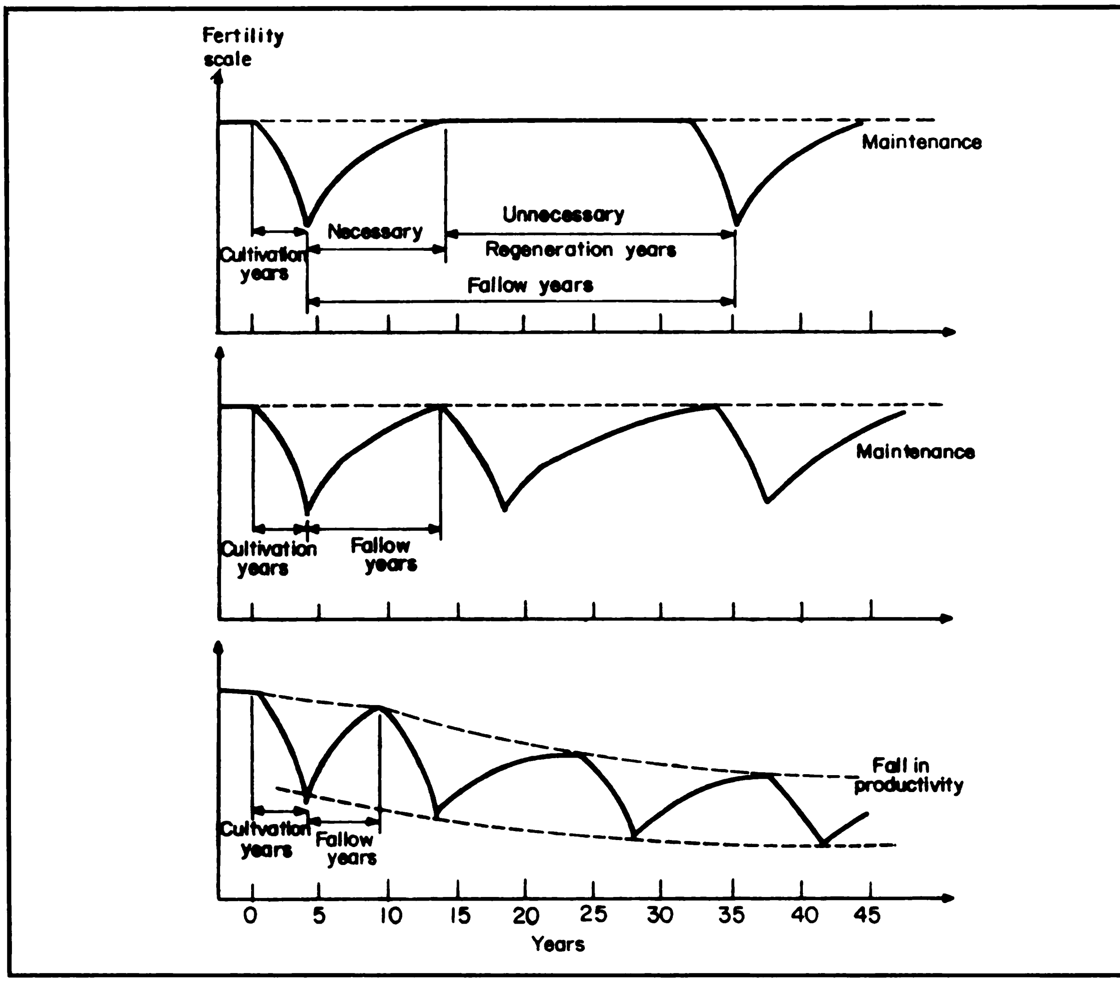

Figure 1-2. Theoretical relationship between length of fallow and soil productivity (Guillemin, 1956). When fallow periods are shortened beyond a restorative threshold point, soil fertility and productivity decline. (Agron. Trop. II, 143-176)

for restoring soil productivity. Food crops grow well on newly cleared land after a long rest period.

The efficiency of shifting cultivation depends on two related factors: (1) the duration of the fallow period, and (2) the nature and density of the fallow vegetation. Rapid increases in human population and the associated increases in demand for farmland and wood products have over-stretched this traditional system. Long fallow periods, which in the past lasted 10-25 years, have been shortened drastically or have disappeared in most areas of Africa. This has resulted in increasing degradation of farmland, increasing infestation by problem weeds, and declining food crop yields. Fertilizer use has not been a viable option in much of the tropics, because of its high cost and unavailability to most smallholder farmers, especially those in sub-Saharan Africa. Even where such inorganic fertilizers are available, continued use of high rates of N fertilizer may lead to soil acidity problems.

The loss of soil fertility proceeds rapidly, because the nature of much of Africa's soils is such that over-exposure and over-cultivation can easily lead to their degradation. Agricultural land in the humid and sub-humid tropics is dominated by low activity clays (LAC) soils. The inherent characteristics and limitations of LAC soils make the large upland areas which they dominate less suitable for conventional mechanized and high-chemical-input farming methods. These soils have inherently low fertility, and are highly erodible when left unprotected.

1.1.3 The Potential of Agroforestry

It is widely recognized that the biggest challenge facing agricultural research in the tropics is the development of farming systems capable of ensuring increased and sustained productivity with minimum degradation of the soil resource base. Reversing the trend of declining per-capita food production in sub-Saharan Africa, therefore, does not depend solely on the development of improved and high-yielding crop varieties. Development of sustainable production systems is necessary to foster and maintain advantages derived from such improved varieties. Systems are needed that incorporate the biological stability and nutrient balance characteristic of the traditional shifting cultivation system, while allowing intensification of production over the long-term.

Africa's agricultural predicament presents a two-fold challenge for agricultural research:

- to increase the productivity and income of small-scale, resource-poor African farmers
- to provide such farmers with appropriate technologies and systems that will enable them to intensify their production.

What type and level of technologies and systems are needed? This is a big question. According to the U.S. Office of Technology Assessment (1988), desirable technologies should meet four criteria. They should be:

- technically and environmentally sound,
- socially desirable,
- economically affordable, and
- ecologically sustainable.

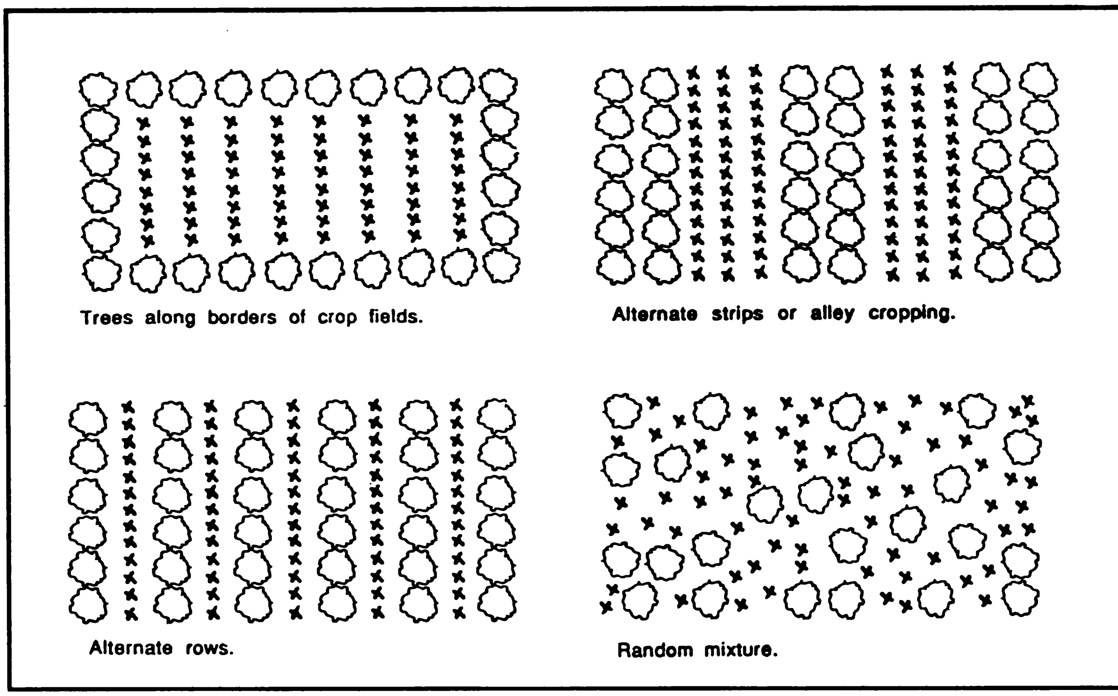

Figure 1-3. Agroforestry systems under various spatial arrangements. Alley farming is one type of agroforestry.

During the past two decades there has been an increasing interest in using the agroforestry approach for developing more productive, low-input, and sustainable land use technologies. Agroforestry technologies frequently meet all four of the above criteria. Agroforestry is an integration of a tree component into an agricultural production and land use system (Figure 1-3). Such systems have been widely acclaimed as a solution to tree depletion, soil degradation, and declining yields under shifting cultivation. Agroforestry is a sustainable land management system which increases the overall yield of the land. It combines, simultaneously or sequentially, the production of trees and the production of crops and/or animals on the same unit of land, and it applies management practices that are compatible with the cultural practices of the local population.

In the tropics, trees have long been recognized as essential both for the stability of the environment and for maintenance of soil fertility for crop production. Trees have been recognized as major elements in soil fertility regeneration and conservation, as reflected by their prominence in traditional farming systems. One agroforestry system that has received a good deal of research attention and has shown great promise for sustainability is alley farming.

Figure 1-4. **A newly planted alley farming plot. Hedgerows of multipurpose trees are planted at 4-6 meter intervals for humid or sub-humid zones. Food or fodder crops are planted in the "alleys" between. This farmer produces his own fertilizer.**

1.2 DESCRIPTION OF ALLEY FARMING

1.2.1 Essential Characteristics of the System

Alley farming is an agroforestry system in which food or forage crops are grown in the "alleys" between hedgerows of trees or shrubs. The trees or shrubs — preferably fast-growing, leguminous (nitrogen-fixing) species — are established in hedgerows usually spaced 4-8 meters apart. The trees are periodically pruned and managed during the cropping phase to prevent shading of the companion crops. The prunings of foliage and young stems are incorporated into the soil as green manure or used as mulch. Some portion of the tree foliage can be harvested and fed to livestock, particularly small ruminants. Alley farming is a scale-neutral system; though initially developed for smallholders, it can also be adapted for mechanized large-scale farming. The system has been tested successfully with the use of appropriate woody species and crop combinations under on-farm conditions in West, Central, and East Africa.

Alley farming goes by different names in certain publications and regions. The International Council for Research in Agroforestry (ICRAF) calls the system "hedgerow intercropping". In Sri Lanka, it is called "avenue cropping". Some authors call it "contour hedgerow farming". Similar farming approaches have been tried with success in other parts of the tropics such as the *Leucaena* contour terracing system in eastern Indonesia and the sloping agricultural land technology (SALT) in the southern Philippines. Certain authors make a distinction between "alley farming" (livestock component included) and "alley cropping" (no livestock component). In this manual, such a distinction is not used.

Figure 1-5. Alley farming with bananas and *Leucaena*. The hedgerows allow more intensive banana production by providing mulch, poles, and shading of young plants.

1.2.2 Comparison to Bush-Fallow System

Alley farming is designed to be a sustainable alternative to traditional bush-fallow systems (shifting cultivation). It is a low-input, improved bush-fallow system that can be sustained even under conditions of land scarcity. As a substitute for traditional slash-and-burn systems, it offers the opportunity to reduce deforestation and land degradation.

The woody hedgerow component of the alley farming system retains the basic features of the bush-fallow for soil protection, nutrient recycling, weed suppression, and for provision of browse, staking material, and firewood. Alley farming parallels

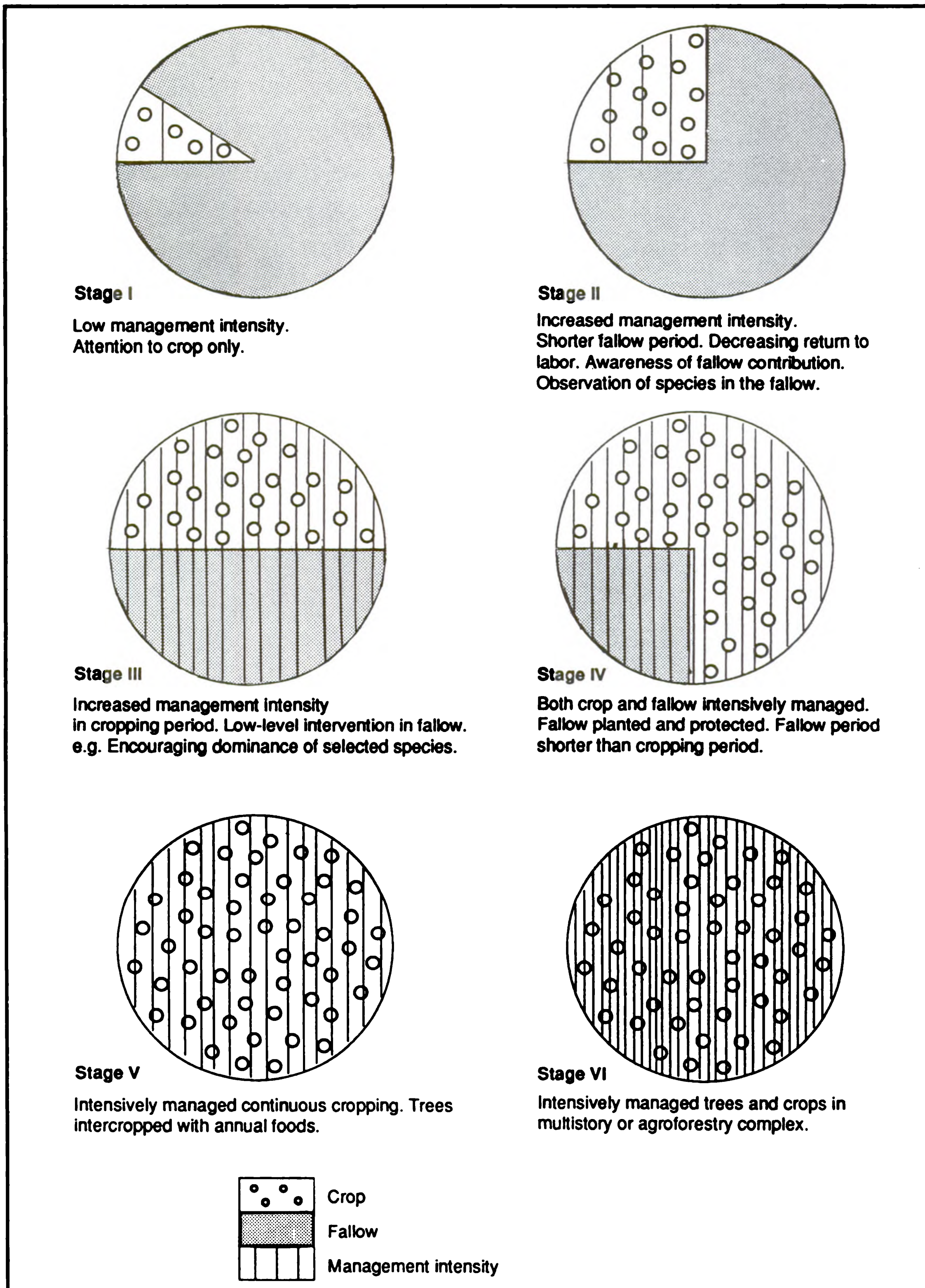

Figure 1-6. Stages in the evolution of managed fallows and multistory agroforestry in the humid tropics. Stages I, II, and III represent traditional bush-fallow systems. Alley farming techniques may be incorporated in stages IV, V, and VI.

bush-fallow systems in the sense that tree foliage is used to maintain and improve soil fertility. However, land-use efficiency is higher because cropping and fallow are carried out on the same plot of land, at the same time.

As an improved system, alley farming has various advantages over the bush fallow system, but also requires more labor and management inputs, as shown in Table 1-1. Alley farming may be most attractive in places where farmers feel a need to intensify crop production but face soil fertility and/or soil erosion problems. This situation is often characteristic of densely populated areas, but may also occur wherever some farmers wish, or are forced, to increase production on a plot of limited size.

Table 1-1. Differences in management of traditional bush fallow and alley farming systems (Source: Kang et al., 1989).

Traditional Bush-Fallow	Alley Farming
• Mixed native woody species retained	• Woody species selected, preferably fast-growing legume species
• Irregular planting pattern	• Hedgerow pattern
• Before cropping, trees and shrubs are cut back and burnt to release nutrients	• Trees and shrubs are periodically pruned, with prunings used as mulch and green manure
• Fire used for controlling growth	• Periodic prunings control hedgerow growth
• Short-term cropping allowed	• Continuous cropping allowed

1.2.3 Summary of Benefits

Alley farming shows great promise as a sustainable production system. An alley farming system has the potential to provide the following major benefits:

- allows a longer cropping period, more intensive cropping, and higher crop yields,
- regenerates soil fertility rapidly and effectively,
- reduces requirements for external inputs of fertilizer.

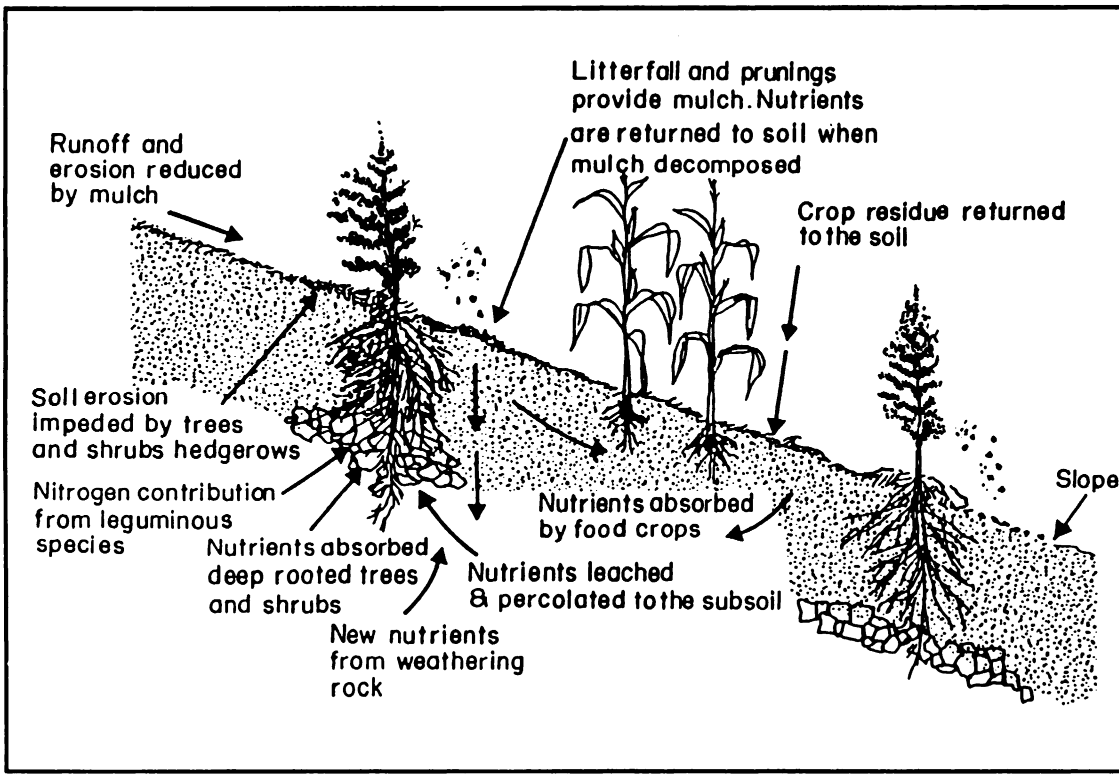

Figure 1-7. A schematic representation of the benefits of nutrient cycling and erosion control in an alley farming system (Kang et al., 1989).

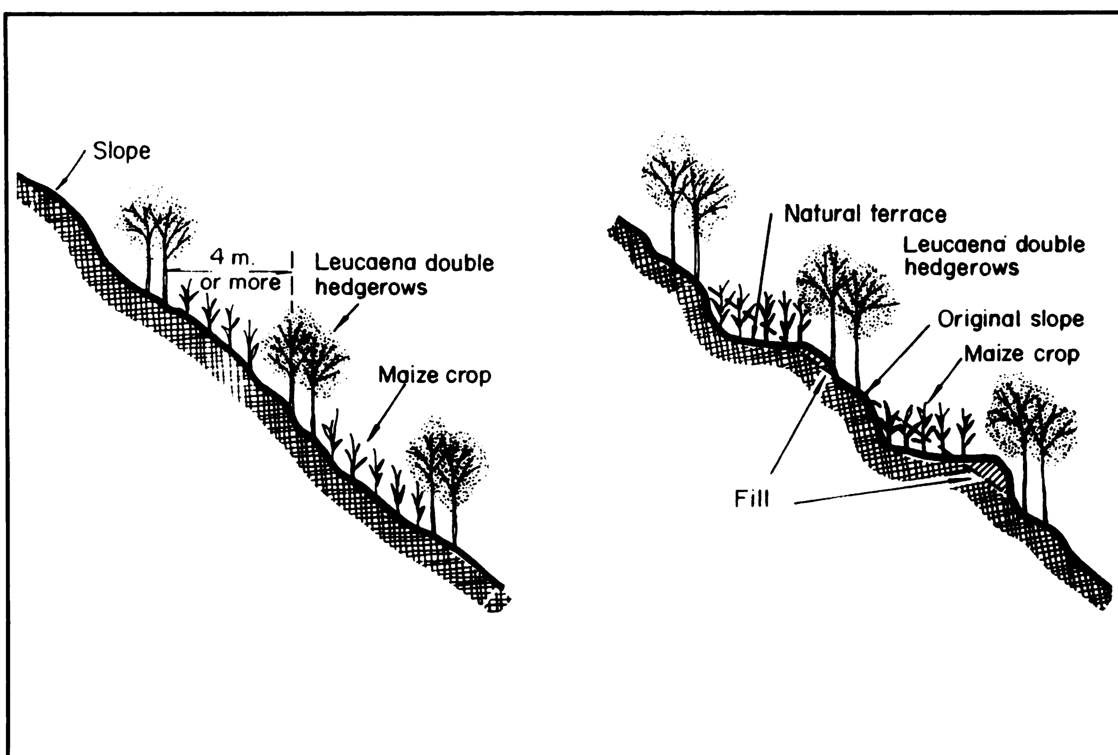

Figure 1-8. Formation of natural terace across the slope after 3 years of continuous alley farming management (After Picardo, 1984).

Obtaining the full benefits of the system depends on an appropriate design, successful hedgerow establishment, and efficient management. Fertility regeneration and other key benefits depend on the use of appropriate multipurpose trees species in the hedgerows.

The hedgerows in the system can offer some or all of the following benefits:

- provide green manure and mulch for companion crops,
- provide biologically fixed nitrogen for companion crops,
- improve soil conservation,
- create favorable conditions for beneficial soil organisms,
- provide high-protein fodder for livestock,
- provide staking material and/or firewood.

If portions of the hedgerow prunings are fed to livestock, this will reduce the quantity available for fertilization purposes.

1.3 HISTORY OF ALLEY FARMING RESEARCH

Some aspects of the alley farming system have been used for generations by traditional farmers at Mbaise in southeastern Nigeria. In this production system on highly acid Ultisols, farmers plant *Acioa barteri* hedgerows for nutrient cycling, weed suppression, browse, and especially for staking material. The *Acioa barteri* hedgerows are pruned and burned before a short cropping cycle of 1-2 years. They are again pruned before starting the next cycle.

As far back as the early 1920s, Nalaad farmers in the Philippines were practicing a basic form of alley farming, using the leguminous tree *Leucaena leucocephala* to terrace steep slopes and provided green manure for crops. In the 1930s, the Dutch colonial government introduced the same technology on contour terraces on the island of Timor in eastern Indonesia, planting *Leucaena* hedgerows three meters apart to control erosion and improve soil fertility. The first published research on alley farming, by Hernandez in 1961 (cited in Benge, 1987), reported on four years of continuous intercropping of maize with *Leucaena* in the Philippines. The trees were planted on sloping land in hedgerows one meter apart and pruned bimonthly. Hernandez, (cited in Benge, 1987), reported that erosion was reduced and maize yields substantially increased.

At the International Institute of Tropical Agriculture (IITA), research on the use of woody species in food crop production systems started during the 1970s. Investigations initially involved the introduction and evaluation of species such as *Leucaena* and *Cajanus*. In 1976, the first alley farming trial was established in order to assess the potential of intercropping woody species with food crops as a land use system for managing fragile uplands dominated by low activity clays. The experiment was set up on a low fertility sandy soil (Psammentic ustorthent) using direct seeded *Leucaena* hedgerows.

The encouraging results of this trial created a great interest in research on alley cropping systems (Kang et al., 1981). IITA's alley-system research has been conducted primarily on the institute's headquarters farm at Ibadan, Nigeria, in the subhumid/humid transition zone, with a total annual rainfall of about 1200 mm. Research on a smaller scale is conducted on acid soils at the Onne substation, which has an annual rainfall of about 2400 mm. In some 150 on-station experiments, involving more than 10 hedgerow species, IITA scientists have focused mainly on two issues: the enhancement of soil fertility, and the establishment and management of hedgerow species.

The main research thrust has been development of the technology for use by Africa's resource-poor smallholders. However, IITA's limited experimentation with tractorized operations suggests that alley farming can be adapted to large-scale enterprises (Figure 1-9).

In the 1980s, IITA placed increasing emphasis on on-farm trials designed to develop and evaluate techniques suitable for small-scale alley farming. During the two crop years 1987-1989, collaborating farmers planted more than 80 alley experiments on their farms in the subhumid and transitional zones of Nigeria. Researchers collaborating with IITA in other countries in West and Central Africa have established similar trials on farmers' fields.

Realizing the potential of leguminous hedgerows in particular as a source of browse for livestock, the International Livestock Centre for Africa (ILCA) has expanded the alley farming concept to include livestock production. By using a portion of the foliage for animal feed in a cut-and-carry system, ILCA scientists have developed a new package which has potential benefits for both crops and animals (Okali and Sumberg, 1985).

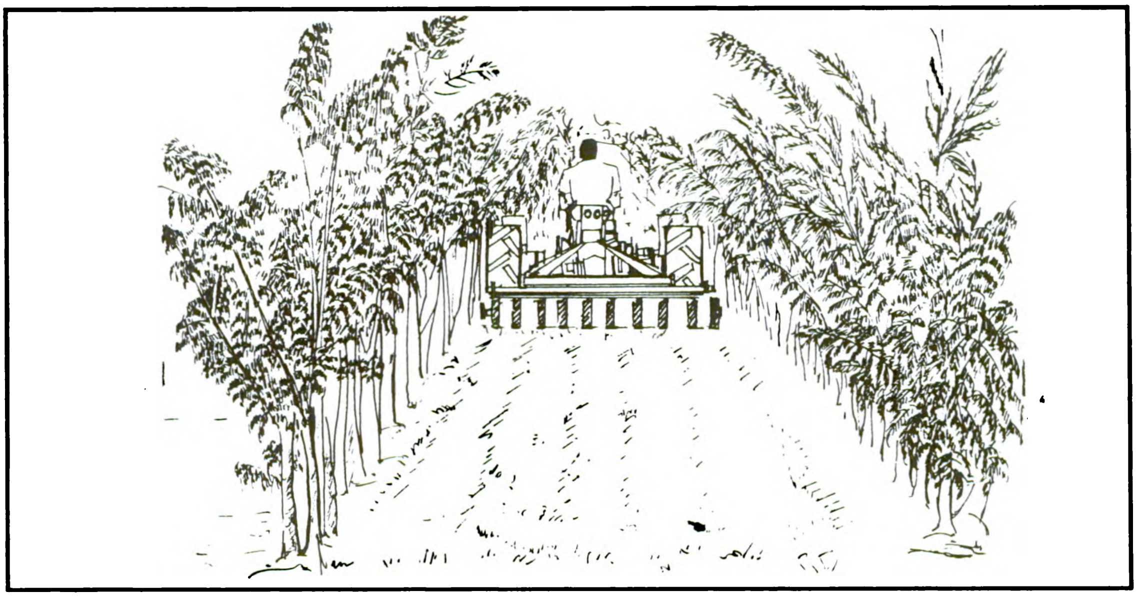

Figure 1-9. Mechanized alley farming using *Gliricidia sepium*. Alley farming is scale-neutral, and can be adapted to large farms such as this.

In East and Southern Africa, national research institutions began to conduct their own alley farming experiments during the 1980s in countries such as Rwanda, Kenya, and Zambia. The Nairobi-based International Centre for Research in Agroforestry (ICRAF), with its extensive experience with multipurpose trees, has played a leading role in encouraging alley farming and related agroforestry research in these regions.

Currently alley farming techniques and similar approaches are being researched and tested, or are already used in farmers fields, in various parts of the humid tropics, as shown in Figure 1-10. Outside Africa, particularly important work is being done in Haiti, Sri Lanka, Indonesia, and the Philippines.

1.4 REVIEW OF RECENT RESEARCH

This section reviews the results of recent research that has demonstrated alley farming's beneficial effects on soil properties, crop production, and livestock nutrition. Most of the investigations were conducted at sites in Nigeria by the International Institute of Tropical Agriculture (IITA) or the International Livestock Centre for Africa (ILCA) Humid Zone Program.

Figure 1.10 Distribution of alley farming activities world-wide. Large circle ◉ represent major centers of research.

1.4.1 Effects on Soil Properties

In alley farming, prunings from the leguminous trees are used as green manure and mulch for maintaining soil fertility. With proper management, hedgerow prunings of some species can produce a large amount of biomass and nutrient yield, as illustrated in Table 1-2.

Table 1-2. Biomass and nutrient yields of woody species from five prunings of hedgerows grown on an Alfisol at Ibadan, south-western Nigeria. Inter-hedgerow spacing was 4m (B.T. Kang, unpublished).

Species	Dry matter* (t/ha/yr)	Nutrient Yield				
		N	P	K	Ca	Mg
		(kg/ha/yr)				
Acioa barteri	3.0	41	4	20	15	5
Alchornea cordifolia	4.0	85	6	48	42	8
Gliricidia Sepium	5.5	169	11	149	66	17
Leucaena leucocephala	7.4	247	19	185	98	16

*Wood harvest not included

Repeated addition of prunings in the alleys plays an important role in maintaining high soil organic matter and nutrient status. A recent study measured the long-term effects of the addition of Leucaena and Gliricidia prunings on soil properties and crop yield (Kang and Ghuman, 1989). As compared to a tree-less control plot, the alley farming plots recorded 80% higher soil organic matter after six years of cropping (Table 1- 3). Although Leucaena and Gliricidia prunings have short half- lives of 2-3 weeks, their continuous addition in large quantities has been found effective in maintaining high soil organic matter levels. (A half-life is the time required for half of a substance to decompose. One half of the prunings remain after 2-3 weeks, one quarter after 4-6 weeks, etc.)

Table 1-3. Effects of 6 years of alley farming on properties of surface soil, run off, soil loss and maize yield on an Alfisol with 7% slope (Kang and Ghuman, 1989).

Treatment	Acidity H20 (pH)	Organic Carbon (%)	Runoff** (mm) (% of rainfall)	Soil loss** (t/ha)	Maize*** yield (t/ha)
Control (no hedgerows)					
Tilled	5.3	0.5	66.0(9.4)	6.18	2.3
No-till	5.4	0.9	5.6(0.8)	0.43	2.4
Alley farmed and tilled*					
2 m-*Gliricidia*	5.2	0.8	4.8(0.7)	0.57	3.2
4 m-*Gliricidia*	5.1	0.8	23.1(3.3)	1.44	2.8
2 m-*Leucaena*	5.1	0.9	2.6(0.4)	0.17	3.5
4 m-*Leucaena*	5.1	1.1	10.7(1.5)	0.82	3.1

*Inter-hedgerow spacing: 2 and 4 m.
**Measured during first season (March-July 1988). Total amount of rainfall - 704.2 mm.
***Fertilizer

Mulching is known to have favourable effects on physical soil properties (Lal, 1974). The presence of an adequate amount of mulch cover alleviates the negative effects of continuous cropping in many ways (Table 1-4).

Table 1-4. The beneficial effects of mulch cover on soil properties.

Mulch cover helps to:

- Maintain high soil nutrient status and high biological activity
- Reduce Al and Mn toxicity derived from soil acidification
- Protect the soil against high temperature, impact of high intensity rains, soil erosion and run off
- Prevent the breakdown of soil structure and resultant soil compaction and increase soil permeability
- Increase soil moisture retention

In alley farming, addition of Leucaena prunings has been shown to increase soil moisture retention (Kang et al., 1985). The mulching effect combined with the barrier effect of the hedgerows brings about a marked reduction in runoff and soil erosion on sloping land. Leucaena, which forms more dense hedgerows than Gliricidia, provides better control of runoff and soil erosion.

1.4.2 Effects on Crop Production

Alley farming has been tested, with encouraging results, using a variety of crops, including cereal crops (maize, upland rice), grain legumes (cowpeas, soybeans), root and tuber crops (cassava, yam), and plantain and vegetable crops, under both monocropping and intercropping systems. In an alley farming trial on an eroded Alfisol (Oxic Paleustalf) at Ibadan, south- western Nigeria, maize yields under alley cropping with various hedgerow species were significantly higher, with or without applied nitrogen, than in the control plots which had no trees (Figure 1-11). This trial also showed that, in addition to nitrogen benefit, the generally improved soil conditions resulting from alley farming also had a positive effect on maize yield.

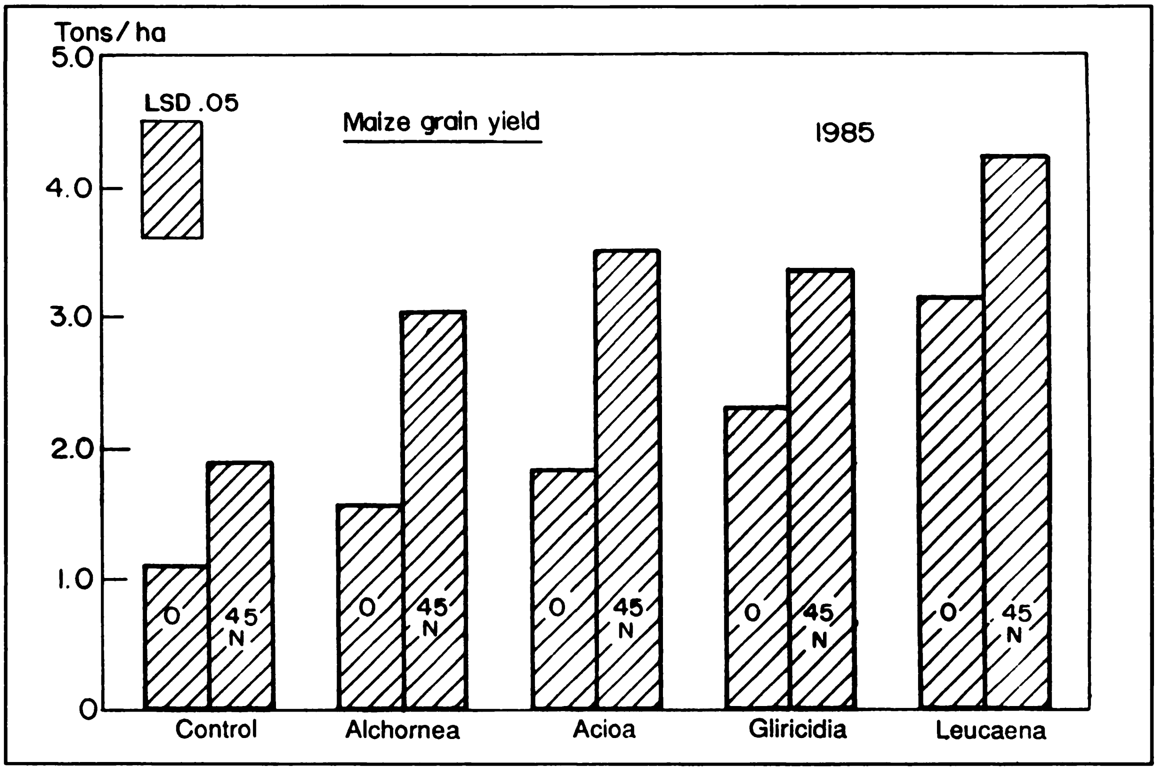

Figure 1-11. Grain yield of maize on eroded Alfisol (Oxic Paleustalf) at Ibadan, south- western Nigeria, as affected by alley farming with woody species (Acioa barteri, Alchornea cordifolia, Gliricidia sepium and Leucaena leucocephala). Rates of nitrogen fertilizer application are shown (kg N/ha). (B.T. Kang, unpublished data).

A very important aspect of alley farming is the sustainability of crop yields over time. Results of long-term alley farming trials, also conducted at Ibadan, have shown that by applying Leucaena prunings, even without N application, maize yields can be maintained for many years at the reasonable level of approximately 2 tons per hectare (Figure 1-12). Higher yields were obtained when the prunings were supplemented with fertilizer N. The alley farming techniques thus provide flexibility in the development of low-chemical-input production systems. Removal of some or all of the prunings from alley farming plots results in a reduction of the benefits received by the crop, though application of some inorganic N can compensate for the loss.

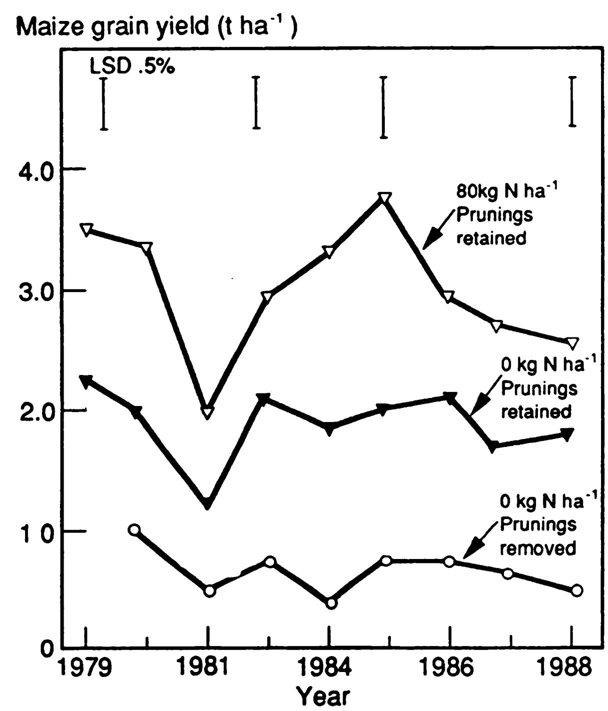

Figure 1-12. Grain yield of first season maize in maize-cowpea sequential cropping on a Psammentic ustorthent in alley farming with Leucaena leucocephala at Ibadan as affected by N application and prunings of hedgerows (B.T. Kang, unpublished data).

Nodulating leguminous MPTs such as Leucaena and Gliricidia produce prunings with high nitrogen (N) yield (Table 1-2). For example, when inoculated with appropriate strains of nitrogen-fixing bacteria, Leucaena fixed 70 to 135 kilograms of nitrogen per hectare in six months. The N contribution from the prunings to crop(s) has been widely studied in recent years. Despite the high N-yield obtained, N-use efficiency from prunings by the associated crop(s) is known to be low. The efficiency is affected by the contents of the prunings, the decomposition rates, the timing of application in relation to crop growth, and the placement method. Kang (1988) estimated the N contribution from Leucaena and Gliricidia hedgerows to alley-farmed maize to be about 42 kg N/ha (Table 1-5). This represents a low N-use efficiency of 18 and 33%, respectively. By comparison, Gevarra (1976) reported a higher N-use efficiency of 36% for Leucaena prunings by a maize crop. More research is needed to increase the efficiency.

Table 1-5. Nitrogen yield (kg N/ha) from hedgerow prunings during one maize cropping season, N uptake by the alley-farmed maize, and estimated N gain from hedgerows to the system (B.T. Kang, 1988).

Woody hedgerow	N yield from prunings[1]	N uptake by maize	Estimated N gain[2]	Maize grain yield(kg/ha)
Control	-	26.2	-	1632
Legumes:				
Gliricidia sepium	127.8	68.6	42.4(33.1)	3349
Leucaena leucocephala	231.1	68.1	41.9(18.1)	3210

[1] Not including N removed with harvested wood.
[1] Figures between brackets show percentage N utilization from prunings.

Little information is available on the interactions between the hedgerows and the crops. Kang et al. (1985) have shown that on non-acid soils in the humid zone the maize crop and Leucaena hedgerows do not compete for soil moisture, as Leucaena hedgerows use soil moisture from lower depths in the profile than the crop. In the humid zone, competition between the hedgerows and the crop is mainly for light. In dry regions, careful selection of MPT species and wider spacing of hedgerows is needed, so as to minimize competition for water. On acid soils, where crop and tree roots are concentrated at the soil surface, competition for nutrients can be a problem.

In alley farming with Leucaena, maize plants grown adjacent to hedgerows show poorer performance as compared with plants grown farther away, due to the shading effect. Negative effects on crops due to shading are more probable under conditions of high soil fertility. Under low fertility, the higher nutrient contribution from the litter fall near the hedgerows more than compensates for the shading effect. Thus, under low fertility, maize plants grown adjacent to hedgerows perform better (Fayemelihin, 1986).

1.4.3 Supplemental Nutrition for Livestock

The fodder resources available on smallholder farms in Africa consist mainly of residues from subsistence crops and vegetation on fallow lands. Both of these sources of animal nutrition are highly seasonal, with quality and quantity declining as the dry season progresses. Thus, one of the major constraints to livestock production in Africa is animal nutrition, especially in the dry season. It has been observed that the nutritional problem is more severe with confined animals, as free-roaming animals can select the most nutritious part of grasses and browse. Recent research conducted by ILCA scientists has demonstrated that the leguminous trees in an alley farming system constitute a valuable means for alleviation of this problem by providing nutritious fodder that can be fed to confined animals or browsed by free-roaming animals. This subject is taken up in depth in Unit 4.

1.4.4 Wood Production

Depending on the species, prunings from the hedgerows can produce substantial quantities of wood for use as fuel or as staking material (e.g., for yam cultivation). Fully grown *Leucaena* and *Gliricidia* hedges, sequentially cropped with maize and cowpeas in the Ibadan area and periodically pruned back to a height of 75 cm, produced over 5.7 and 1.4 tons per hectare respectively of dry weight of stakes. Utilizing subsoil moisture during the four-month dry season, *Leucaena* and *Gliricidia* hedgerows grew 4.0 m and 2.5 m, respectively. When allowed to grow freely for one year, the *Leucaena* hedgerows reached a height of over 7.5 m and produced more than 88 tons of wood per hectare.

1.5 RESEARCH NEEDS

As previously mentioned, alley farming is based on an age-old concept and practice, but it is a new science. Despite considerable interest in using the technique, information on its potential use and limitations remains inadequate. Further research is needed to better assess the processes and merits of the technique, to improve it further, and to fine-tune the technology for local adoption. Many applied research issues can best be tackled by Africa's national agricultural research systems (NARS).

Priority areas for research are listed below. Each area of applied research is covered in a separate unit of this Core Course, namely: MPT Screening (Unit 2), Alley Farming Management (Unit 3), Livestock Integration (Unit 4), On-Farm Research (Unit 5), and Socio-economic Assessment (Unit 6). The basic research issues listed below are not covered in this manual.

1.5.1 Multipurpose Tree (MPT) Screening

1. For every agroecological zone and sub-zone, there is the need to identify suitable MPTs that could grow vigorously and be productive when subjected to alley farming management. This type of work is highly site specific and is recommended as a starting point for sites where alley farming work has never been carried out.

2. Alley farming has so far been tried with a relatively small number of MPTs. Evaluation and testing of a wider spectrum of indigenous and exotic MPTs in alley farming is needed, particularly for acid soil conditions, the semi-arid tropics, and the tropical highlands.

3. There is a need to develop methods for producing high-quality seeds of important MPTs for alley farming.

4. There is a need for improved experimental designs for screening MPTs for use in alley farming.

1.5.2 Alley Farming Management Studies

1. Having selected suitable tree species for a particular zone or site, management studies are then conducted to fine-tune management techniques for local conditions. Typical trials in this category investigate the following:

   - Problems of hedgerow establishment and management;

   - Effect of inter-and intra-row spacing of MPTs on hedgerow establishment and productivity;

   - Effect of hedgerow prunings of different MPT species on soil fertility and crop productivity;
   - Fallow integration and management in alley farming system;

- Integration of arboreal tree stands in alley farming for pole and fuelwood production;

- Problems of crop husbandry;

- Problems of pest management and disease.

2. Since managing alley farming may require a greater input of labor than traditional bush-fallow systems, more efficient tools are needed for hedgerow management so as to increase labor productivity.

3. More efficient experimental designs are needed for conducting alley farming trials so as to reduce the need for large experimental fields.

1.5.3 Livestock Integration

1. The effect of livestock integration on crop productivity, as well as the response of livestock receiving supplementation from alley farming tree fodder, need to be determined. Both cut-and-carry fodder management and the grazing of alley farms in fallow years can have implications for soil fertility maintenance and crop yield sustainability.

   Experimental topics with a livestock focus include the following:

   - Screening of fodder trees and assessing the effects of their integration into the alley farming system,

   - Pasture production in alley farming context (tree/grass combinations),

   - Performance of livestock under nutritional supplementation from different alley hedgerow species,

   - Effects on crop production, soil fertility, and livestock nutrition of utilizing different proportions of hedgerow prunings as (a) mulch or (b) livestock fodder.

1.5.4 On-Farm Research and Socio-economic Assessment

1. On-farm research and development activities need to be carried out in a broad range of agroecological and socio-economic conditions for the fine-tuning of the technology, the assessment of its productivity and efficiency relative to traditional

farmer practices, and the determination of the acceptability and potential adoptability of the system.

2. Socio-economic studies are needed to better assess the costs and benefits of alley farming, both short-term and long-term.

3. As there is a slow adoption rate for alley farming on the African continent, socio-anthropological studies are required to determine constraints to adoption at the farm level and to develop suitable transfer mechanisms.

1.5.5 Basic Research Needs

1. Investigations are needed to determine the factors and processes that contribute to yield sustainability and maintenance of soil productivity. There is a need to better quantify the turnover of soil organic matter and its effect on soil properties and biotic activities.

2. Information is scarce on the spatial interface, particularly the subterranean interactions, between woody hedgerows and crops. Better information on the use of and competition for soil nutrients and water can assist in developing more productive alley farming systems.

3. Information is still scanty on the soil and nutrient requirements of MPTs with potential for alley farming. Better quantification is needed of the requirements for rhizobium inoculation, of the N_2 fixation process in MPTs, and of the benefits received by crops from the nitrogen and other nutrients found in tree prunings. Similarly, the role of mycorrhizal inoculation in enhancing phosphorus nutrition to MPTs and the phosphorus contribution to crops need to be assessed.

1.6 THE ALLEY FARMING NETWORK FOR TROPICAL AFRICA

The Alley Farming Network for Tropical Africa (AFNETA) was set up to enhance cooperation between the international agricultural research centers (IARCs) and national agricultural research systems (NARS) of Africa in the area of alley farming research. Until AFNETA commenced operations in 1989, the involvement of national institutions in research on alley farming was minimal. The three international centers, IITA, ILCA, and ICRAF, are considered the founding members of AFNETA. They provide technical backstopping in the areas of library services, research, and training. The network is currently operating in twenty countries in tropical Africa (Figure 1-12).

The AFNETA/NARS collaborative research program currently involves more than 50 experiments at 32 institutions in 20 different countries (Figure 1-13). The NARS/AFNETA projects in Africa are supplemented by external projects in U.S. universities that address research issues of a basic and strategic nature. Funding is sought for an additional 30 experiments at 23 institutions.

The AFNETA/NARS projects are investigating a broad range of research issues, classified in four main categories:

1. Screening and evaluation of multipurpose tree species,

2. Alley farming management trials,

3. Integration of livestock in alley farming systems,

4. On-farm research and development, and socio-economic assessment.

1.6.1 Research Strategy

AFNETA has mapped out a research strategy for scientists and institutions interested in addressing the foregoing research issues (Sanginga, 1990). Where there has been no previous history of alley farming — as in most of the semi-arid and arid zones — there may be need for a strong on-station component initially to determine if alley farming has any potential. A typical pattern could be that tree selection and management experiments are carried out mainly on-station, with major farmer involvement occurring only when biologically sound prototypes have been developed. For countries such as Nigeria, where alley farming has already shown promise, on-farm and livestock integration experiments will be justified.

A major network goal is to test the adaptability of alley farming across the agro-ecological zones of tropical Africa: humid, sub-humid, semi-arid and highlands (Figure 1-14). The collaborative research program also aims to move increasingly into on-farm, adaptive research. To enable comparison of results and allow regional analysis, AFNETA requires participating researchers to use standard methods and a minimum data set.

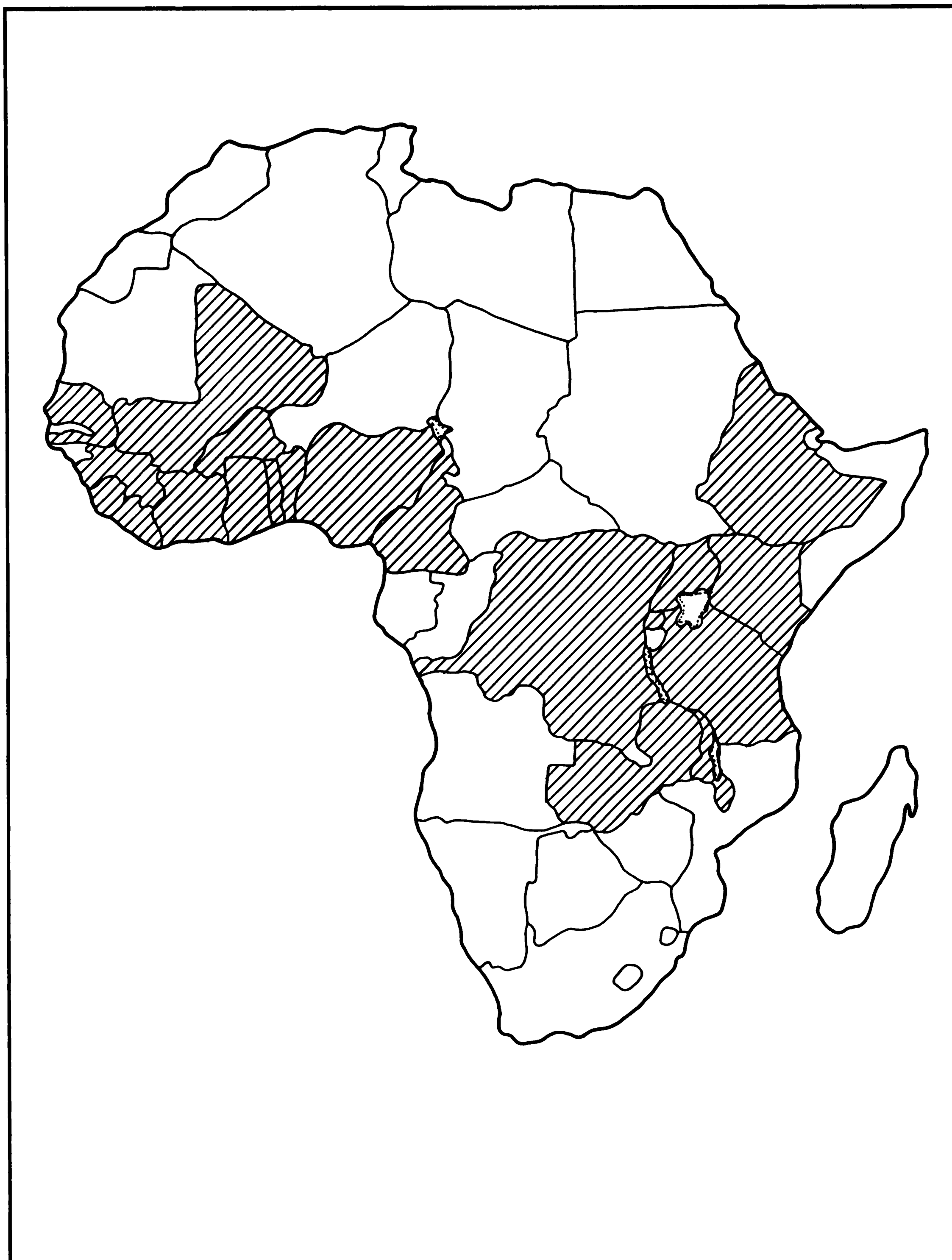

Figure 1-13. Distribution of AFNETA's ongoing collaborative research projects in 1990-1991, by country.

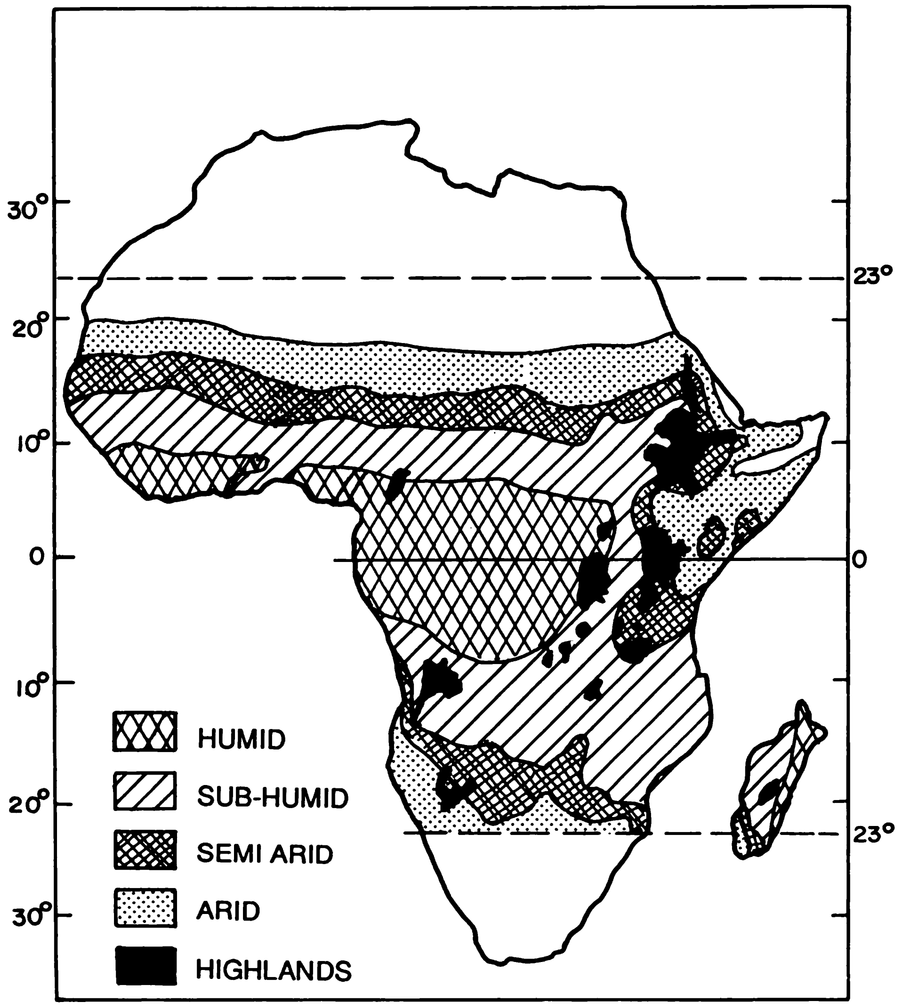

Figure 1-14. The agroecological zones of tropical Africa.

It might seem scientifically sound for each AFNETA project to proceed as in Figure 1-15A: first by identifying suitable MPTs; next by incorporating these in management research; then by using the knowledge gained to design and test prototypes; and finally, when confident about their performance, by proceeding to on-farm or extension research. However, such a sequence could take over 30 years (Willey and Young, 1990). In practice, the different types of research may proceed more nearly in parallel, with a continuous transfer of knowledge from one to the other, as in Figure 1-15B. Management trials are likely to be established from the start of the program, at the same time as the MPT screening and evaluation, making use of such multipurpose trees as are believed to be suitable during the testing of prototypes. Similarly, the recommendation to extension will not be handed over at a specified time. Instead, recommendations will progressively improve as the program advances.

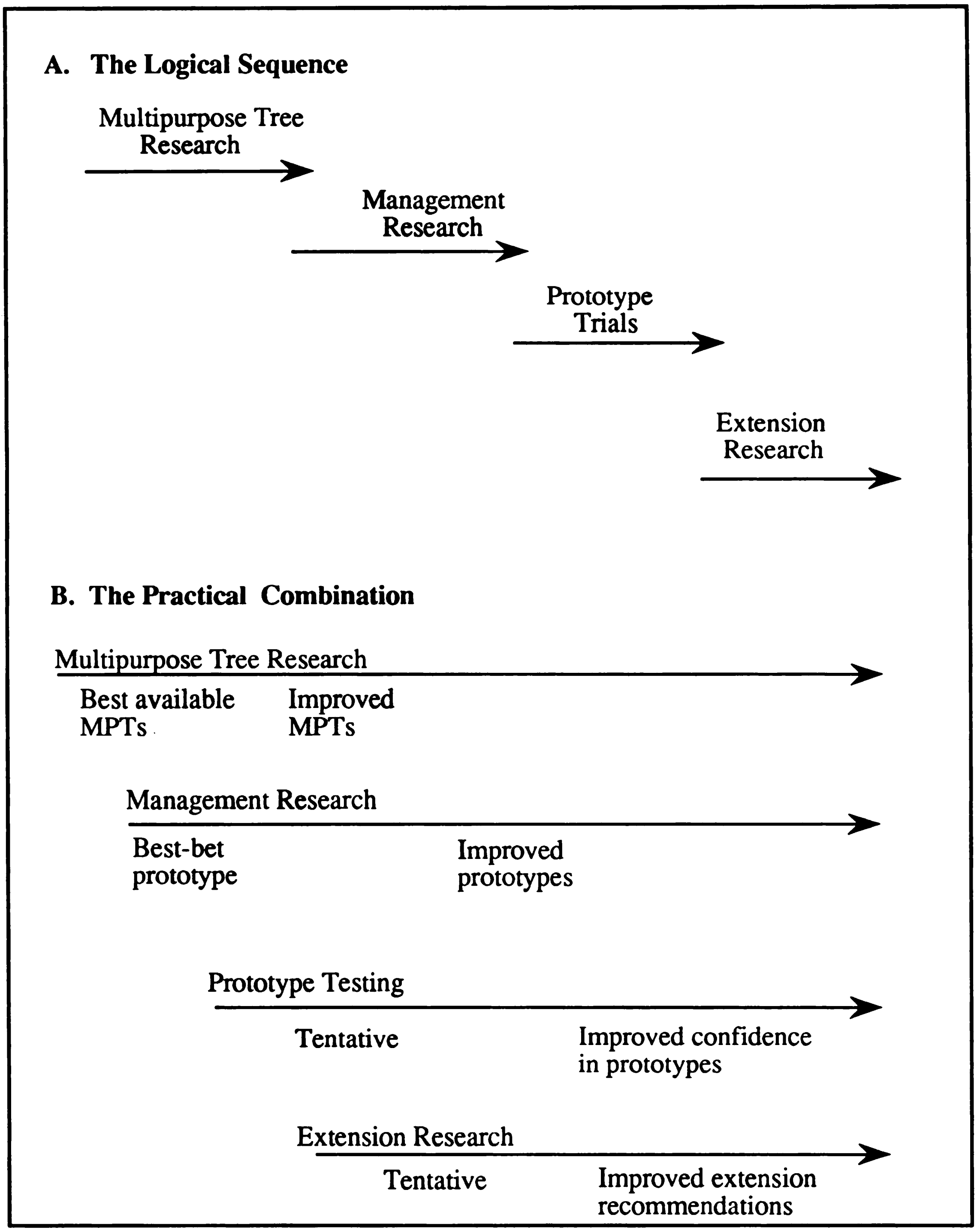

Figure 1-15. Alternative research strategies. AFNETA's collaborative research program employs strategy B.

1.7 FEEDBACK EXERCISES

All answers can be found in the text and figures of Unit 1.

1. The following five statements concern Africa's agricultural and environmental crisis. Circle T for true statements or F for false ones:

i)	Low activity clays soils are rare in sub-Saharan Africa.	T	F
ii)	Sub-Saharan Africa is a net importer of food.	T	F
iii)	Repeated flash burning of vegetation causes "grassification."	T	F
iv)	Per-capita food production has declined less in Africa than in Asia.	T	F
v)	Population pressure on land has not yet reduced fallow periods.	T	F

2. Provide brief answers to the following questions:

   i) How is soil fertility restored in bush-fallow systems?

   ii) Why are many African soils susceptible to rapid declines in soil fertility?

   iii) What is agroforestry, and why do agroforestry technologies show promise for low-input land use systems?

   iv) Why is alley farming considered to be one type of agroforestry?

3. Fill in the blanks with the missing words or phrases.

   i) Alley farming is defined as the growing of ____________________ or ____________________ crops in the "alleys" between rows of ____________________.

   ii) Hedgerows are pruned during the growing season in order to prevent and to provide ____________________for crops and/or ____________________ for livestock.

   iii) Land-use efficiency is higher in alley farming than in bush-fallow system because ____________________ and ____________________ are carried out simultaneously.

   iv) Bush-fallow uses fire for controlling vegetation and allows short-term cropping. In contrast, alley farming uses ____________________for control and allows ____________________ cropping.

4. a.) List three overall benefits of alley farming:

   1. ______________________________
   2. ______________________________
   3. ______________________________

b.) List at least six benefits provided by the hedgerows in the system:

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________
6. ______________________________

5. The following statements concern the history of alley farming research. Circle T for true statements or F for false ones:

i)	Alley farming was invented by scientists at IITA.	T	F
ii)	Alley farming systems have been used by generations of farmers in the Philippines and Nigeria.	T	F
iii)	Scientists at ILCA pioneered the expansion of alley farming to include livestock production.	T	F
iv)	Africa's national agricultural research systems were not involved in alley farming research until the AFNETA network began operations in 1989.	T	F
v)	The only tree species to receive research attention so far are *Leucaena leucocephala* and *Gliricidia sepium.*	T	F

6. Provide brief answers to the following questions:

i) In recent experiments, prunings of *Leucaena* and *Gliricidia* have been shown to have positive effects on soil properties. Cite several specific examples of such effects.

ii) In general, what are the beneficial effects of mulch cover on soil properties?

iii) In IITA's long-term trials at Ibadan, what level of maize yields (in t/ha) have been maintained *without* application of N fertilizer? What levels have been possible there *with* application of N fertilizer?

iv) Alley farming systems must be managed to minimize competition between hedgerows and crops. What types of competition would be of greatest concern in a humid area? In a semi-arid area?

7. Researchers have identified four main categories of research needs for further development of alley farming technologies. List them.

1. Multipurpose Tree Screening
2. ______________________________
3. ______________________________
4. ______________________________

8. At the time this manual was published, AFNETA's collaborative research program involved experiments in 20 countries. Name the countries in your own region of Africa (West, Central, East, or Southern) in which AFNETA experiments are located.

1.8 SUGGESTED READING

Kang, B.T. 1991. Sustainable agroforestry systems for the tropics: concepts and examples. IITA Research Guide 26. Ibadan: IITA.

Kang, B.T., L. Reynolds, and A.N. Atta-Krah. 1990. Alley Farming. Advances in Agronomy 43:315-359. *Available in IITA Reprint series.*

Kang, B.T., and G.F. Wilson. 1987. The Development of Alley Cropping as a Promising Agroforestry Technology. In: H.A. Steppler and P.K.R. Nair (eds.). Agroforestry: A Decade of Development. pp 227-243. Nairobi: ICRAF. *Available in IITA Reprint series.*

1.9 REFERENCES

Benge, M.I. 1987. "Agroforestry System" (mimeo), Bureau of Sci. Technol., U.S. Agency for International Development, Washington, DC.

Fayemelihin, A.A., 1986. Effect of alley cropping with woody legume *(Leucaena leucocephala)* and nitrogen application on intercropped maize *(Zea mays)*. Training Report. Ibadan, Nigeria: IITA.

Guevarra, A.B. 1976. Ph.D. Thesis, Univ. of Hawaii, Honolulu.

Kang, B.T. 1988. Nitrogen cycling in multiple cropping systems. In: J.R. Wilson (ed.) Advances in Nitrogen Cycling in Agricultural Ecosystems: pp. 333-348. Wallingford, England: CAB. Int.

Kang, B.T., and B.S. Ghuman. 1989. Alley Cropping as a Sustainable Crop Production System. Paper read at International Workshop on Conservation Farming on Hillslopes. Taichung, Taiwan, R.O.C. March 20-29, 1989. (In press.)

Kang, B.T., N. Grimme, and T.L. Lawson. 1985. Alley cropping sequentially cropped maize and cowpea with *leucaena* on a sandy soil in southern Nigeria. Plant and Soil 85: 267-277.

Kang, B.T., A.C.B.M. van der Kruijs, and D.C. Couper. 1989. Alley cropping for food crop production in humid and subhumid tropics. In: B.T. Kang and L. Reynolds (eds). Alley Farming in the Humid and Sub-humid Tropics. pp. 16-26. Ottawa, Canada: IDRC.

Kang, B.T., G.F. Wilson, and T.L. Lawson. 1984. Alley Cropping: A stable alternative to shifting cultivation. Ibadan, Nigeria: IITA. 22p.

Kang, B.T., G.F. Wilson, and L. Sipkens. 1981. Alley cropping maize (*Zea mays*) and *leucaena* (*Leucaena leucocephala* Lam.) in southern Nigeria. Plant and Soil 63: 165-179.

Lal, R. 1974. Role of mulching techniques in tropical soil and water management. Tech. Bull. IITA, Ibadan, Nigeria.

Okali, C., and J.F. Sumberg. 1985. Sheep and goats, men and women: Household relations and small ruminant development in southwest Nigeria. Agricultural Systems 18: 39-59.

OTA (Office of Technology Assessment), 1988. Enhancing agriculture in Africa. A role for U.S. development assistance. OTA, Congress of the United States, Washington DC, USA.

Picardo, E.P., 1984. Soil erosion and ecological stability. In: E.T. Crasswell, J.V. Remenyi, and L.G. Nallana (eds). Soil Erosion Management. ACIAR, Proc. 6, Canberra: 82-85.

Sanginga, N. 1990. Summary comment on and finalization of country projects, submitted to IFAD. Unpublished AFNETA document.

UNIT 2

Multipurpose Tree Screening and Evaluation

Unit 2: Multipurpose Tree Screening and Evaluation

Major Contributor: F. Owino

2.0 PERFORMANCE OBJECTIVES

Unit 2 is intended to enable you to:

1. Name the multipurpose tree species (MPTs) that have received the most attention in studies of alley farming.

2. Recall the criteria for selecting suitable MPT species for alley farming, including special considerations for production of livestock forage and for acid soils.

3. Describe the most significant insect pest threat to *Leucaena*.

4. Recognize in the field the best-known alley farming MPT species.

5. Describe the three experimental stages in MPT evaluation.

6. Recall important guidelines for screening MPTs.

7. Describe nursery operations for raising vigorous and uniform seedlings for field experimentation.

8. Name organizations which can supply well documented propagules for experiments.

9. Discuss the importance of MPTs germplasm collection and documentation.

2.1 SUITABLE TREE AND SHRUB SPECIES FOR ALLEY FARMING

A number of multipurpose tree and shrub species (MPTs) are potentially suitable for alley farming, but only a handful have been tested. Woody species that have been most commonly studied in the system worldwide include *Leucaena leucocephala*, *Gliricidia sepium*, *Cassia siamea*, *Calliandra callothyrsus*, *Flemingia macrophylla* and *Acacia auriculiformis*. Some indigenous African tree species such as *Alchornea cordifolia* and *Acioa barteri* have also been studied in alley farming trials.

2.1.1 General Selection Criteria

Leguminous trees and shrubs that can fix atmospheric nitrogen are preferred over non-legumes. Multipurpose species that have additional uses are generally preferable because they give the alley farming system more flexibility. Ideally, trees and shrubs suitable for alley farming should meet the following criteria:

- establish easily,
- grow rapidly,
- have a deep root system with few lateral branches near the surface,
- have a suitable branching pattern, including high branch and leaf productivity, both quantitatively (biomass production) and qualitatively (mulch quality and decomposition, etc.),
- regenerate readily after pruning,
- have good coppicing ability,
- provide useful by-products such as fuelwood, stakes, food,
- be free from pest and diseases, particularly those of crops grown in the alleys,
- the above qualities should not be impeded as the tree matures

Few tree species meet all of the above criteria and some have serious disadvantages that must be overcome. For example, *Leucaena* has slow early growth and its seedlings must be protected against weeds during early establishment; once established, however, the seedlings grow vigorously. Occasionally, it may be desirable to choose a species that is excellent for one specific purpose, for example, *Acioa barteri,* for its slow decomposing mulch, or the fast-growing *Calliandra callothyrsus* for its ability to produce large quantities of biomass within a short time.

2.1.2 Additional Criteria for Forage Production

When livestock production will be incorporated into an alley farming system, the tree or shrub must provide forage in addition to its other functions. Again, the legumes are preferred because of their high protein value. The following characteristics are desirable:

- high forage productivity that is unimpeded by maturity, (good juvenile - mature correlation),

- good feeding value and high palatability.

Again, the legumes are preferred because of their high protein value.

2.1.3 Environmental Adaptation Selection Criteria

A species should grow well under the specific limitations of the site, such as drought, flooding, heavy winds, insect pests, or other hazards. Species should perform will in spite of a site's limiting climatic and soil factors. The ongoing AFNETA/NARS collaborative research program, and other research efforts, should eventually yield a good deal of information on the performance of numerous MPTs under alley farming management across a very broad spectrum of conditions in Africa. In the meantime, results of research to date permit several important generalizations to be made. These are presented in Table 2-1 and below.

<u>Non-acid soils</u>

- *Leucaena leucocephala* and *Gliricidia sepium* are the best performing hedgerow species for alley farming for the low altitude humid and subhumid tropics. Although optimum rainfall for good performance of these species has not been established, field observations have shown that a minimum annual rainfall of 1000 mm may be needed.

- Other species with good potential for alley farming at low altitudes are *Flemingia macrophylla*, *Cajanus cajan* (pigeon pea), and *Sesbania sesban*. *Cajanus* and *Sesbania* hedgerows, however, may require frequent replanting.

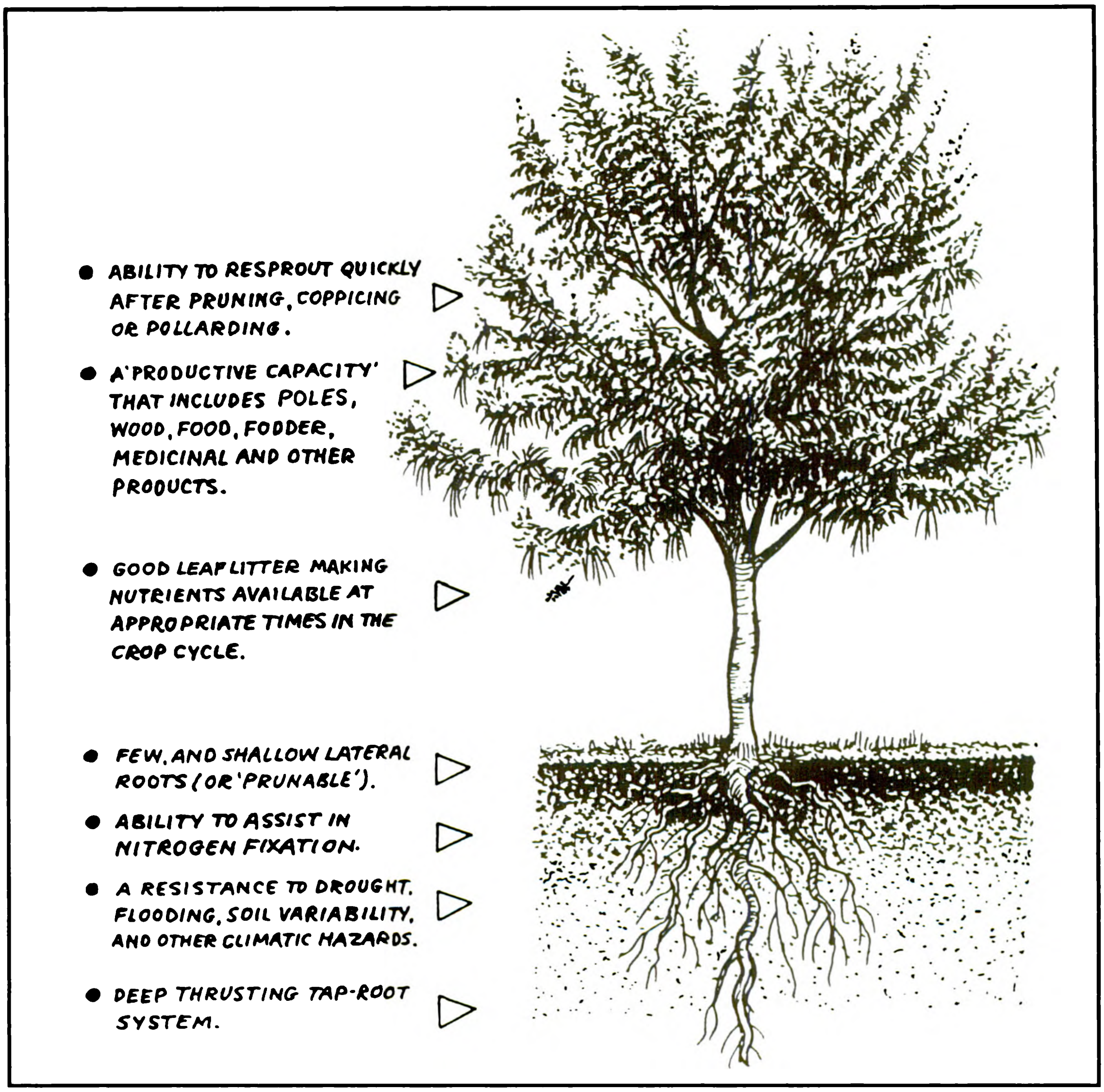

Figure 2-1. Some characteristics of trees or shrubs suitable for alley farming.

- Woody species suited to lowland non-acid soils generally do not grow well in highland areas. Table 2-1 contains list of species tentatively identified for low, middle, and high altitudes.

<u>Acid soils</u>

- Acidic soils (pH lower than 5.0) may occur in areas with high rainfall. Results of observations at IITA's high rainfall station at Onne in southeastern Nigeria indicate that *Acioa barteri, Flemingia macrophylla* and *Tephrosia candida* do well on lowland acid soils. Additional research on acid-tolerant MPTs is needed. The value of indigenous species in this case cannot be over-emphasized, indicating the need for natural forest explorations to find new and better-adapted species.

Table 2-1. Tentative list of suitable multipurpose tree and shrub species for alley farming systems in the humid and subhumid zone.

Environment	Humid Zone	Subhumid Zone
Non-acid Soils		
Lowlands (0-750m)	*Leucaena leucocephala* (1) *Gliricidia sepium* *Flemingia macrophylla* *Cajanus cajan* (2) *Tephrosia candida* *Acioa barteri* (3) *Milletia* sp.	*Leucaena leucocephala* (4) *Leucaena diversifolia* *Flemingia macrophylla* *Acacia auriculiformis*
Middle Alt. (750-1500m)	*Sesbania sesban* *Leucaena leucocephala (4)* *Leucaena diversifolia* *Flemingia congesta* *Tephrosia candida* Highland *Leucaena* species and hybrids. *Calliandra calothyrsus*	*Leucaena leucocephala* (1) *Gliricidia sepium* *Cajanus cajan* *Cassia floribunda*
Highlands (>1500m)	*Albizia* species *Erythrina poeppigiana* *Inga juniciul* *Sesbania sesban*	*Albizia* species *Erythrina* species *Sesbania sesban*
Acid Soils		
Lowlands (0-750m)	*Acioa barteri* *Cassia siamea* *Cassia spectabilis.* *Flemingia congesta* *Tephrosia candida* *Acacia auriculiformis* *Paraserianthes falcataria*	*Cajanus cajan* *Acacia auriculiformis*
Middle Alt. (750-1500m)	*Cassia floribunda* (5) *Flemingia macrophylla* *Calliandra calothyrsus* *Sesbania sesban*	*Cassia floribunda* *Flemingia macrophylla* *Calliandra calothyrsus*
Highlands (>1500m)	*Albizia* species *Erythrina* species *Sesbania sesban*	*Albizia* species *Erythrina* species *Sesbania sesban*

(1) Var. K8, K28, K636.
(2) Needs frequent replanting.
(3) Not a legume.
(4) Var. K636.
(5) Non-nodulating.

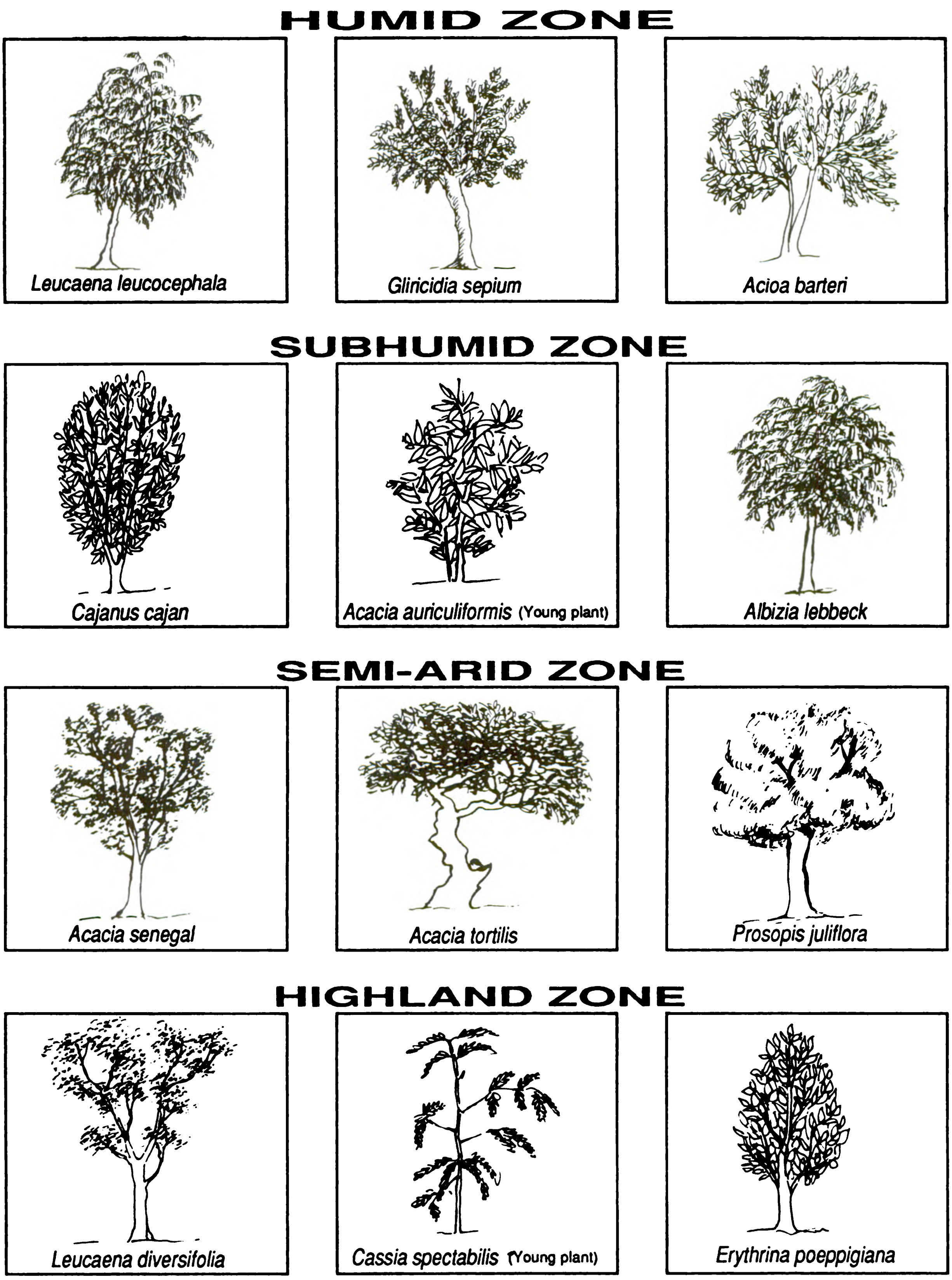

Figure 2-2. Pictoral guide to certain better known multipurpose tree and shrubs, showing goal potential for alley farming in tropical Africa. The appearance of most trees is altered under alley farming management.

Insect Pest Threat to *Leucaena*

- The need for futher selection and research on a wider spectrum of MPTs has taken on added importance with the threat posed to *Leuceana* by an insect pest. A sap-sucking psyllid, *Heteropsylla cubana*, has caused widespread devastation of the lowland *Leucaena leucocephala* in East Asia and the Pacific. The advance of this pest to the Indian continent has also been reported. It is thus essential that testing of tolerant or resistant *Leucaena* species such as *Leucaena diversifolia* and *Leucaena pallida* be taken up as a research priority.

2.2 METHODS FOR MPT SCREENING AND EVALUATION

2.2.1 Stages of Experimentation

In theory, the number of multipurpose tree and shrub species (MPTs) with potential for alley farming is high. For example, the number of potentially useful MPTs currently entered in the MPTs database at the International Council for Research in Agroforestry (ICRAF) stands at 1,600. Most of these MPTs have not been subjected to scientific study the world over. The task of comprehensive evaluation of MPTs for agroforestry development is large, presenting a major challenge to ICRAF and its partner institutions all over the world.

In practice, of course, alley farming researchers in Africa do not have to wait for the completion of such a comprehensive review. They are able to design manageable, effective MPT screening experiments by working with a limited number of promising species. The initial evaluation of MPTs should be carried out in three stages:

1. A **list of promising MPTs** is developed based on previous research worldwide experience with local MPTs, and local research priorities. The criteria for suitable alley farming MPTs should be applied (discussed in section 2.1). Both local and exotic species should be included on the list. In AFNETA/NARS research projects, a total of about 10 species and accessions is suggested as a manageable number.

2. Field trials for **continuous growth assessment** are conducted. Continuous growth trials permit general evaluation of each species for adaptation to local conditions, relative growth performance, and freedom from pests and diseases.

3. In a separate set of field trials, each species is subjected to **alley farming management**. This permits evaluation of hedgerow establishment, biomass production, and pruning recovery.

The field trials (stages 2 and 3) may be conducted simultaneously for improved efficiency. In the AFNETA/NARS projects, experimental design is kept simple: the continuous growth and alley farming management trials both employ the Randomized Complete Block design with three or four replications. Details of the recommended AFNETA designs are given in a separate AFNETA manual.

The end result should be a short list of "best-bet" MPTs that are promising enough to merit further experimentation (e.g., spacing and fertilization trials, on-farm testing). If very few or no species perform satisfactorily, or if there is a need for MPT improvement, the experimentation process should be repeated with a new list of species and accessions.

2.2.2 Additional Guidelines for MPT Screening Experiments

The experimental design issues in species and provenance research are generally well known to researchers in agriculture and forestry. For example, comprehensive coverage is provided in Burley and Wood (1976). Six issues worth stressing in connection with screening MPTs for agroforestry development are:

1. In cases where the numbers of species and provenances are likely to be large, the simpler designs such as the Randomized Complete Block design may not be the most efficient. Incomplete Block Designs such as lattice designs could be more efficient in such experiments. Principles of experimental design are covered in Volume 2, Technical Paper 7.

2. When screening mixtures of trees and shrubs, care should be taken to subdivide the species into near-homogenous sets with respect to their growth forms and rates. Such an arrangement will safeguard against undue competition for light in the later stages of field experiments.

3. The issues of plot size and shape should be given special consideration. Small rectangular plots (including single and two-row plots) are used in screening MPTs, instead of the traditional large, square plots. In extreme cases, experiments have five-tree, single-row plots.

4. As compared with the cultivars and provenances which are currently used in intensive forestry and agricultural production systems, the MPTs of potential value in agroforestry systems are at much lower levels of domestication. At these lower levels, great opportunities exist for exploiting within-species genetic variation. The traditional research path in forestry has been to screen for species and subsequently to screen for the best provenances within top priority species. This time-consuming path may not be necessary for MPT screening, because information on general growth performance of numerous species is now more readily available to researchers. Efforts should be made to combine both species and provenance screening in appropriately designed experiments.

5. For ease of comparison of data among scientists, it is important that measurements of trees and shrubs be standardized. A partial list of standard measurements is given in the Annex. Standardization becomes even more important in experiments which are established on a network basis.

6. The Diagnosis and Design (D&D) methodology developed at ICRAF can assist in the selection and assessment of MPTs. D&D provide a rationalized approach for diagnosing land use system needs and designing suitable agroforestry interventions. See Volume 2, Paper 4, for information on D&D.

2.3 SOURCES OF SEEDS AND SEEDLINGS

Successful experimentation with MPT species depends on finding a reliable source for tree seeds and/or seedlings. Because MPT susceptibility to pests can be disastrous, it is always wise to use a wide genetic base. Where possible, use seeds from a variety of cultivars and parent trees.

In this section, brief mention is made of key factors affecting quality of seedlings obtained from nurseries and seeds obtained from external sources. Information on production of *Leucaena* and *Gliciridia* in on-station seed orchards is provided in the Appendices.

2.3.1 Nursery Operations

Not all alley farming research projects will need to establish their own nursery. In regions with more than 1000 mm rainfall, planting of trees can be timed such that establishment from direct seeding is satisfactory. In semi-arid regions, help to ensure adequate numbers of viable seedlings by protecting young trees from the relatively harsh environment . Another reason to establish nurseries would be to protect scarce germplasm; a nurseries can help to minimize wastage of seeds or cuttings.

For all seedlings raised for field experimentation, detailed information should be recorded on potting medium, fertilization, seed pre-treatment, use of inoculants, and use of fungicides and insecticides.

The overall goal of all nursery operations should be the production of vigorous seedlings raised as uniformly as possible for field experiments. Since MPT screening trails will be aimed at detecting small differences in growth performance at early stages, care must be taken to avoid differential treatment of seedlings in the nursery.

Unfortunately, this precaution is seldom observed. Instead, relatively large, healthy, vigorous stock of a particular species is outplanted with unhealthy, retarded, or spindly stock of another. It is no suprise that the species of good stock commonly shows superior initial development in the field. It is important to avoid this mistake in all AFNETA experiments involving screening and evaluation of MPT for continous growth and/or alley farming studies.

As manuals and reports fully describe nursery operations, only important points are summarized briefly here. The recommendations are based on Briscoe (1990).

<u>Nursery germination</u>

The objectives of germination in the nursery phase include the following:

- evaluation of germination and seedling survival percentages on an operational scale,
- provision of suitable planting stock for field trials,
- evaluation of juvenile characteristics, and
- establishment of juvenile/mature correlations using mature characteristics acquired at a later date.

Seeds should be of known origin. Germination procedures should be kepts as uniform as possible for a particular species or provenance. Such procedures may include seed pre-treatment. Requirements and guidelines for pre-treatment are covered in Unit 3.

Containers and Beds

The date of sowing should be scheduled so as to allow the time necessary for the species to attain a suitable size by the planned date of planting. Most fast-growing species take three to six months to reach plantable size, but each nursery must determine its own rate of development for each species.

Various containers for sowing are commonly used. Currently, the most popular is a black polyethylene bag, approximately 10 x 15 cm when flat. The bag is perforated with 8 to 12 holes from the bottom up to half total depth. Plastic bags are popular because they are relatively cheap and convenient to use; however, the round shape encourages undesirable circling of the roots, and the drainage holes, although essential, permit the roots to emerge and enter the underlying soil.

To keep roots from penetrating into the soil, move the bags periodically to break off all escaped roots, set them on a sheet of plastic to prevent roots from entering the soil, or do both. Where rainfall and drainage conditions may cause saturation or flooding, avoid using such plastic sheets.

Beds and containers should be well-drained and usually kept above mean ground line to prevent waterlogging, improve aeration, and reduce root rot.

Seedling Care

Care of the seedlings (also called culture) is necessary from the time seed is sown until the planting stock is dispatched to the field. The small size of the plants and their concentration in a small area (10 to 400 per $m^{2)}$ makes care relatively economical and permits close supervision. Seedlings are most delicate during the first three months after germination.

2.3.2 Acquisition of Seed from External Sources

It is important to ensure that only well documented seeds and other propagules are used in all experiments. Seeds obtained from commercial supliers are often not good enough. While the ICRAF multipurpose trees and shrubs seed directory is very useful as a general guide, it is recommended that consultations be made with organizations which can supply well documented propagules for experiments. Such organizations include:

- National Tree Seed Centers
- National Gene Banks
- Regional Seed Centers
- CSIRO (Australia)
- DANIDA Forest Seed Center (Denmark)
- Oxford Forestry Institute (UK)
- Royal Botanic Gardens, Kew (UK)
- CAMCORE (USA and South America)
- CATIE (Costa Rica)
- NFTA (Hawaii)

The AFNETA secretariat, ICRAF, ILCA, and IITA can assist in the acquisition of seeds for alley farming trials in many cases.

When acquiring seeds, distinction must be made between unclassified seed, source-identified seed (seed stands), selected seed (known parents), and certified seed (seed orchards). In order to reduce storage requirements, every attempt should be made to synchronize time of seed acquisition with expected sowing dates. Furthermore, it must be emphasized that arrangements for seed and other propagule acquisition(s) should be made much in advance of the planned establishment of field experiments, often as much as one year in advance.

2.4 MPTs GERMPLASM DOCUMENTATION AND IMPROVEMENT

Many potentially useful MPTs are presently unknown to science. Valuable MPT germplasm remains to be collected and properly documented. This activity requires particularly urgent attention in tropical countries experiencing rapid rates of devegetation threatening total loss of some species and varieties. National, regional, and international research centers could accord high priority to this activity.

ICRAF and the International Board for Plant Genetic Resources (IBPGR) have recently initiated MPT germplasm collection and documentation projects in East and West Africa. Similar initiatives have been made in both francophone and anglophone West Africa. The International Livestock Centre for Africa (ILCA) maintains a germplasm collection of fodder trees and shrubs. IBPGR and the Royal Botanic Gardens, Kew, have published a valuable reference book on forage and browse plants for arid and semi-arid Africa (IBPGR, 1984).

However, much still remains to done in strengthening national institutions in the tropics for collection, documentation, and storage of MPT germplasm. Great gains could also be derived from breeding MPT for agroforestry development. This would required the initation of well planned MPT germplasm improvement programs. ICRAF is currently developing cooperative breeding strategies with national research systems.

2.5 FEEDBACK EXERCISES

All answers can be found in the text and figures of Unit 2.

1. a.) List eight of the general criteria for selecting a suitable tree or shrub species for an alley farming system:

 1. ______________________________
 2. ______________________________
 3. ______________________________
 4. ______________________________
 5. ______________________________
 6. ______________________________
 7. ______________________________ 8. ______________________________

b.) List two additional criteria for species that will be used for livestock forage:

1. ______________________________

2. ______________________________

2. For the following MPT species, indicate the suitable environments. Use the coding: A for acid soils or NA for non-acid soils; H for humid zone or SH for sub-humid; L for low-altitudes, M for middle altitudes, or H for highlands. More than one environment may be possible for some species.

Species Name	Soil Type(s)	Climate(s)	Altitude(s)
Leucaena leucocephala	NA	H	L, M
Gliricida sepium			
Sebania sesban			
Cajanus cajan			
Albizia spp.			
Acacia auriculiformis			
Flemingia macrophylla			
Acioa barteri			
Cassia floribunda			

3. Provide a brief description of each of the following experimental steps in MPT evaluation:

i) Development of MPT list: ______________________________

____

____

ii) Continuous growth assessment: ______________________________

____

____

iii) Alley farming managment assessment: ______________________________

____

____

4. The following five statements concern experimental guidelines for MPT screening and evaluation. Circle T for true statements or F for false ones:

i)	When the number of species to be screened is large, the Randomized Complete Block designs are always the most efficient.	T	F
ii)	Small rectangular plots are used in MPT screening.	T	F
iii)	MPT provenances are at a high level of domestication as compared to cultivars used in agricultural systems.	T	F
iv)	ICRAF's Diagnosis and Design (D&D) methodology is not relevant for MPT screening because it operates at a macro level.	T	F
v)	The evaluation of MPTs is not important for agroforestry research since ICRAF has already evaluated 1,600 MPTs.	T	F

5. Provide brief answers to the following questions concerning nursery operations:

   i) State the overall goal of nursery operations.

   ii) Name several specific objectives of nursery operations.

   ii) Describe the use of plastic bags as containers for sowing.

6. a.) List five organizations that you might wish to contact when acquiring seeds for MPT experiments.

   1. ______________________________
   2. ______________________________
   3. ______________________________
   4. ______________________________
   5. ______________________________

   b.) The seed used for agroforestry interventions could be of four types. One type is mentioned below. Give the name of the other three types:

   1. unclassified seed
   2. ______________________________
   3. ______________________________
   4. ______________________________

2.6 SUGGESTED READING/ REFERENCES

Briscoe, C.B. 1990. Field Trials Manual for Multipurpose Tree Species. Second edition. Winrock International Institute for Agricultural Development, Morrilton, Arkansas, USA.

Burley, J., and Wood P.J. 1976. A manual on species and provenance research with particular refrence to the tropics. Oxford, England: Commonwealth Forestry Institute.

IBPGR (International Board for Plant Genetic Resources). 1984. Forage and browse plants for arid and semi-arid Africa. Rome: IBPGR.

International Development Research Centre. 1983. *Leucaena* Research in the Asia-Pacific Region: Proceedings of a workshop held Singapore, 23-26 November 1982. IDRC - 211E. Ottawa, Canada: IDRC.

Kang, B.T., G.F. Wilson, and T.L. Lawson. 1984. Alley cropping: a stable alternative to shifting cultivation. Ibadan, Nigeria: IITA

Owino, F. 1990. Small-scale farmer oriented strategy for evaluation and improvement of multipurpose trees. In: C. Haugen, L. Medema and C. Lantican (eds.) Multipurpose Tree Species Research for Small Farms: Strategies and Methods. Proc. of International Conference held 20-23 November 1989, Jakarta, Indonesia. Forestry/Fuelwood Research and Development Project (F/FRED) and IDRC. pp. 167-170.

Reynolds, L., and A.N. Atta-Krah. 1989. Alley farming with Livestock. In B.T. Kang and L. Reynolds (eds). Alley farming in the humid and subhumid tropics. pp. 27-36. Ottawa, Canada: IDRC.

UNIT 3

Establishment and Management of Alley Farming Systems

Unit 3: Establishment and Management of Alley Farming Systems

Main contributors: A.N. Atta-Krah, B.T. Kang

3.0 PERFORMANCE OBJECTIVES

Unit 3 is intended to enable you to:

1. Describe procedures for planting trees by the direct seeding method, including planting depths and seed pretreatment procedures.
2. Explain when inoculation of MPT seeds may be required, and when inoculation would not be required.
3. Describe procedures for planting trees from seedlings or cuttings.
4. Discuss factors affecting the optimal spacing and orientation of hedgerows.
5. Sketch the layout of IITA's prototypical alley farming system, and indicate appropriate adaptations for various environments.
6. Anticipate common establishment problems and recall the relevant preventative or curative procedures.
7. Describe appropriate techniques for pruning hedgerows, and understand the principles that apply to the scheduling of prunings.
8. Explain the roles played by mulching, fertilizer application, and short fallow periods in the management of an alley farm.
9. Explain alley farming's contributions to weed control.

3.1 INTRODUCTION

From a technical viewpoint, obtaining the full benefits from an alley farming system depends on the following factors:

- correct choice of tree species,
- successful hedgerow establishment,
- efficient hedgerow management.

The first factor, choice of MPT species, was covered in the previous chapter. This current chapter will review the recommended practices for establishing and maintaining the hedgerows. The recommendations are based on alley farming research to date.

By reducing trial and error, the recommendations in this chapter can save time and effort for alley farming researchers and practitioners. Yet, the recommendations are certainly not cast in stone. Alley farming is a young science, and its techniques require continuous development. Many aspects of hedgerow establishment and management offer fruitful topics for new research. For example, AFNETA/NARS research projects are seeking to fine-tune aspects of tree spacing, pruning regime fertilizer application, and fallowing, among other techniques.

Leucaena leucocephala and *Gliricidia sepium* are used as examples of hedgerow species throughout this chapter. The two species are the most popular and best-researched trees for alley farming in the tropics. However, it bears repeating that *Leucaena* and *Gliricidia* will not always be the best choice, particularly when the local site lies in a semi-arid or highland zone, or has acidic soils.

3.2 GUIDELINES FOR HEDGEROW ESTABLISHMENT

3.2.1 Land Preparation and Timing of Planting

Hedgerows can be planted on ridged (heaped) or unridged land. The land should be cleared of all weeds just before planting. For experimental trials, intensive site preparation is often practiced, including land preparation such as plowing, subsoiling, harrowing, leveling, terracing, and/or irrigation.

The trees should be planted at the start of the major rainy season. If planting must follow a food crop, as is often the case, it should be done as soon as possible in order to minimize shading during establishment, when the seedlings are prone to competition from fast-growing weeds. In the case of alley farming with maize, the trees may be sown immediately after the maize crop.

3.2.2 Planting by Direct Seeding

Trees and shrubs in hedgerows may be established from seeds, seedlings, or stem cuttings, depending on the species used. Direct seeding is feasible where annual rainfall is 1200 mm or more, and the growing season lasts a minimum of approximately 6 months. Seeds carried in pockets or small bags can be planted by hand or with simple planters. Direct seeding is the cheapest and simplest method of hedgerow establishment. However, seeds tend to have short longevity (e.g., *Acioa barteri*) and to be unavailable at certain times of the year. An additional limitation is that the seedlings which sprout from direct seeding are usually very small during early establishment, and must be given extra care and protection.

One cheap and easy way of establishing *Leucaena* hedgerows is by direct seeding in the same row as a crop such as maize. With this method of establishment, no extra weeding cost is incurred for the *Leucaena* during early growth. The slower-growing *Leucaena* can also benefit from the residual fertilizer applied to the maize crop. At the time of maize harvest, the *Leucaena* would normally have reached a height of 50-75 cm and be able to outgrow any weeds.

When the direct seeding method is used, special attention should be paid to:

- seed planting depth,
- requirements for seed pretreatment, and
- requirements for seed inoculation with rhizobia.

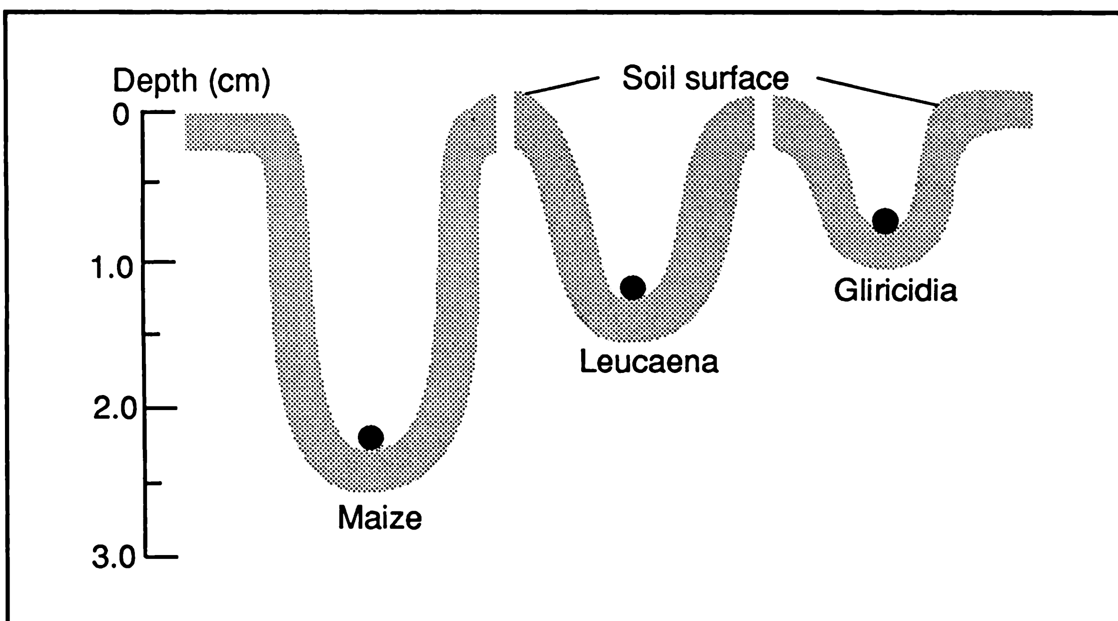

Figure 3-1. Recommended planting depths for maize, *Leucaena*, and *Gliricidia*.

3.2.3 Seed Planting Depth

Deep seed placement hampers germination and emergence, particularly of *Gliricidia*. Ideally, depth of planting should be about 2.0 cm for both *Leucaena* and *Gliricidia*. The number of seeds per hole depends on the germination percentage of the seeds but generally, for seed batches with 75% germination or more, two or three seeds should be planted per hole. Figure 3-1 illustrates the recommended planting depths.

Table 3-1 Seed pretreatment and rhizobium inoculation requirements for certain MPTs commonly used in alley farming research

Species Name	Seed Pretreatment	Rhizobium Requirement
Acacia auriculiformis	A	Nodulates freely
Acacia senegal	Overnight soaking	Nodulates freely
Albizia lebbeck	A, B	Cowpea miscellany
Calliandra calothyrsus	A	Nodulates freely
Cajanus cajan	None	Nodulates freely
Cassia siamea	A, B	Does not nodulate
Flemingia macrophylla	None	Nodulates freely
Gliricidia sepium	None	Nodulates freely
Inga juniciul	None	
Leucaena leucocephala	A, B rhizobia	Fast-growing
Prosopis juliflora	A,B	Nodulates freely
Sesbania sesban	A, B	Reciprocal affinity between cowpea and soybean rhizobia
Tephrosia candida	None	Nodulates freely

A. Hot water treatment
B. Conc. sulfuric acid treatment

3.2.4 Seed Pretreatment Procedures

The seeds of most legumes have hard, water-resistant coatings. The seed dormancy must be broken to allow maximum germination rates. Seed pretreatment procedures, called scarification, are required for species such as *Leucaena* or *Cassia,* but not for others such as *Gliricidia.* Table 3-1 provides information on pretreatment requirements. Scarification can be done mechanically (manually), or by hot water or acid treatments.

Mechanical Pretreatment

Seeds may be rubbed against an abrasive surface such as sand paper or an iron file. Care should be taken not to damage the seed embryo. Mechanized treatment is tedious for large numbers of seeds.

Hot Water Pretreatment

The simplest and most frequently used method of scarification is the hot water treatment. However, it may give erratic results. Boiling (100°C) water is poured onto seeds and the mixture is stirred for 3 or 4 minutes. The seed:water ratio should be 1:2 by volume. Effective treatment requires a minimum water volume of one liter. The water is then poured off and the seeds dried in the sun.

Alternatively seeds may be immersed in twice their volume of boiling water and allowed to soak in the gradually cooling water for 12-24 hours. The water should not be heated after seed immersion, since seeds will be killed by prolonged heating.

Acid Pretreatment

Acid treatment gives consistent results and is more reliable, but it is dangerous and expensive. Seeds are treated for 60 minutes with concentrated (commercial grade) sulfuric acid (98%, 36 *N*) at a seed to acid ratio of about 10:1 by volume. Following treatment the seeds are immediately rinsed in running water to remove traces of acid and dried for storage.

3.2.5 Inoculation of Legume Seeds

The leguminous MPTs preferred for alley farming, such as *Leucaena* and *Gliricidia*, rely on rhizobium bacteria in the soil to fix atmospheric nitrogen. Like all legumes, they develop root nodules where nitrogen fixation occurs — but only in the presence of a suitable strain of rhizobium bacteria (See Table 3-1). In cases where a leguminous hedgerow species is being introduced for the first time in an area, artificial inoculation may be necessary to guarantee rapid establishment.

When to Inoculate

There are five conditions under which soils may be devoid of rhizobia and warrant inoculation:

- in the absence of the same or a symbiotically related legume in the immediate past land use history;
- if poor nodulation occurred when the same crop was grown previously;
- when the legume follows a non-leguminous crop in a rotation;
- in land reclamation;
- when environmental conditions are unfavorable for rhizobium survival (e.g., extremes of pH).

How to Inoculate

A simple and inexpensive way to introduce the appropriate rhizobium is to mix the seeds before planting with soil collected from around established trees of the same species growing nearby.

Alternatively, seeds may be mixed with a rhizobium culture, either in a laboratory or in the field. Researchers may obtain rhizobia by:

- Purchasing an inoculant packet from a commercial producer,
- Requesting rhizobia from a culture collection (e.g., at a research institute), or
- Isolating rhizobia from nodules, dried root material, or soil.

Certain types of commercial inoculant packets can be readily used by field workers and farmers. More detailed information on inoculation techniques is provided in the Appendices.

3.2.6 Planting with Seedlings or Cuttings

The use of seedlings or cuttings is profitable for quick establishment, and may be required due to the above-mentioned limitations of direct seeding. In sub-humid or semi-arid environments with less than six rainy months and 1200 mm of annual rainfall, establishment by seedlings is preferred.

The advantages of planting with seedlings are that, in general, seedlings are tall enough to compete successfully with weeds and they require less care and protection during early development. A hedgerow planted from seedlings will attain a large size quickly. Disadvantages include the need to establish a nursery, the difficulty and expense of transporting seedlings, and the requirement for water — which should be applied immediately after transplanting.

Seedlings are grown in nursery bags from seeds planted 8-10 weeks prior to the rainy season. The seedlings should be transplanted (with or without bags) during the major rainy season as soon as the rains have stabilized. Nursery procedures are reviewed in Unit 2. In some instances, bare-root seedlings can be used with a high degree of success in the humid zone with species such as *Leucaena*.

The use of stem cuttings is feasible for some species such as *Gliricidia sepium* and *Erythrina* spp., but is generally less preferred when direct seeding is possible. Establishment of an alley farming system generally requires a large number of cuttings. This can be costly, inconvenient, and impractical if parent trees from which cuttings could be obtained are not locally available.

3.2.7 Spacing and Orientation of Hedgerows

The position and spacing of hedgerow and crop plants in an alley farming system depend on plant species, climate, slope, soil conditions, and the space required for the movement of people and tillage equipment. Ideally, hedgerows should be positioned in an east-west direction so that plants on both sides receive full sunlight during the day. The spacing used in field trials usually ranges from 4 to 8 meters between the rows and from 25 cm to 2 meters between the trees within rows. The closer spacing is generally used in humid areas and on sloping lands. The wider spacing is suitable for very humid areas (where radiation is limited) and in the sub-humid or semi-arid regions (where moisture is limited). See Table 3-2.

Position and spacing of hedgerows may also be affected by slope and the placement and design of soil and water conservation structures, where these are combined with alley cropping. On sloping land, hedgerows should always be placed on the contour (Figure 3-3). If this means that they do not have desirable east-west orientation, then they may need regular trimming to prevent excessive shading of adjacent crops.

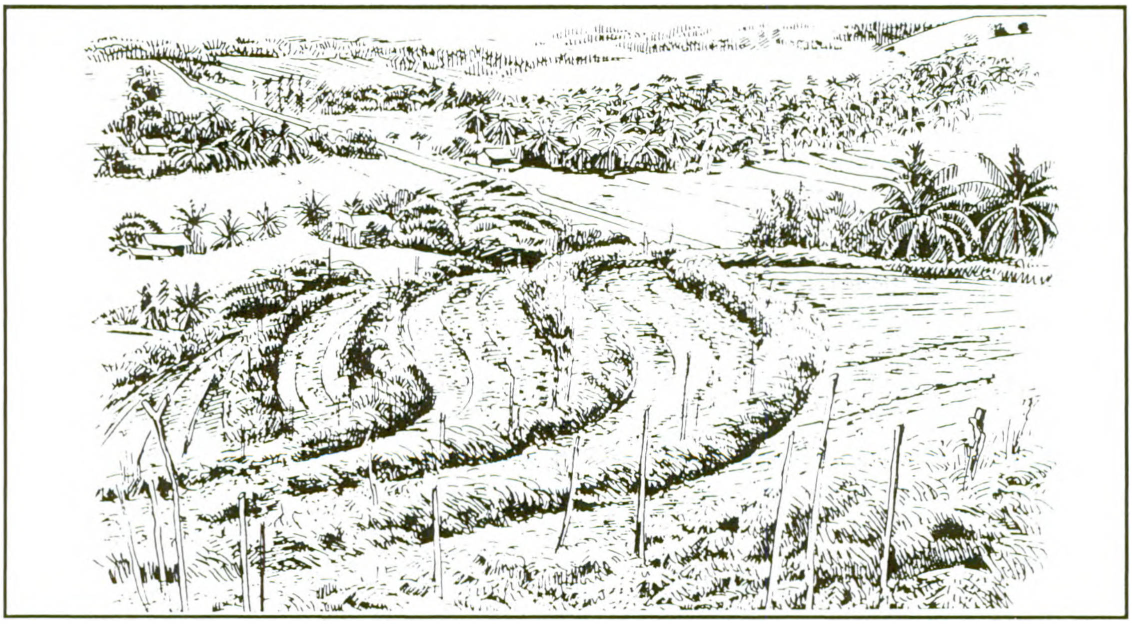

Figure 3-2. Alley farming on sloping land. Hedgerows follow contour lines.

If the land slopes steeply (e.g., on hillsides) the hedgerows will be spaced closer together. Also, on steep slopes the contour lines should be determined more accurately than can be achieved by eye alone. A simple A-frame device is adequate for establishing contour lines. (Refer to the Appendices for information on use of an A-frame and other simple techniques for planting along contour lines).

3.2.8 Humid Zone Prototype with *Leucaena* and/or *Gliricidia*

Based on years of experimentation, scientists at IITA have developed a prototype for alley farming with *Leucaena* and *Gliricidia* (Figure 3-3). The system performs optimally in the humid tropics, at low altitudes, and on non-acid soils.

Hedgerows can be established economically by planting seeds of *Leucaena* or *Gliricidia* with a food crop at the beginning of the rainy season. Plant *Leucaena* and *Gliricidia* seeds, as shown in the diagram, in rows between the rows of a crop such as maize. The rows of *Leucaena* may also be planted with maize as shown. (This arrangement is for the first year only; as *Leucaena* grows, there will be no more space for maize plants in the hedgerow itself). The trees can be planted at the same time as the maize seeds or shortly after the maize emerges.

The recommended spacing of *Leucaena* and *Gliricidia* rows for smallholders is 4 m, with 25 cm between planting holes. Using this spacing, and planting 3 seeds per hole, requires 1.7 kg of *Leucaena* seeds and 2.5 kg of *Gliricidia* seeds per hectare. In

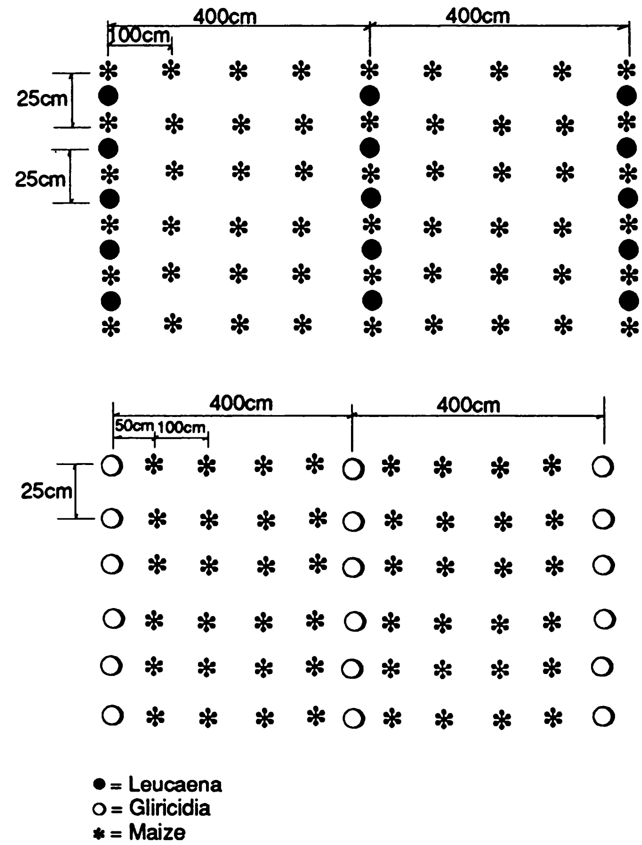

Figure 3-3. Arrangements for planting *Leucaena* and *Gliricidia* hedgerows with maize to create alleys 4 meters wide.

the subhumid zone, an alley width of 6 m is better. For tractorized operations, an alley width of > 9.0 m will be more convenient.

Mixing *Leucaena* and *Gliricidia* (or any two MPT species) in the same hedgerow is not recommended, as one species will tend to dominate the other. However, it will be advantageous in some circumstances to plant alternate rows of *Leucaena* and *Gliricidia*, for example, in alley farming with livestock.

3.2.9 Variations on the Prototype

The main thrust of current alley farming research in Africa is the adaptation of the humid-zone, non-acid soil prototype to other environments. The key experimental issues in this research effort are:

- choice of MPT species for hedgerows,
- choice of spacing between hedgerows, and
- rationale for establishing hedgerows in crop land.

The issue of MPT choice was covered in Unit 2, where it was noted that species other than *Leucaena* and *Gliricidia* would be more suitable for acidic soils or a dry environment (e.g., *Flemingia macrophylla* or *Acacia* spp., respectively). Necessary variations in inter-row spacing were also touched upon in earlier sections. The recommended spacings for different environments are summarized in Table 3-2.

Researchers have recognized that a farmer's rationale for establishing an alley farm also varies between agroecological zones. An important case in point is the semi-arid zone, where the need to minimize competition for water compels farmers to establish hedgerows at wide spacings of 6-8 m or more. The resulting low density of trees diminishes the value of the hedgerows as a source of mulch. There may not be enough prunings available per hectare to make a significant impact on food crop yields. However, hedgerow prunings could still provide an important source of supplementary

Table 3-2 Recommended inter-row spacings for various environments.

Environment	Inter-row Spacing
Smallholder Operations	
Perhumid Zone (overcast)	6 m
Humid Zone	4-6 m
Subhumid Zone	4-6 m
Semi-Arid Zone	8-12 m
Tractorized Operations	> 9 m

fodder for livestock production, which is commonly an important farm activity in the semi-arid zone. The widely-spaced rows could also provide excellent protection against wind and/or soil erosion.

Alley farming in dry areas or on acidic soils may benefit from the modification of establishment and management practices (e.g., a lighter pruning regime in semi-arid zones). Furthermore, in areas where competition between hedgerows and crops for water and nutrients is of concern, the introduction of new practices such as root pruning may become important. Normal plowing of the alleys in preparation for crop planting accomplishes tree root pruning. Special root-pruning procedures tend to be prohibitively labor-intensive.

The major differences between humid-zone and semi-arid zone prototypes are summarized in Table 3-3.

Table 3-3. Alley farming prototypes.

Humid Zone		Semi-Arid Zone	
1.	Narrow alleys (4-6 m)	1.	*Wide alleys (6- 8 m or more)
2.	*Leucaena*, *Gliricidia*, etc.	2.	**Acacia* spp., *Prosopis* spp., etc
3.	Hedgerow prunings for mulch/ green manure/fodder	3.	Hedgerow prunings for fodder
4.	Hedgerow for soil erosion/ runoff control	4.	Hedgerows/shelter belts for wind erosion/soil erosion/ runoff control

*Tentative recommendations.

3.2.10 Fertilizer Requirements during Establishment

On fertile land, such as newly cleared fallows, fertilizer may not be necessary. However, on moderate to low fertility soils, fertilizer is needed to boost initial growth of the tree seedlings. This should be applied 4 to 6 weeks after planting, as a side-dressing of a 15-15-15 N:P:K compound fertilizer at 15-20 grams of fertilizer per seedling or 300-400 grams per 5-meter row (equivalent to about 150 kg fertilizer per ha). This fertilizer application may not be necessary if the companion crop is fertilized.

3.2.11 Common Establishment Problems

Leucaena is highly prone to attack by rodents and termites. Although it is difficult and expensive to control termites, rodent attacks can be reduced by clean weeding. *Gliricidia* is susceptible to grasshopper attack during the dry season. Older leaves seem to be preferred to young emerging leaves. It is also highly susceptible to aphid infestation in the dry season; however, the aphids are harmless and disappear when the rains begin.

Young trees, especially *Leucaena*, may be eaten by free-roaming animals if access is possible. Protection may be necessary in some areas. It will be too expensive for a smallholder to put wire fencing around a field, but thorn bushes or similar "unfriendly" materials can be planted or cut to provide a barrier. Where the forage trees are planted more densely, as in an intensive feed garden (see Unit 4), less fencing material will be required.

Using hired labor to weed an alley farm can pose problems, because the laborers are usually not familiar with the tree seedlings, and may think they are weeds. Farmers using hired labor should themselves weed strips along the tree rows before contracting out the rest of the field for weeding, or they should supervise the work carefully.

Tree seedlings, especially those of *Leucaena*, grow slowly at first, and thus need attention and care during the early establishment phase. Farmers should not plant trees on land earmarked for fallow in the next year, or leave them unmanaged.

3.2.12 Hints on Successful Seedling Establishment

Weeds pose a great challenge to the young tree seedlings, especially in the first months of growth. Strips of land on which tree rows will be established must be weeded thoroughly before planting and kept weed-free during the first 3 months of growth.

It is easier to establish trees on a food-crop farm if the crops are planted in rows. The rows must run across the slope so that the trees effectively check erosion.

Trees should not be planted in shaded conditions, such as in mature stands of cassava, or with creeping crops such as melon. If yam is an intercrop, staking of the yams will be needed, especially near the tree rows. Late planting, especially of *Leucaena*, can result in poor seedling development.

Hedgerows should not be thinned because this would curtail biomass production. Certain earlier works on alley farm establishment recommended thinning; however, this is unnecessary, as hedgerow density is self-regulating.

Although the hedgerows can be established with a number of companion crops, short-duration and short-statured crops have been found to be more compatible.

3.3 GUIDELINES FOR HEDGEROW MANAGEMENT

In an alley farming system, the crops grown between hedgerows are managed in essentially the normal way. For example, the introduction of hedgerows in a smallholder's maize cropping system would not require changes in the normal practices for maize planting and maize harvesting. The major management issues which do arise in an alley farming system are:

- pruning regime (when and how to prune),
- application of mulch (how to apply mulch and expected contributions of hedgerow prunings to crops),
- fertilization (whether or not external fertilizer is needed),
- fallows (if and when to incorporate short fallow periods), and
- weed control.

3.3.1 Pruning Regimes

Once established, the hedgerows will need to be pruned occasionally. Pruning serves two purposes: it minimizes shading of the companion crop, and it makes leaves and branches available, e.g., for mulching, staking, and firewood. Hedgerow pruning is a pivotal activity in alley farming. It is the most labor- and management-intensive component of the system.

A pruning regime refers to the type and frequency of pruning practiced at a site. The choice of pruning regime depends on several factors, including the crop and hedgerow species, the relative importance and type of products, by-products, and services expected from the hedgerows, and the amount and timing of labor available for hedgerow management and harvesting. The optimal pruning regime choice will often be a compromise between keeping the woody plant in good condition for long-term production, providing adequate mulch (and stakes, etc.) for the farm, and avoiding short-term damage to the companion crops.

Pruning Techniques

There are two types of pruning techniques, as illustrated in Figures 3-4, 3-5 and 3-6. In *coppicing*, the preferred technique in most cases, the trees are cut close to the ground — at a height of 30 to 60 cm. New shoots will be produced from the stump. In *pollarding*, the crown of a tree is cut back to a height of roughly 2 meters. Regrowth

Figure 3-4. *Leucaenaa leucocephala* and most other alley farming species should be coppiced at a height of 30-60 centimeters.

will be beyond the reach of browsing animals. Pollarding is sometimes preferred by farmers. However, coppicing at roughly 60 cm is usually best, because if the stumps are any taller, the regrowth may give too much shade to companion crops. Recent experience in East Africa suggests that, where shading competition is not a problem, a coppicing height of 1 meter may be advantageous because it minimizes workers' back strain. If stumps are shorter than 30-60 cm, tree productivity is reduced.

Figure 3-5. Coppicing with a Swede saw. The trees have been pruned many times previously.

Figure 3-6. Pollarding involves the removal of the tree's crown, leaving a main stem of about 2 meters.

For manual pruning, a sharp cutlass or slasher should be used. A blunt cutlass or slasher that splits up the stem and strips the bark may predispose the trees to disease and delay regrowth; this can result in the death of the trees. Mechanized pruning could be used to save labor. For pruning large plots, cutting back one hectare of 1-year old

Leucaena hedgerows (spaced 4 m apart) using Howard rotary blades takes about one hour. Small 2.5-horsepower backpack brush cutters have also given satisfactory results for pruning uniformly sized plants with a diameter of less than 3 cm. It takes about 8 hours to prune one hectare with brush cutters.

Pruning Schedules

A prototypical pruning schedule is shown in Figure 3-7. *Leucaena* is planted with maize at the start of the first growing season. The maize is harvested at the end of the first season, but the *Leucaena* is allowed to grow continuously for a full year. As the second year's maize crop is established, the hedgerows are coppiced to just above knee height (approx. 60 cm), and the prunings are used as mulch. The average height at one year is usually in the range of 2.0 to 2.5 m, but is dependent on environmental conditions.

Regrowth in the second and subsequent years is rapid. The new shoots will need to be pruned to prevent excessive shading of the maize growing in the alleys. For *Leucaena*, the new shoots should be at least 1 m long before the next cutting. In the humid zone, on non-acid soils, shoots usually reach 1m in about 6 weeks during the rainy season and 8 to 12 weeks in the dry season. Thus, the farmer will need to cut back the hedgerows once or twice as the maize matures (as shown in Figure 3-7).

If a second-season crop will be grown, such as cowpea, the hedgerows should be coppiced again at the start of the second season. The prunings can be applied as mulch for the cowpeas. Hedgerows should be pruned as necessary to prevent excess shading — perhaps once or twice during the second cropping season. In the dry season, hedgerows can be left unpruned for continuous growth (as in Figure 3-7). Or, if the hedgerows are used for livestock fodder, they may be pruned when new shoots are of suitable length.

Table 3-4. Recommended pruning frequencies of *Leucaena* hedgerows spaced 4 meters apart. Greater pruning height requires more frequent pruning to prevent shading of adjacent crops.

Pruning Height	Maize (1st season)	Cowpea (2nd season)
25 cm	2 prunings	1 pruning
75 cm	3 prunings	2 prunings

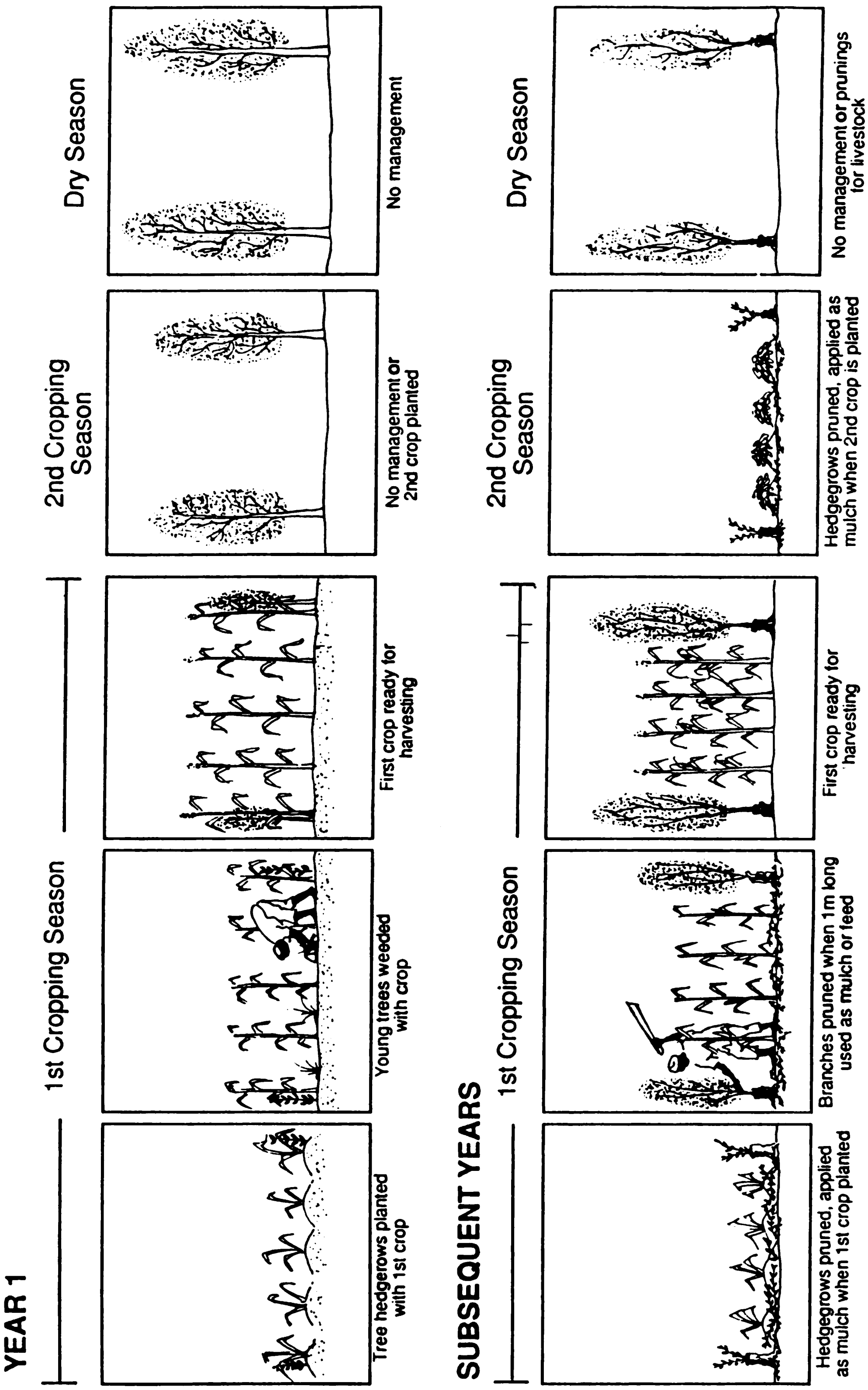

Figure 3-7. Schedule for establishing and managing a prototypical alley farm.

From the *Leucaena*/maize/cowpea prototype schedule, we may extract the following generally applicable principles of hedgerow pruning:

- When the hedgerow is established, pruning should be avoided for the first 6-12 months. In semi-arid areas, pruning should be delayed for 12-18 months after planting, or even longer.
- At the time of planting food crops in an established alley farm, the trees should be coppiced to provide mulch and fertilizer for the crop and also to avoid shading crop seedlings.
- Regrowth after this initial cutting may be harvested selectively and continuously for feeding livestock, or it may be pruned periodically to be used as additional mulch for soil fertility maintenance and to avoid shading.
- As a general rule, the lower the hedgerows and the taller the crop, the less frequently is pruning needed (Table 3-4). Frequent pruning favors leaf biomass over wood yield.
- The second year pruning schedule can be repeated in the third and subsequent years of alley farming. In total, the hedgerows will be pruned 4 to 6 times per year.

These principles may be applied, for example, to farms where two or more food crops are grown simultaneously in the alleys. Figure 3-8 illustrates the schedule for alley farming with maize and cassava.

3.3.2 Application of Mulch and Fertilizer

In mulching, hedgerow prunings are distributed on the soil surface in the alley before planting and while crops are growing. The potential benefits of applying the pruning as mulch to companion crops are reviewed in Unit 1. One crucial benefit is the fertilization effect of the mulch. For example, *Leucaena* and *Gliricidia* hedgerow prunings contribute about 40 kg of N per hectare to the companion crop (as reviewed in Unit 1).

Prunings from *Leucaena* are a more effective source of nitrogen when incorporated into the soil than when applied as mulch. This is because prunings decompose at a faster rate in the soil. When buried in the soil, fresh *Leucaena* prunings have a half-life of less than 10 days.

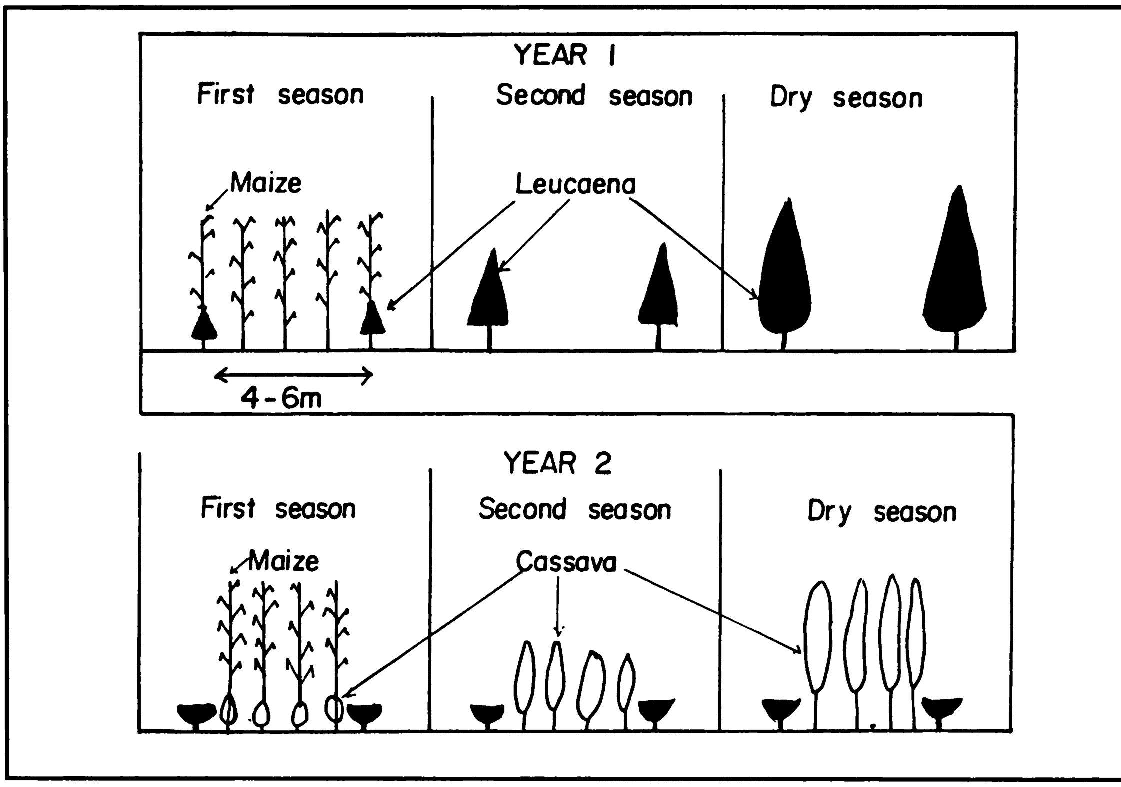

Figure 3-8. Cropping sequence diagram for establishing *Leucaena leucocephala* hedgerows for alley farming with maize/cassava.

Crops typically use N from prunings at low rates of efficiency (18-36%), probably due to lack of synchronization between crop demand and N supply, and because of losses of N through volatilization and leaching. Small amounts of supplementary N fertilizer may be needed to realize maximum yield of the alley-farmed maize. Research has shown that the presence of mulch tends to increase the effectiveness of fertilizer application.

As a general rule, optimum long-term management of an alley farm will include occasional applications of prudent amounts of fertilizer. For most environments, the idea that alley farming eliminates all external requirements for fertilizer is a misconception. For farmers who cannot afford either fertilizer or long fallows, alley farming can be a valuable management option for sustaining and/or intensifying production. However, farmers who *can* afford external inputs of fertilizer (whether inorganic fertilizers, animal manure, etc.,) will be able to obtain better results. For these farmers, the optimum strategy for managing an alley farm will include inputs of external fertilizer and/or short fallow periods (see below).

3.3.3 Short Fallow Periods

Alley farming allows long periods of continuous cultivation on one plot. For low-input agriculture in areas where long fallow periods have become a luxury, alley farming provides clear benefits over traditional systems. Yet the question arises: should an established alley farm be cropped indefinitely? Recent research shows that this is probably not the optimum management practice.

Farmers who can afford an occasional fallow will enhance the sustainability of the alley farming system through the integration of short fallows into the farming cycle. No crops are grown for two years, and small ruminants may be allowed to graze. Such fallows show positive effects on survival, growth, vigor, and productivity of hedgerows, and on their soil fertility maintenance and regeneration abilities. These benefits have been demonstrated on both acid and non-acid soils.

For example, a long-term alley farming and grazing trial with *L. leucocephala* compared a continuous alley farming system with a rotational system of alley farming and a short (2-year) grazing fallow. After the fallow period, the rotation system yielded about 35% and 55% more maize than the continuously alley farmed system and the control plot (no trees), respectively. The rotation system showed higher yields for at least three years after the fallow.

Short fallow periods in alley farming also allow the satisfaction of farmer requirements for stakes, wood, and fodder. Moreover, they are effective in combating noxious and problem weeds such as *Imperata cylindrica* and *Chromolaena odoratum*.

An example of a rotation system of 8 years' alley farming to 2 years' fallow is illustrated in Figure 3-9. The fallow may be left completely unmanaged. Alternatively, the following management practices could be used during the fallow period:

- Pruning of hedgerows and application of prunings as mulch (for soil improvement and weed suppression).
- Infrequent pruning to provide firewood and stakes.
- Pruning after the rainy season to prevent leaf drop in species such as *Gliricidia*. This will maximize dry season availability of foliage.
- Grazing by small ruminants or cattle (for fodder and soil improvement).

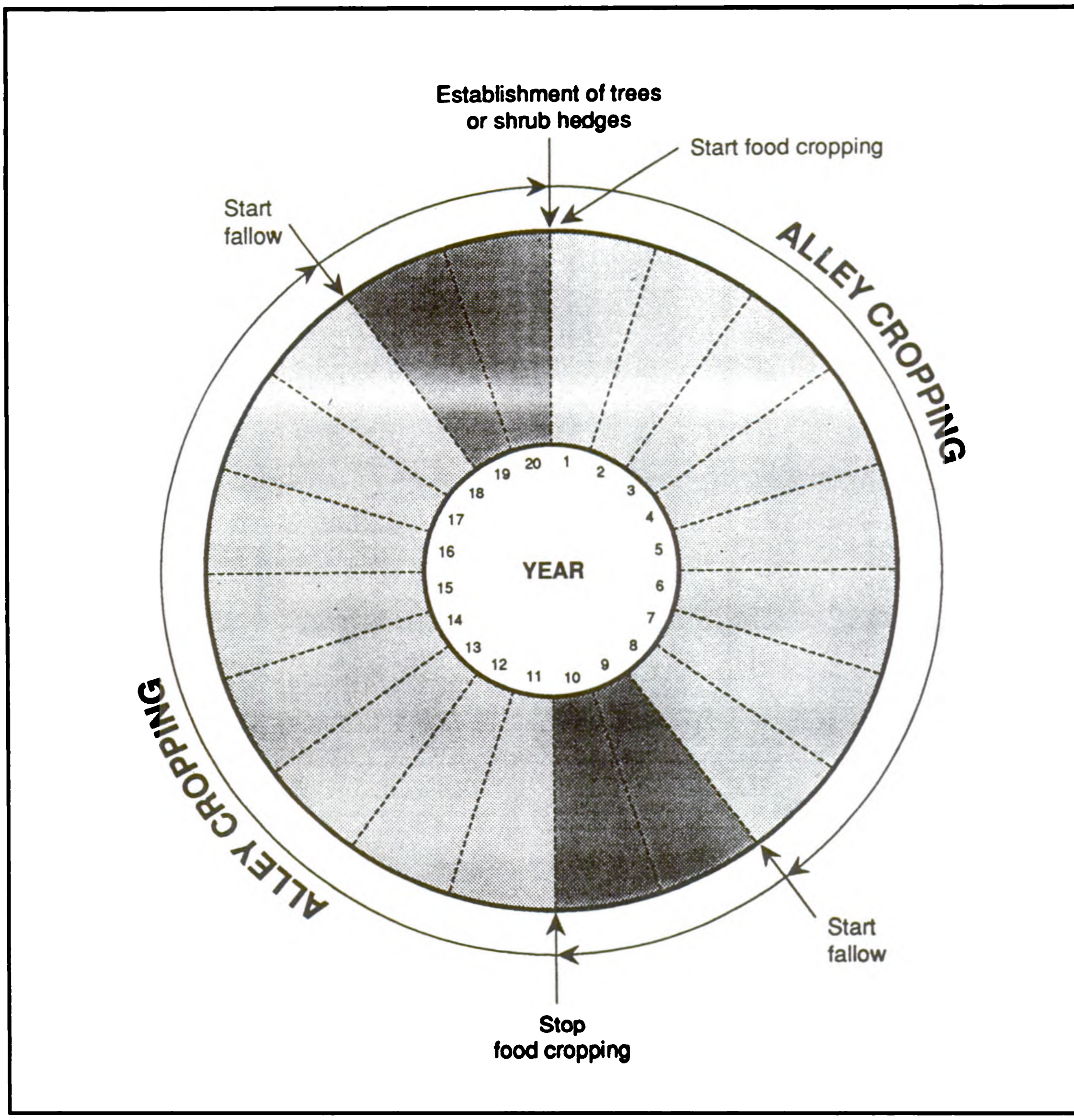

Figure 3-9. Rotation of 8 years' alley farming and 2 years' fallow. Integration of short fallows can improve the sustainability of the system.

- Occasional weeding, especially if volunteer *Leucaena* seedlings pose a weed problem.

3.3.4 Weed Control

Alley farming can aid in the suppression of weeds by providing mulch cover and by shading the plot during the dry season. Prunings from slow-decomposing MPT species, such as *Acioa barteri* and *Alchornea cordifolia,* can suppress weed growth if applied in sufficient quantity. There is evidence that, as alley farming enriches the soil, food crops are better able to compete with problem weeds such as *Imperata* grass. Weed suppression can be a significant benefit of alley farming, especially in small-scale farming systems, where weeding can account for over 30% of labor used in crop production.

Moreover, alley farming provides a means to recover cropland that has been taken over by problem weeds. If the hedgerows are allowed to grow for two years and close their canopies, most troublesome weeds will be shaded out. *Gliricidia sepium* and *Acioa barteri* have proven particularly effective in this regard. Weed research in alley farming is a new field, however, and there is little information on how or when alley farming systems suppress weeds. The key parameters for monitoring weeds are weed density, species composition, seed bank analysis, and weed dry weight.

Some MPT species have the unfortunate characteristic of producing large quantities of seeds. *Leucaena*, for example, can pose a major weed problem during fallow periods. Volunteer *Leucaena* seedlings need to be controlled early before they develop an extensive root system.

3.4 FEEDBACK EXERCISES

All answers can be found in the text and figures of Unit 3.

1. Name three key technical factors for obtaining the full benefits of alley farming systems:

   1. ______________________________
   2. ______________________________
   3. ______________________________

2. The following statements concern recommended practices for establishing hedgerows. Circle T for true statements or F for false ones:

i)	The trees should be planted at the end of the major rainy season.	T	F
ii)	Trees and shrubs must be planted by machine.	T	F
iii)	*Leucaena* may be planted in the same row with maize.	T	F
iv)	Deep seed placement hampers germination and emergence.	T	F
v)	Pretreatment of legume seeds with acid is the preferred method of scarification in all cases.	T	F
vi)	Inoculation is a technique for preventing tree diseases.	T	F
vii)	If a legume tree species was grown succesfully in a plot in the previous year, replanting of the same species may not require inoculation with rhizobia.	T	F
vii)	Planting with seedlings requires establishment of a nursery and facilities for transporting seedlings to the field.	T	F

3. For smallholder alley farming in the humid zone, the recommended spacing between hedgerows is 4-6 meters. Complete the table below by indicating whether the various environments require alleys that are wider or narrower than 4-6 meters.

Environment	Alley Width (Compared to Smallholder/Humid Zone)
i) Tractorized operations	Wider
ii) Perhumid zone	________________
iii) Subhumid zone	________________
iv) Semi-arid zone	________________
v) Steep slopes in humid zone	________________

4. Provide brief answers to the following questions:

   i) The rationale for alley cropping in the semi-arid zone differs from that in the humid zone. Explain.

   ii) Farmers observe that their *Gliricidia* hedgerows have become infested with aphids, and that their *Leucaena* hedgerows are being attacked by termites. Which of these problems is potentially serious, and which one can most likely be ignored?

   iii) Why is coppicing preferable to pollarding as a pruning technique?

   iv) What is meant by the term "pruning regime"?

5. Imagine you are setting up an alley farm using *Leucaena*. Assume you will be planting maize during the first season (May-Aug), cowpeas during the second (Sept-Dec), and no food crop during the dry season (Jan-April). Assume also that at each pruning you will cut back the trees to a height of 25 cm. Use the calendar below to plan the necessary establishment and management activities, paying special attention to the scheduling of tree prunings. There is more than one possible "correct" calendar.

   Use these codes:

PM = Plant maize	PL = Plant *Leucaena*	PC = Plant cowpea
HM = Harvest maize	Pr = Prune *Leucaena*	HC = Harvest cowpea
W = Weed plot		

	J	F	M	A	M	J	J	A	S	O	N	D
Yr. 1												

Yr. 2 |_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|
J F M A M J J A S O N D

Yr. 3 |_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|
J F M A M J J A S O N D

6. If optimum long-term performance of a plot is desired, alley farming in most environments will reduce but not eliminate the need for (a) fertilizer and (b) fallow periods. Explain.

____

____

____

____

____

7. Describe two ways in which alley farming contributes to weed suppression.

1.____

____

2.____

____

3.5 SUGGESTED READING

Atta-Krah, A.N. and G.O. Kolawole. 1987. Establishment and growth of Leucaena and *Gliricidia* alley cropped with pepper and sorghum. Leuc. Res. Rep. 8: 46-49.

Atta-Krah, A.N. 1984. The weediness of *Leucaena leucocephala* (Lam.) de Wit and its control in *Leucaena*-based agroforestry systems. Ph.D. Thesis. Univ. of Ibadan, Ibadan, Nigeria.

Atta-Krah, A.N. 1990. Alley Farming with *Leucaena* : Effect of short grazed fallows or soil fertility and crop yields. Expl. Agric. 26: 1-10.

Briscoe, Buford C. 1989. Field trials manual for multipurpose tree species. MPT species Network Research series, Manual No. 3. Winrock International Institute for Agricultural Development.

Duguma, B., B.T. Kang, and D.U.U. Okali. 1988. Effect of pruning intensities of three woody leguminous species grown in alley cropping with maize and cowpea on an Alfisol. Agroforestry Systems. 6: 19-35.

Gichuru, M.P., B.T. Kang and S. Hauser. 1990. Alley cropping with Acioa barteri, *Cassia siamea, Flemingia macrophylla* and *Gmelina arborea* on an Ultisol. Agronomy Abstracts, ASA: 57.

Guevarra, A.B. 1976. Management of *Leucaena leucocephala* (Lam) de Wit for maximum yield and nitrogen contribution to intercropped corn. Ph.D Thesis, Univ. of Hawaii, Honolulu.

Kang, B.T. 1988. Nitrogen cycling in multiple cropping systems. In: J.R. Wilson (ed.) Advances in nitrogen cycling in agricultural ecosystems. pp. 333-348 Wallingford, England: CAB International.

Kang, B.T. and B. Duguma. 1985. Nitrogen management in alley cropping systems. In: B.T. Kang and J. van der Heide (eds.). Nitrogen in farming systems in the humid and subhumid tropics. pp.269-284. Haren, Netherlands: Inst. Soil Fertility.

Kang, B.T. and B.S. Ghuman. 1989. Alley cropping as a sustainable crop production system. Paper presented at Int. workshop on conservation farming on hillslopes, Taichung, Taiwan, R. O .C. , 20-29 March , 1989.

Kang, B.T. and A.S.R. Juo. 1983. Management of low activity clay soils in tropical Africa for food crop production. In F.H. Beinroth, H. Neel and H. Eswaran (eds.). Proc. fourth international soil classification workshop, Kigali, Rwanda. pp 450-470 Brussels, Belgium: ABOS-AGCD.

Kang, B.T., L. Reynolds and A.N. Atta-Krah. 1990. Alley Farming. Advances in Agronomy 43: 315-359.

Kang, B.T., G.F, Wilson, and T.L. Lawson. 1984. Alley cropping : a stable alternative to shifting cultivation. Ibadan, Nigeria: International Institute of Tropical Agriculture.

Kang, B.T., Osinubi, O.A., Vadivel, R., and Gatmmaitan Jr F.M. 1986. Establishing and managing alley cropping plots. Ibadan, Nigeria : IITA.

Laguihon, W.A. and H.R. Watson, 1986. How to farm your hilly land without losing your soil (mimeo). Davao Del Sur, Philippines: Mindanao Baptist Rural Life Centre.

National Academy Press (NAP). 1982. Ecological aspects of development in the humid tropics. Washington, D.C.: National Academy Press.

Reynolds, L., A.N. Atta-Krah and P.A. Francis. 1988. Alley Farming with livestock — guidelines. Ibadan, Nigeria: ILCA.

Rocheleau, D., F. Weber and A. Field-Juma. 1988. Agroforestry in dryland Africa. Nairobi: ICRAF.

Ryan, K.T. and S. Boonchee, 1988. Vegetative and tillage strategies for erosion control. In N.T. Vergara and N.D. Briones (eds.). Agroforestry in the Humid Tropics. Honolulu, Hawaii: Env. Policy Inst., East-West Center, pp. 111-124.

Steppler, H.A. and P.K.R. Nair (eds.), 1987. Agroforestry: a decade of development. Nairobi: ICRAF.

Vega, E., C. van Eijk-Bos and L.A. Moreno, 1987. Alley cropping with Gliricidia sepium (Jacq.) Walp and its effect on the soil losses on hill slopes in Uraba, Colombia. In D. Withington, N. Glover and J.L. Brewbaker (eds.). Gliricidia sepium (Jacq.) Walp. Management and Improvement. NFTA special publ. 87-01. Honolulu, Hawaii.

Yamoah, C.F., Ay, P. and Agboola, A.A. 1986. The use of *Gliricidia sepium* for alley cropping in the southern guinea savanna zone of Nigeria. International Tree Crops Journal. 3:267-79.

Young, A., 1989. Agroforestry for soil conservation. Wallingford, England: CAB International.

UNIT 4

The Integration of Livestock Production in Alley Farming

Unit 4: The Integration of Livestock Production in Alley Farming

Main Contributors: L. Reynolds, J. Cobbina

4.0 PERFORMANCE OBJECTIVES

Unit 4 is intended to enable you to:

1. Discuss the importance of livestock production in tropical Africa.

2. Recall the contributions which leguminous tree can make to livestock nutrition, including increased productivity and provision of protein-rich feed during the dry season.

3. Demonstrate familiarity with recent research concerning the benefits to livestock productivity from supplemental feeding with hedgerow prunings.

4. Explain the dry-season constraints to livestock production, and the corresponding solutions offered by alley farming.

5. Describe three ways of producing forage for livestock from alley farms on which food crops are grown.

6. Describe the systems for growing grass alongside hedgerows, including intensive feed gardens, alley grazing, and fodder tree banks.

7. Recall special considerations for establishing tree/grass intercrops, such as the need to protect young trees, requirements for fertilizer inputs, and harvesting schedules.

8. Recall recommended practices for managing fodder trees and for feeding their foliage to livestock.

9. List important research issues for the integration of livestock production with alley farming.

4.1 INTRODUCTION TO ALLEY FARMING IN SMALLHOLDER LIVESTOCK PRODUCTION

In alley farming with livestock, the hedgerows of trees or shrubs are managed to provide high-quality fodder for sheep, goats, and/or cattle. There are two main types of systems that integrate alley farming principles with livestock production:

- alley farming with food crops and livestock
- alley farming with grass and livestock

In the first system, the hedgerows are managed to provide fodder for the animals and mulch for the crops. In the second type of system, both the trees and the intercropped grass are fed to animals.

Livestock are a minor enterprise and generally receive little attention in most mixed crop/livestock farming areas of sub-Saharan Africa. Thus, any innovation to improve livestock production should also benefit other farm activities in order to be acceptable to the farmers. Alley farming with food crops and livestock allows smallholders to follow a low-cost pathway to improving both crop and livestock production, reducing reliance on external inputs, and increasing sustainable offtake from the land. Alley farming with grass and livestock is an innovative means of overcoming the nutritional constraints faced by livestock production in many areas of tropical Africa.

The importance of livestock production in tropical Africa is many-sided. Livestock products, in the form of meat, milk, and various dairy products, contribute about one fifth of high quality dietary protein in sub-Saharan Africa. These proteins have a higher biological value than pulses and cereals, and are also preferred by consumers. In addition to providing high-value food, livestock provide:

- a means for investing capital and a source of ready cash,
- security against food shortage,
- a means for strengthening social relationships (e.g., through loans for establishment of new herds),

- draught power and manure (especially with cattle), and
- hides and skins.

In southern Nigeria, where ILCA scientists first developed alley farming with livestock, small ruminants are the predominant farm animals. In that region, a typical small farm extends over 2 ha of cultivated land, with perhaps 6 ha of fallow. The major crops are maize, cassava, and yam, and the typical herd size is 3-6 animals. Household production must support 6-8 people. The primary objective of the farmer is to grow sufficient food for the family, with any surplus going for sale. In southwestern Nigeria, animals roam freely, scavenging for household waste to supplement natural grass and the browse that grows around the village. In southeastern Nigeria, where human population pressure on land is greater, confinement and tethering are more common, especially during the rainy season, to limit damage to crops.

Although ILCA's initial interest in alley farming was directed towards sheep and goats, the potential of leguminous tree forage for cattle is also being explored. Feed gardens, comprising tree and grass combinations, are being encouraged for stall-fed dairy or beef cattle in Kenya, Malawi, and Zimbabwe. The derived savannah region of West Africa offers similar possibilities.

4.2 CONTRIBUTIONS OF LEGUMINOUS TREES TO LIVESTOCK NUTRITION

The leguminous multipurpose trees which in alley farms provide nitrogen-rich mulch to enhance soil fertility can, at the same time, provide an on-farm source of high quality supplementary feed for ruminant livestock. Two tree species, *Leucaena leucocephala* and *Gliricidia sepium*, have been most widely used for alley farming with livestock. The foliage from both these species contains over 20% crude protein (3.4% nitrogen) and hence provides a valuable high protein feed supplement for livestock.

The leguminous trees are used as supplements only, and should not become the main feed source. *Leucaena* is, in fact, toxic to animals when it exceeds 30-40% of their total feed intake. The toxicity is due to the high levels of mimosine in *Leucaena*. Mimosine poisoning leads to hair loss and illness, and can even be fatal.

4.2.1 Increased Productivity

Some of the important results of feeding sheep and goats with *Leucaena* and *Gliricidia* foliage are:

- It increases total food intake.
- It increases the overall productivity of dams as measured by weight of offspring weaned/dam/year (Figure 4-1).
- When offered to dams during late pregnancy and lactation, and to the offspring from weaning to 6 months of age, it enhances growth rates and survival rates (Table 4-1).
- Provision of supplementary browse increases the rate of weight gain in growing and fattening sheep (Table 4-2).

On-farm studies of alley farming with food crops in southwestern Nigeria have shown that the tree productivity on farmers fields was 5.4 t dry matter (DM) per hectare per year, with 75% being available during the growth of the first-season food crop. Farmers offered 176 kg of foliage DM/year to their goat herds as cut-and-carry browse on 10 days per month, at a rate of 147 g edible DM/animal/occasion. The productivity index of these browse feeders was 11.3 kg as compared to just 7.8 kg for goats that were not fed MPT foliage, an increase of 44%. (The productivity index is the weight of kids at 12 months/doe/year times doe survival rate).

This increase in productivity reflected the improvements in litter size, parturition intervals, and survival rates associated with supplemental feeding. (See Table 4.3.) A number of farmers in subsequent years have planted tree-only feed gardens specifically to increase the amount of forage available.

4.2.2 Solutions to Dry Season Constraints

Nutritional benefits to livestock assume particular importance during the dry season. In vast areas of tropical Africa, farmers face serious problems of low quantity and quality of forage to feed their animals at this time. Tropical grasses are low in protein, especially in the dry season. Most crop residues and other grazing resources are low in digestibility and N content during these months. However, the multipurpose trees and shrubs used in alley farming have long tap roots and so can access water at

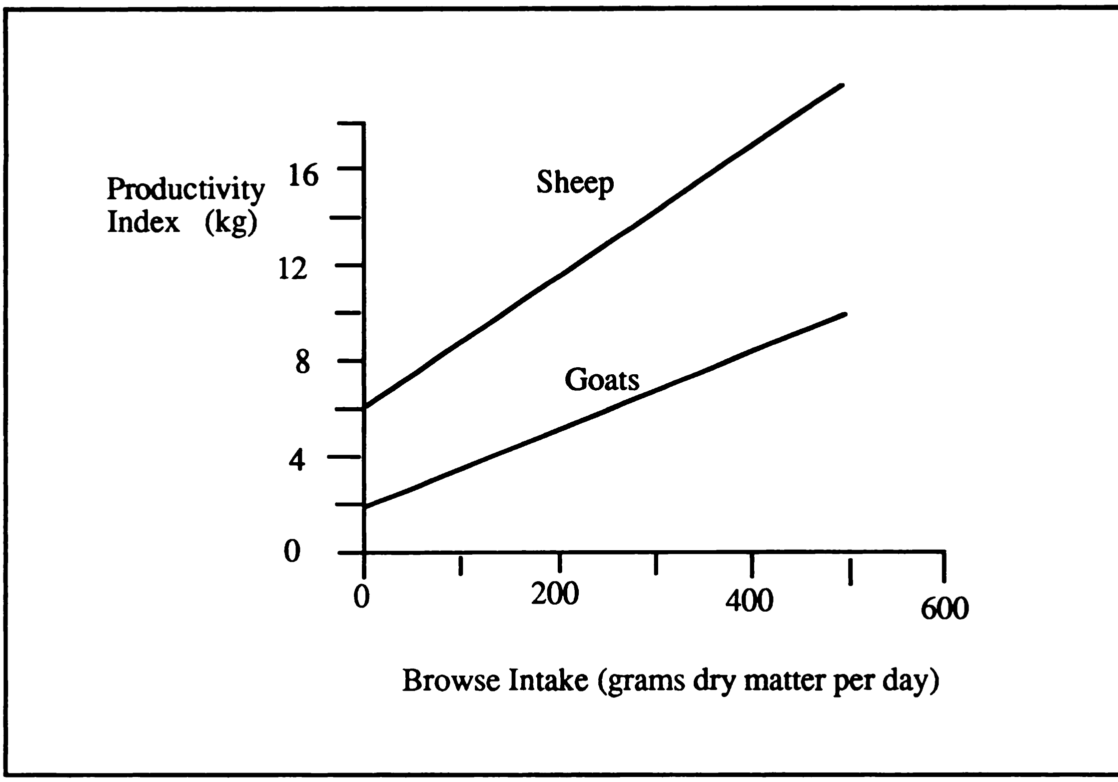

Figure 4-1. Effect of browse intake on the productivity of sheep and goats, Ibadan, Nigerian humid zone, 1986/87.

deeper soil levels than shallow-rooting plants. Thus, the MPTs can produce leaves and branches for forage throughout the year.

The importance of high-protein fodder in the dry season stems from the basic nutrition mechanism in ruminants. Ruminants (cattle, sheep and goats) have a multi-compartment stomach, unlike the simple stomach found in non-ruminants (pigs, humans). This allows ruminants to make use of the nutrients found in fibrous materials, such as grass, that humans cannot use. The primary breakdown of fibrous food is carried out, not by the animal itself, but by billions of microbes that live in the largest of stomach compartments, the rumen, which acts as a fermentation vat.

Furthermore, ruminants do not require the high quality protein feeds needed by non-ruminants. Rumen microbes can make their own essential amino-acids from simple nitrogenous compounds, such as ammonia, to the benefit of the animal when the microbes die and are digested.

Table 4-1. The effects of supplementary *Leucaena* and *Gliricidia* browse on the growth and survival rates of West African Dwarf goats and West African Dwarf sheep. Note that the response of sheep to supplementation is twice that of goats (Source: ILCA, 1988).

	Browse Intake (g DM/day)		Growth Rate (g/day) Birth to		Survival to 24 weeks
	Dam (a)	Offspring	(b)Weaning	(c) 24 weeks	
Goats	143	39	17.4	14.0	0.36
	254	83	28.7	20.1	0.46
	554	160	25.9	20.9	0.82
	719	246	31.9	28.3	0.94
Sheep	0	0	39.0	25.4	0.50
	120	34	46.7	30.7	0.62
	239	77	57.2	34.0	0.70
	441	136	66.3	44.5	0.89
	741	250	84.0	50.3	1.00

(a) During the final two months of pregnancy up to weaning.
(b) From weaning to 24 weeks.
(c) Weaning at 12 weeks for lambs, and 16 weeks for kids.

An active population of microbes in the rumen is, therefore, essential to the well being of the animal, allowing ruminants to exist on feed that is unusable by non-ruminants, and to convert fibrous waste into meat and milk. In the dry season, when the level of protein in grass falls below 6%, rumen microbes are unable to make enough protein to maintain their own growth and reproduction rate. As a result, the microbe population falls, and, because food will not pass out of the rumen until it has been partially digested by the microbes, the flow of food through the intestinal tract slows down. Food intake by the animal is therefore reduced. Animals lose body condition and milk production is reduced.

Supplying additional protein during the dry season will maintain or increase the microbial population, increase digestion rates, and raise food intake. The total amount of nutrients available to the animal will rise in two ways: higher intake and better

Table 4-2. Effect of supplementary browse on the growth and fattening rate (g/day) of West African Dwarf lambs offered a basal ration of ad-libitum Guinea grass (*Panicum maximum*).

Group	Age range	Intake *Panicum*	(g DM/day) Browse	Total	Growth g/day
Males	6-18 months				
1		630a	237a	915a	30.3a
2		613a	491b	1155b	41.7b
3		379b	689c	1116b	48.9c
Females	6-15 months				
1		670a	196a	914a	25.8a
2		605b	453b	1196b	29.0a
3		337c	604c	986c	37.7b

Within a sex group, values in columns with different letters are significantly different ($P<0.05$)

All groups received 50 g/day of sun-dried cassava peel.

Table 4-3. Production parameters for free-roaming village West African Dwarf goats in SW Nigeria.

	Browse feeders	Non-browse feeders
Litter size	1.48	1.41
Parturition interval (days) (1)	280	298
Weight at 12 months (kg)	9.5	10.1
Survival to 12 months	0.67	0.64
Survival of adults	0.92	0.70
Productivity index (kg) (2)	11.3	7.8

(1) 60% of adult females kidded more than once
(2) Productivity index = wt of kids surviving to 12 month/doe surviving over a 12 month period/year.

digestibility. On commercial cattle ranches, oilseed cake or urea are often used to increase crude protein intake, but this is rarely feasible for smallholder farmers raising sheep or goats. Cultivation of leguminous MPTs is a viable alternative.

4.3 ALLEY FARMING WITH FOOD CROPS AND LIVESTOCK

In a typical alley farming system, food crops such as maize or rice are grown in the alleys between hedgerows. In this system, there are three ways to produce forage for livestock:

- Forage production during the cropping phase,
- Forage production from hedgerows during a fallow period, and
- Grazing of the alleys in a fallow period.

Here a fallow period refers either to the dry season in a normal cropping year, or to an optional short fallow period during which no crops are grown for one or two years. The first two methods are cut-and-carry systems in which the trees are cut occasionally to feed animals. The animals may be fattening cattle, milking cows, or calves. Cut-and-carry is also for suitable sheep and goats, both free-roaming and confined in pens.

4.3.1 Forage Production during Cropping

The two sources of feed for animals in alley farms with food crops are:

- hedgerow prunings, and
- crop residues (e.g., maize stover)

The hedgerows are pruned occasionally to prevent shading and are generally used as mulch to restore or maintain soil fertility. Some of the prunings are taken out of the cropland to feed ruminant livestock . The crop residue could also be used as mulch, or could be removed for feeding to livestock on a cut-and-carry basis. Alternatively, the crop residue could be grazed by ruminant livestock *in situ* during the short fallow periods between one crop and the next. The main question to consider here is the amount of fodder that can be made available from hedgerow prunings without detriment to crop yield.

In order for the system to sustain itself, a proper balance needs to be worked out between prunings used as animal feed, and prunings used as mulch and green manure. Total removal of the prunings, a condition that may occur in a cut-and-carry alley farming system, would most likely reduce the crop yield. An on-station trial conducted by ILCA in Ibadan has shown that the most essential pruning to be used as manure and mulch during the growing season of a maize crop is the first pruning prior to planting (Table 4-4). With *Leucaena* hedgerows, this first pruning increased the maize yield by 35%. The foliage produced after this pruning can be safely fed to livestock without any substantial loss in crop yield. However, if there will be a second crop (e.g., maize, or cowpeas as in Figure 3-7) the pruning just prior to planting of the second crop should also be returned to the land. In the ILCA trials, prunings were at 6-week intervals, for a total of 5 prunings per year. More research is needed in this area with other food crops.

To summarize the current ILCA recommendations, about 75% of hedgerow prunings — those obtained after pre-planting pruning — can be fed to livestock without significant crop yield losses.

Table 4-4. Maize grain yield and forage availability as influenced by quantity of pruning used for mulching.

	Maize yield (t/ha		
Prunings applied as mulch	Unfertilized plots	Fertilized plots	Foliage for feed (1) (t/ha)
None	3.1	4.8	4.95
First (pre-planting)	4.3	4.9	1.85
First two	4.6	5.3	0.68
All three	4.8	5.3	None

1 Total forage available throughout the cropping season.

4.3.2 Forage Production from Hedgerows during Fallow

As pointed out in Unit 3, short fallow periods are helpful in sustaining the productivity of land and trees in alley farming. Scientists at the ILCA substation in

Ibadan have conducted trials to determine the best cutting schedule to produce forage from *Leucaena* and *Gliricidia* in fallowed alley farming plots. From their results, presented in Table 4-5, it is observed that after a uniform cutting in January, the two prunings taken in October (9 months regrowth) and January (13 months regrowth) produced the highest forage dry matter yield.

Table 4-5 Effect of tree pruning scheme and regrowth periods on edible forage dry matter yield of *Leucaena* in alley farming fallow plots.

Pruning regime	Intermediate Harvest (month) 3	6	9	January harvest	Total harvest
	Dry Matter Yield (t/ha)				
Pruned Jan.	-	-	-	4.50	4.50
Pruned Apr. and Jan.	1.48	-	-	1.72	3.20
Pruned Jul. and Jan.	-	2.90	-	1.66	4.56
Pruned Apr. Jul. and Jan	1.43	1.18	-	1.33	3.94
Pruned Oct. and Jan.	-	-	5.29	1.06	6.35
Pruned Apr. Jul. Oct. and Jan.	1.40	1.12	1.15	0.72	4.38

During fallow periods in alley farming with food crops, ruminant livestock can be allowed onto the plots. Pruning the hedgerows just after the rainy season helps to maximize fodder production. If left unpruned, *Gliricidia* and certain other species will tend to lose their leaves and flower during the dry season. When the understorey plant material in grazed alley fallow is sparse and unpalatable, the animals will spend most of their time browsing the hedgerows. In such a situation, a common problem that has been observed is the debarking of the trees which can often lead to serious tree mortalities.

Debarking of hedgerows is more of a problem with goats than with sheep, and does not occur with cattle. Solutions can be found through proper management of the system. For example, animals can be allowed into fenced fallow plots for limited periods. Alternatively, in cases where the fallow period will last 1-2 years, pasture grass species can be planted in the alleys. The grass should be sown just at the time of reverting alleys to fallow to provide palatable, grazeable understorey material for the animals. Pasture species which could be planted may include Guinea grass (*Panicum maximum*) and herbaceous legume species such as stylo (*Stylosanthes guianensis*).

4.4 ALLEY FARMING WITH GRASS

A promising modification of the alley farming system involves planting grass between trees rows, rather than planting food-crops. The result is a low-input forage production system which provides a balanced feed ration on a single plot of land. Alley farming with grass forms a two-storey system that allows more efficient use of light, space, and soil resources. If the tree or shrub mixed with the grass is a legume, such as *Leucaena*, the system can provide cheap but constant energy and protein sources to raise animal productivity through the different seasons of the year.

Some grass species which have been found compatible with *Leucaena* hedgerows include:

- African star grass (*Cynodon nlemfuensis, C. dactylon*)
- Buffel grass (*Cenchrus ciliaris*)
- Elephant grass (*Pennisetum purpureum*)
- Guinea grass (*Panicum maximum*)
- Pangola grass (*Digitaria decumbens)*
- Signal grass (*Brachiaria decumbens)*

The rationale for alley farming with grass is based on the previously mentioned observation that tropical grasses are low in protein, especially during the dry season. This condition limits livestock production in many areas. In industrialized countries, inorganic fertilizers are used to improve the quantity and quality of grass; however, this management option may prove too costly in most of tropical Africa and would not solve the dry season feed problem.

A low-cost alternative will be to interplant the grasses with legumes. In fact, herbaceous legumes have been used in many places to provide a cheap source of protein for livestock, but have been difficult to sustain under grazing. This problem can be overcome by planting woody legumes instead, such as the leguminous trees and shrubs used in alley farming. They have large carbohydrate reserves in the roots and can tolerate frequent grazing or pruning.

In most areas where *Leucaena* /grass pastures have been used for grazing, impressive animal performances have been recorded. For instance, researchers in Queensland, Australia, reported that with stocking rates of 2.5 yearlings per hectare, *Leucaena* pastures persisted over 10 years and produced an average of 311 kg/ha liveweight gains (Jones and Jones, 1982).

Alley farming technology can be combined with grass production in various ways. ILCA scientists have found at least four separate systems showing good potential in the humid tropics:

- Intensive Feed Gardens
- Alley Grazing - Rotational System
- Alley Grazing - Permanent System
- Fodder Tree Banks

4.4.1 Intensive Feed Gardens

Intensive feed gardens are plots where hedgerows are planted at close spacing (2-4 m) and grass is sown in the alleys between. An example of an intensive feed garden is shown in Figure 4-2. This system is intended to produce the maximum amount of fodder per hectare through the intensive cultivation of fodder trees, and grasses on a limited area. It is usually established on a small piece of land (10 x 20 m). This is sufficient to feed 3 to 5 small ruminants.

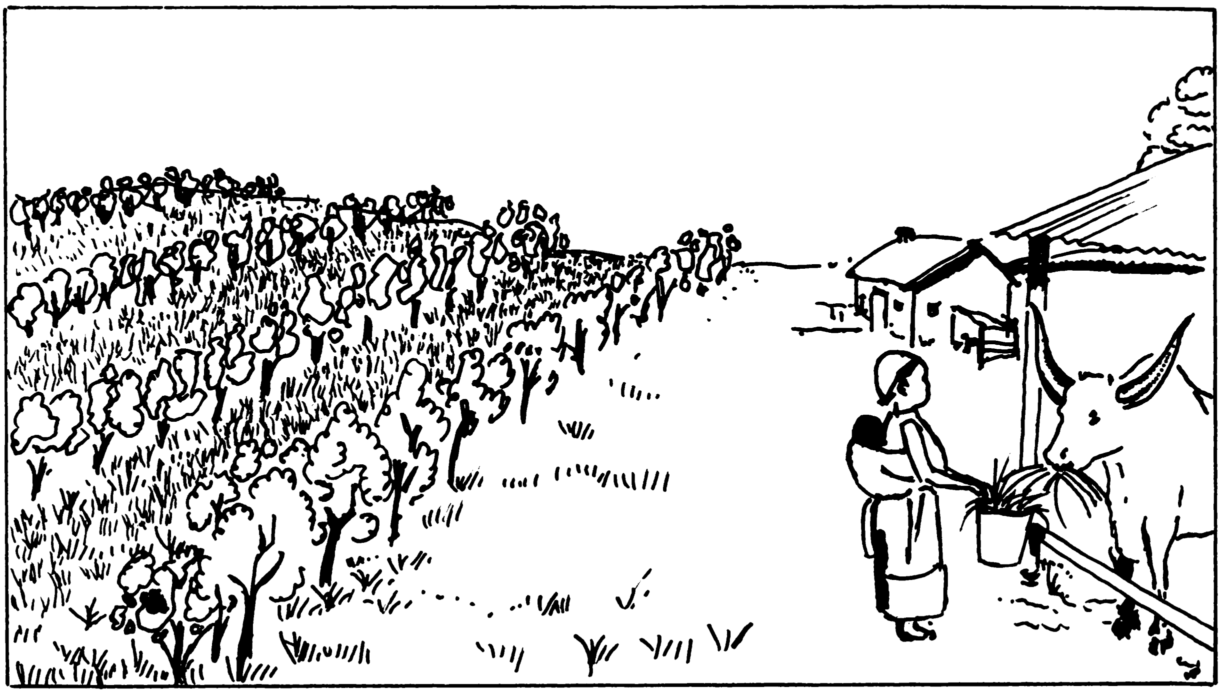

Figure 4-2. Intensive Feed Garden: Cut-and-Carry System. Grass is intercropped with hedgerows of legume trees (2-4 m spacing). Animals are stall fed.

The intensive feed garden is ideal where increased human population has led to scarcity of land, intensive cultivation, compound farming, and/or compulsory confinement of livestock. Under such conditions, farmers have to practice cut-and-carry feeding to compensate for the dwindling feed resources from natural pasture and fallow lands. Establishment of such a garden close to the household provides good quality supplementary feed for confined animals.

The system is also suitable for more intensive cattle operations, such as stall-fed beef or dairy units. In Kenya, this system is the basis for a successful smallholder dairy project. Crossbred cattle are either completely stall fed (zero grazed) or allowed to graze on natural pasture and offered supplementary forage in their pens at the end of the day.

A recent study at ILCA-Ibadan tested forage yield under different intensive feed gardens design. *Leucaena* and *Gliricidia* were planted in rows spaced 2.5 or 4.0 m apart with 2 or 4 rows of Guinea grass *(Panicum maximum)* or elephant grass *(Pennisetum purpureum)*; the system yielded about 20 t DM/ha/yr. The tall, erect, bunch type grasses such as Guinea grass and elephant grass allow for easy cut-and-carry management. They are also tolerant to some degree of shading by the tree component.

4.4.2 Alley Grazing – Rotational System

In this system, livestock are allowed periodically to graze tree legume hedgerows and interplanted grass. The alley grazing plot is laid out with rows 3-4 m apart to permit easy access by the animals. The system is intended mainly for grazing and not for cut-and-carry.

The livestock will be rotated between pure grass pastures and the alley grazing plots, or they will be rotated between stall feeding from other sources and the intensive feed garden. For a system with *Leucaena* or *Gliricidia*, a suitable rotation would comprise 2 weeks of grazing with 8-10 weeks' rest period.

A rotational system has two main advantages over continuous grazing. First, the trees regain lost vigor during the rest periods. Secondly, mimosine toxicity in animals grazing *Leucaena* is kept to tolerable levels, as toxicity is related to the length of time animals graze *Leucaena*.

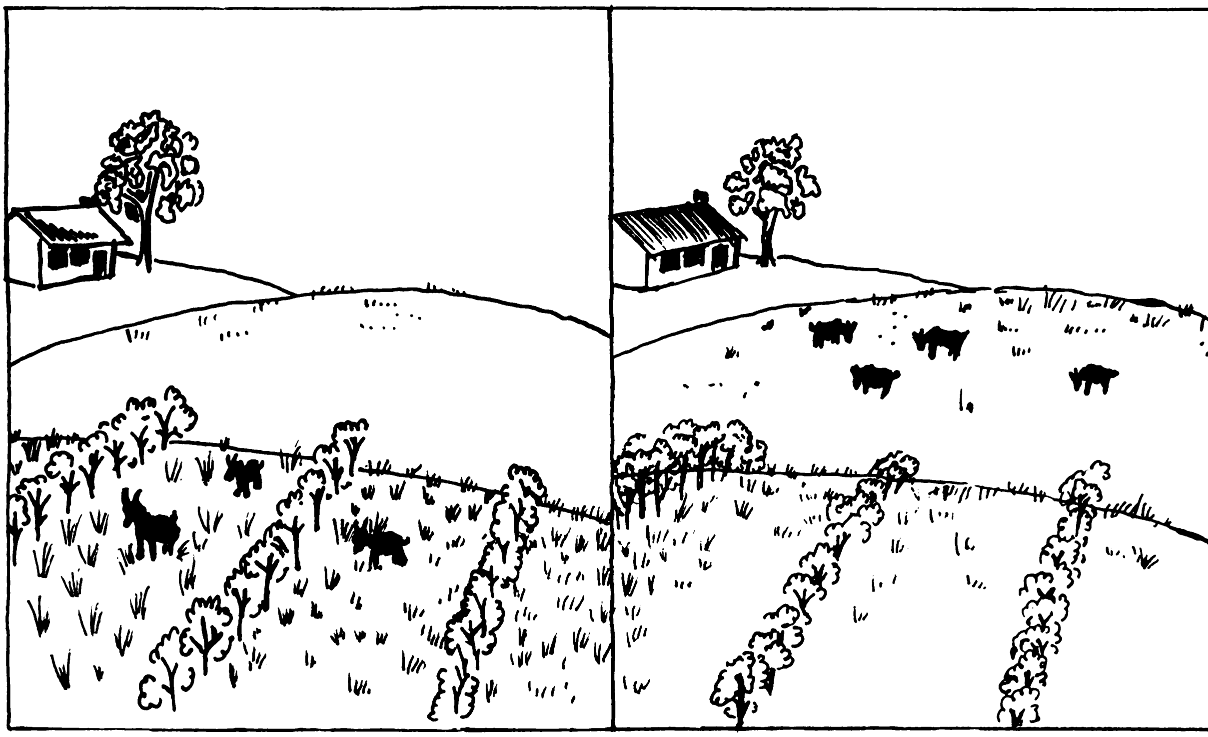

Figure 4-3. Alley Grazing Rotational System. Grass is intercropped with hedgerows of legume trees (3-4 m spacing). Periods of grazing are followed by periods of rest, (e.g., 2 weeks grazing, 8-10 weeks rest).

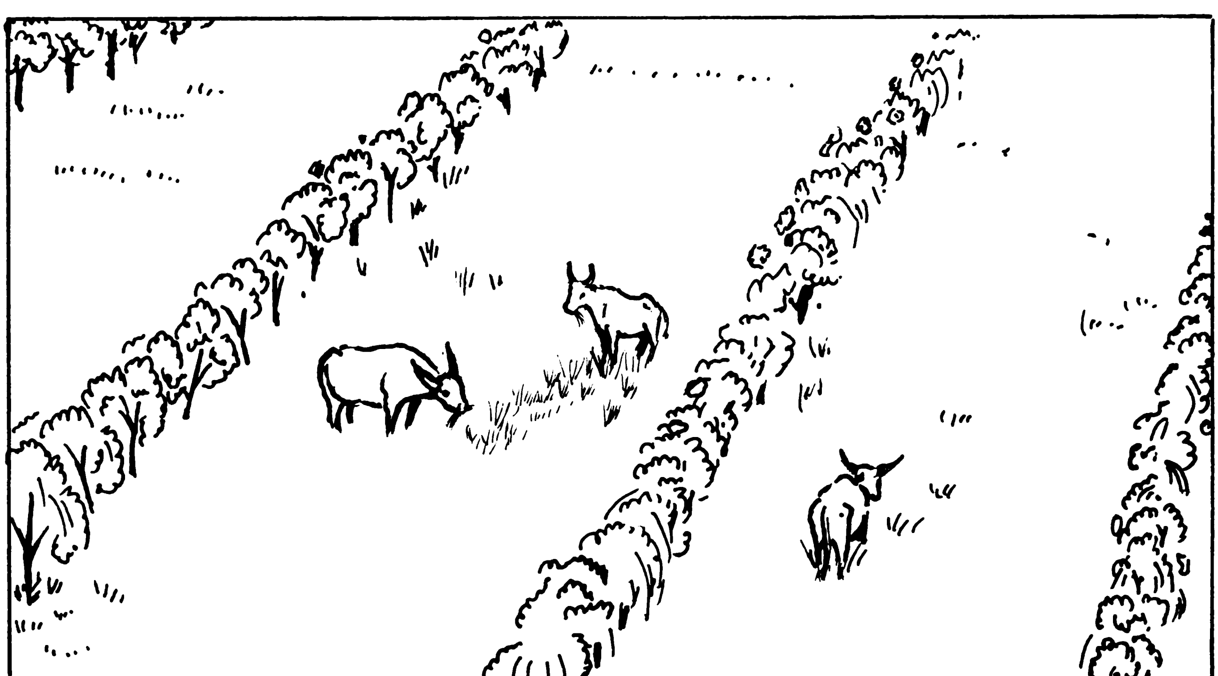

Figure 4-4. Alley Grazing - Permanent System. Shrubby hedgerows are spaced 7 m or more apart.

The advantage of rotational grazing has been demonstrated in studies such as the one carried out in the Ord Valley of Australia (Blunt and Jones, 1977). Animals that were rotated between pure pangola grass pastures and *Leucaena* /pangola pastures gained more weight than did those animals that grazed *Leucaena* pastures all the time.

4.4.3 Alley Grazing — Permanent System

In this system, permanent grass pastures are planted with widely spaced hedgerows of shrubby forage legumes. The spacing between hedgerows should be approximately 7 m. Through pruning, the hedgerow trees should be encouraged to branch heavily close to the soil surface. This system has been studied extensively using shrubby *Leucaena* cultivars. The shrubby *Gliricidia* accession ILG 58 is another good choice, due to its dwarfish stature.

Because free-ranging livestock tend to prefer pasture grasses to hedgerow browse, overgrazing of hedgerows is not a concern if adequate grass cover is available. However, on poor quality pastures or during the dry season, the permanent system of alley grazing may pose problems of mimosine toxicity *(with Leucaena)* and/or debarking of trees (with goats). Management options include: (1) avoiding *Leucaena* altogether in favor of fodder species such as *Gliricidia*, *Calliandra* or local species; (2) restricting access to the pastures at certain times of year; and (3) encouraging vigorous growth of pasture grasses. Planting *Leucaena* and another species in alternate rows may not solve the problem, since *Leucaena* is more palatable and so is preferred.

4.4.4 Fodder Tree Banks

In this system, blocks of closely spaced trees or shrubs are planted in one corner of natural or improved pasture. The trees are planted in hedgerows with 0.25 m spacing between trees and 1.0-1.5 m between rows. Such a layout maximizes protein yield on the available land area, while allowing farmers to enter the blocks with ease.

The blocks of closely spaced hedgerows are planted on 10-30% of the total pasture area. They are managed as "fodder tree banks" — also called "tree protein banks". For improved management, the banks should be fenced off to allow only limited access by grazing animals. Farmers then have the option of allowing access only for certain animals (e.g., pregnant and lactating dams) and for certain time of year (e.g., the dry season).

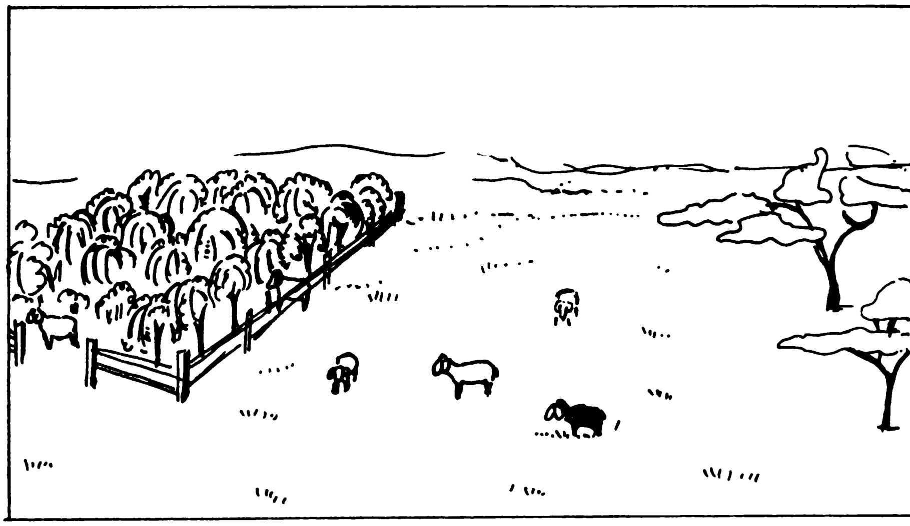

Figure 4-5 Permanent pasture with fodder banks. Closely spaced blocks of legume trees are planted on 10-30% of pasture area.

4.5 SPECIAL CONSIDERATIONS FOR ALLEY FARMING WITH LIVESTOCK

Many of the general recommendations for the establishment and management of alley farms (covered in Unit 3) are valid whether or not livestock are included in the system. For example, seed pretreatments and tree planting procedures are the same with or without livestock. However, there are several special considerations which arise when forage production is an objective, namely:

- Choice of MPT species,
- Establishment of tree/grass intercrops,
- Management of fodder trees, and
- Animal nutrition and health.

4.5.1 Choice of MPT Species

The tree species to be used in any alley farming system with livestock should have the following characteristics:

- Easy establishment from seeds or seedlings,
- Rapid growth with high forage productivity,

- Good coppicing ability,
- Excellent nitrogen-fixing capability,
- Efficient nutrient uptake abilities,
- Deep-rooting system,
- High foliage harvest index, and
- Good feeding value and high palatability.

Table 4-6 presents some tree species which have been shown to possess many or all of the above-listed characteristics, and therefore could be used in a tree-based forage production system. The list is by no means exhaustive. More could be added to meet the varied needs and conditions of different ecological zones. The N_2 - fixing legumes are much preferred because of their ability to fix their own nitrogen through symbiosis and their resulting high protein content.

Where *Leucaena* will be used in intensive feed gardens or rotational grazing systems, it may be prudent to plant every second hedgerow with a different species, such as *Gliricidia*. This helps to avoid the mimosine toxicity problems that result from excessive intake of *Leucaena*. As previously mentioned, alternating rows may not be a solution in free-grazing, permanent systems.

4.5.2 Establishment of Tree/Grass Intercrops

Planting Hedgerows in Pastureland

On a newly cleared site, the technique for land preparation and tree planting will be similar to that described in Unit 3. However, to establish trees in pastureland, different land preparation techniques should be adopted which would facilitate the clearing of the grass and also the tilling of the land. Narrow cleared strips of land, 50-100 cm wide, could be created by using a hand hoe or a disc plough mounted on a four-wheel tractor.

The appropriate seed pretreatment applicable to each MPT species should be employed. Nursery seedlings could be planted as an alternative to direct seeding. There is a need for more research on appropriate land preparation techniques for the various forage production species.

Protecting Young Trees from Grass

Most tree species have extremely slow shoot growth rate and sparse root systems early in their growth cycle. As a result, they compete poorly with grasses, which have profuse, fibrous roots. Thus, the grass and weeds in the immediate vicinity of the trees should be controlled during establishment. This can be done by hoeing, slashing with a cutlass, or spraying herbicide in strips along the tree hedgerows.

In situations where the associated grass is a tall, bunch type such as Guinea grass, the grass should be prevented from shading the trees. In a high-input system, the grass could be mowed and processed into bales as hay. In contrast, for a low-input system with limited access to tractor and mounted implements, the best option will be to hand-slash the grass. Since livestock may damage young trees, the newly planted trees should be allowed time to establish sufficiently well before the first grazing. More research is needed to determine the optimum timing and prerequisite plant height and stem girth for this first grazing.

Fertilization Needs

The tree hedgerows may benefit from fertilization, as mentioned in Unit 3. When trees and grass are to be established together, manure should be applied on the newly cleared plots. In the absence of manure, apply fertilizer (15-15-15 N:P:K compound) at 150-200 kg/ha in 2 or 3 split applications per year. This will ensure prolonged productivity of the grasses.

Because large quantities of biomass are exported from intensive feed gardens and fodder tree banks, serious shortages of non-renewable nutrient elements such as P, K, Ca, Mg, and some trace elements may ensue in the long run. This situation could lead to marked reduction in forage yields with advancing age. There would be a need, therefore, to work out fertilization schemes to replenish some or all of the nutrient elements that have been taken away from the soil. The alley grazing systems are less susceptible to nutrient depletion than the intensive feed gardens and fodder tree banks.

Cutting Schedule for Tree/Grass Intercrop

The grasses are ready for cutting 8 weeks after planting, while the trees may require 8 to 12 months growth prior to the first pruning. Grasses should be cut every 4

Table 4-6. List of fodder species, their characteristics and seed pretreatment information

Species Name	Sub-Family	Description	Distribution	Seed pretreatment requirement	Rhizobium
Acacia senegal (L.) Willd.	*Mimosoiceae*	Bush or tree up to 5 m high	Common in northern tropical Africa	Hand scarify	Cowpea miscellany
Acacia seyal Del.	*Mimosoiceae*	Slender tree 6-11 m tall	Widespread in northern Africa	Hand scarify	Cowpea miscellany
Albizia adianthifolia (schum) W.F. Wight	*Mimosoiceae*	Tall tree with flattened crown	Widespread in tropical Africa	No pretreatment required	Cowpea miscellany
Albizia lebbeck (L.) Benth.	*Mimosoiceae*	Large, tall tree	Native to India but common to all tropics	Hot water Hand scarify	Cowpea miscellany
Cajanus cajan (L.) Millsp.	*Papilionoiceae*	Annual or short term perennial shrub	Native to India and Africa	No pretreatment required	Nodulates freely
Gliricidia sepium (Jacq.) Steud.	*Papilionoiceae*	Shrub or small tree	Native to tropical America now widespread in most tropical agro-forestry systems	No pretreatment required	Nodulates freely
Leucaena leucocephala (Lam.) de Wit	*Mimosoiceae*	Tree but often slender shrub	Native to Mexico, now pantropical in moist regions at low altitude	Hot water. Hand scarify	Fast-growing rhizobia
Sesbania sesban (L.) Merr.	*Papilionoiceae*	Shrubs, annual or perennial	Widespread in warmer latitudes of both hemispheres	Hot water Hand scarify	Reciprocal affinity between cowpea and soybean rhizobia

to 6 weeks, and the trees cut every 8 to 12 weeks, depending on the season. More information on tree pruning practices is provided in the next section.

4.5.3 Management of Fodder Trees in Alley Farming

The parameters of MPT management in alley farming were covered in Unit 3. The management of fodder trees requires special attention to the control of three of those parameters:

- spacing of tree hedgerows,
- frequency of cutting trees, and
- height at which trees are cut.

In manipulating these parameters to advantage, we must consider their effects on quantity and quality of forage produced and on the long-term sustainability of the system.

Spacing of Tree Hedgerows

ILCA recommends a spacing within rows for *Leucaena* and *Gliricidia* of 25-35 cm in areas of high rainfall (more than 1000 mm) and 50 cm for areas with rainfall less than 1000 mm. The spacing between rows depends on the type of system preferred: whether alley farming with food crops (4-8 m), intensive feed gardens (2-4 m), alley grazing — rotational system, (3-4 m), alley grazing — permanent system (7 m or more), or fodder tree banks (1.0 - 1.5).

The optimum spacing to be used depends on the purpose for which the tree is grown and the form in which it is to be harvested. When growing trees for forage, the primary objective is a high yield of good quality fodder. The aim in such situation is a high leaf : shoot ratio which requires a high plant density. Generally, the higher the planting density, the greater the productivity per hectare (Table 4-7). However, there is a tendency for individual plants to survive better at low densities, and for lower individual plant yields at high densities.

Frequency and Height of Hedgerow Pruning

In alley farming with livestock, periodic pruning of the tree hedgerows is required for the following purposes:

- to provide fodder for animals in a cut-and-carry system,
- to keep the greater proportion of leaves and branches accessible to animals in an alley grazing or fodder tree bank system,
- to provide mulch for food crops, and
- to prevent shading of the grass or food crop planted in the alleys.

The last two purposes are also present in alley farming without livestock. They are covered in Unit 3.

ILCA recommends that *Leucaena* and *Gliricidia* in tropical Africa should be pruned to a height of at least 50 cm above ground about every 10 to 12 weeks for optimum forage productivity. It appears that the regrowth can be grazed when it attains a branch length of 1.0 m, although this requires further confirmation through research.

Table 4-7 Effect of plant density and pruning frequency on edible dry matter yield of *Leucaena*. (Source: ILCA, 1987.)

Plant density (number/ha)	Number of prunings per year				Mean
	8	6	5	4	
	<----------------- (Dry Matter t/ha/year)			---------------------->	
80,000	16.9	22.6	29.2	38.2	26.7
40,000	11.9	15.1	20.9	28.2	19.0
26,666	9.1	11.7	15.8	20.7	14.3
20,000	6.7	10.8	12.4	20.3	12.5

The pruning frequency should be short enough to maintain a good leaf-to-stem ratio, but long enough to allow the plants time to recover. Since cutting removes the photosynthetic portions of the trees, time is required for replenishment of the reserves used in new tissue formation. As longer cutting intervals are adopted, greater dry matter yields are realized but the quality of forage (as % protein) declines, as shown in Table 4-8.

The height of cut also influences forage production of trees. As the pruning height is increased, tree foliage dry matter increases as well. But there is an optimum height beyond which foliage dry matter yield will not increase (Table 4-9). The increased foliage production with increasing height of cut is due to the fact that the quantity of fodder produced is influenced by the number of buds that develop into new shoots on the stumps. In general, the taller the stump, the greater the numbers of buds. Thus, in a study in Mexico that used a Hawaiian-type *Leucaena* cultivar, plants that were cut at 30 cm formed an average of 89 buds while those cut at 50 cm produced 112 buds (Perez and Melendez, 1980).

4.5.4 Animal Nutrition

Amount of Feed Produced on Alley Farms

From an alley farming plot with food crops grown between *Leucaena* and/or *Gliricidia* hedgerows, farmers can expect 3 tonnes or more of edible dry matter (DM/ha/yr). The crude protein content will be 20%. An 0.2 ha farm thus will produce 1.6 kg DM/day. This can be used for mulch or for animal feed. Assuming that only 25% is taken for animal feed, the farmer will have 400 g DM/day for his or her animals. Not surprisingly, researcher-managed, on-station plots generally produce higher yields of fodder.

From an intensive feed garden with grass grown between legume tree hedgerows, a farmer can expect 10 tonnes DM/ha/yr. Thus an 0.02 ha/yr plot produces 200 kg annually, or 550 g DM/day. Since intensive feed gardens do not have a food crop component, all the tree foliage will be available for animal feed.

Table 4-8. Effect of pruning frequency on yield and quality of *Leucaena*. (After ILCA, 1987).

Number of prunings per year	Dry matter yield (t DM/ha/yr)	Protein content (%)	Protein yield (t/ha/yr)
8	11.18	30.28	3.38
6	15.08	29.60	4.46
5	19.61	26.36	5.16
4	26.88	25.75	6.92

Table 4-9. Effect of pruning height on *Leucaena* dry matter yield (t/ha) during 6-month period. (Source: Duguma et al, 1988.)

	Pruning height (cm)				
Season	25	50	75	100	150
Wet	3.72	4.32	5.10	5.91	7.74
Dry	2.70	3.42	3.90	4.02	3.90

Animals will eat, in total, the equivalent of 4% of their body weight daily, so a 15-kg goat would consume a total of 600 g DM/day. The amount of fodder available from an alley farm will only provide a supplement to what the animal normally receives.

Feeding Practices

Forage from the legume trees is intended as a supplement to existing food supplies. *Leucaena* can constitute up to 40% of small ruminant diets without toxicity problems. *Gliricidia* can be offered up to 100% of total feed intake, but where possible should be offered in equal quantities with *Leucaena*. In practice, farmers using both *Leucaena* and *Gliricidia* from alley farms and intensive feed gardens as feed supplements are unlikely to experience any toxicity problems, because of the limited amount of *Leucaena* that will be on hand and the availability of other feeds.

Figure 4-6. Feeding hedgerow prunings to confined cattle.

In many countries, consumer demand, and hence market price, of rams and bucks is particularly high for certain festivals, such as the Muslim festival of Id el Kabir. It may be an appropriate use of available browse to offer it selectively to animals that will be marketed for this or other festivals.

One simple way to offer the feed and avoid waste is to hang up equal amounts of *Leucaena* and *Gliricidia* in a bundle (Figure 4-7). Bundles of grass can also be offered. Alternatively, a hayrack can be used.

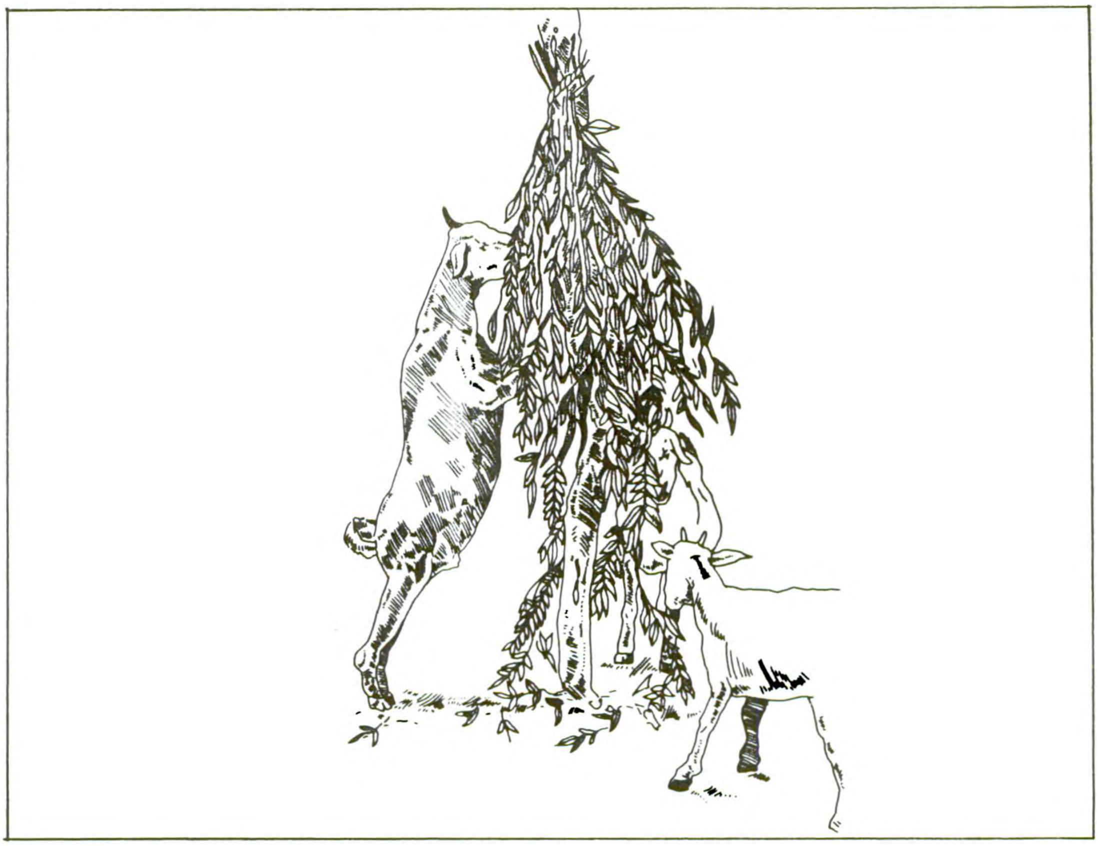

Figure 4-7. Goats browsing *Leucaena* and *Gliricidia* branches which have been hung in a bundle.

4.6 RESEARCH NEEDS FOR ALLEY FARMING WITH LIVESTOCK

Alley farming was originally designed for food crop production systems with no livestock component. Its adaptation to suit integrate a livestock production component has been highly successful. Nevertheless, further research is needed to make the intervention truly a "two-edged sword" as intended. Some researchable issues are as follows:

1. So far, most studies on alley farming have been carried out using the tree legume species *Leucaena* and *Gliricidia*. Research should be conducted to involve other promising woody species.

2. In alley farming with both food crops and livestock, the proportions of prunings used as mulch and fodder must be carefully balanced. More research is needed to determine which prunings, and what proportion of prunings obtained during the growing season of a crop can be taken away without telling drastically on crop yields or harming the long-term sustainability of the system.

3. In order to avoid undue mining of plant nutrients (P, K, Ca, Mg, and some micronutrients), research should be conducted to determine schemes for restoring nutrients lost in harvested forage, especially in the intensive feed garden system – for example, by recycling animal manure into the system.

4. Research on fallows in alley farming should be undertaken to determine optimum pruning regime(s) that produce the greatest forage and permit better preservation of the foliage for use at the height of the dry season. Low-cost methods of drying the foliage for preservation should be developed.

5. For systems in which trees or shrubs are to be established in undisturbed, native, or improved pasture, research is needed on the best land preparation method.

6. For intensive feed gardens in which tree or shrubs are planted at about the same time as tall, erect, bunch-type grasses, more research is needed to determine the best schedule for tree pruning, grass harvesting, and/or grazing.

7. In tropical Africa, most of the work on cultivated leguminous browse has been aimed at small ruminants. For areas such as the derived savannah zone of West Africa, in which cattle populations are increasing and high quality forage is becoming scarce, more work is needed on adapting the system for cattle.

4.7 FEEDBACK EXERCISES

All answers can be found in the text and figures of Unit 4.

1. The following statements concern livestock nutrition in tropical Africa and the potential contributions of leguminous trees. Circle T for true statements or F for false ones:

i)	In most mixed crop/livestock systems of sub-Saharan Africa, livestock nutrition is the overriding concern of farmers.	T	F
ii)	In southwestern Nigeria, as in the highlands of Kenya, farmers cut fodder and carry it to confined animals.	T	F
iii)	Leguminous multipurpose tree are a source of high-quality, nitrogen-rich supplemental feed for livestock.	T	F
iv)	Feeding goats and sheep with *Leucaena* and *Gliricidia* has been shown to decrease overall food intake.	T	F
v)	Problems of livestock nutrition in the dry season include the low digestibility and low protein content of grasses.	T	F
vi)	A low-protein diet has no effect on the populations of microbes in the gastro-intestinal tract of cattle, sheep, and goats.	T	F

2. In alley farming with livestock, hedgerow prunings can be used as mulch for food crops as well and as fodder for livestock. Explain the importance of balancing these two uses, and suggest how this can be achieved.

3. List eight characteristics of the ideal MPT species for use in alley farming with livestock.

   1.______________________________

   2.______________________________

   3.______________________________

   4.______________________________

   5.______________________________

   6.______________________________

   7.______________________________

   8.______________________________

4. This unit covered four different variations on alley farming in which pasture crops (grasses) are grown alongside hedgerows of multipurpose trees or shrubs. The table below has been scrambled. Draw lines to connect the name of each system (column A) with its correct text description (B) and the recommended spacing between hedgerows (C).

(A) Name	(B) Description	(C) Spacing
Intensive Feed Garden	Shrubby hedgerows in permanent pastures	1.0 - 1.5 m
Alley Grazing-Rotational System	Grazing alternates with rest periods.	7 m or more
Alley Grazing-Permanent System	Cut-and-carry system.	3 - 4 m
Fodder Tree Banks	Block of trees on 10-30% of pasture area	2 - 4 m

5. Provide brief answers to the following questions:

   i) Describe a technique for planting hedgerows in pre-established pastureland.

   ii) Young trees should be protected from competition with grasses. Name as many different techniques as you can for accomplishing this.

   iii) Explain why an intensive feed garden requires fertilization for sustained production.

6. a.) List four reasons for pruning tree hedgerows in alley farming with livestock.

   1. ______________________________
   2. ______________________________
   3. ______________________________
   4. ______________________________

   b.) Fill in the blanks: ILCA has developed recommendations for management of *Leucaena* and *Gliricidia*. The recommended pruning height is __________ cm, while the recommended pruning frequency is once every ___________ weeks.

7. Circle the correct answer to the following questions:

   i) If 25 % of hedgerow prunings are used for animal feed, a typical 0.2 hectare alley farm will produce how much dry matter of feed per day?

   a. 100 kg DM　　b. 5 kg DM
   c. 400 g DM　　d. 50 g DM

   ii) Each day a goat will consume the equivalent of what percentage of its body weight?

   a. 1%　　b. 4%
   c. 33%　　d. 75%

   iii) *Leucaena* can be toxic to small ruminants if it constitutes too large a portion of their diet. What portion?

   a. more than 40%　　b. more than 75%
   c. more than 5%　　d. less than 20%

8. Section 4.6 contains a list of seven issues warranting further research. Which two issues would be of most interest in your organization or home area, and why?

Issue: ______________________________
Why important in my area: ______________________________
____
____
____

Issue: ______________________________
Why important in my area: ______________________________
____
____
____

4.8 SUGGESTED READING

Cochan, W.G., T.H. Stobbs, and D.J. Minson. 1979. The influence of the legume *Leucaena leucocephala* and formal-casein on the production and composition of milk from grazing cows. Journal of Agricultural Science, Cambridge. 92: 351-357.

Francis, P.A., and A.N. Atta-Krah. 1989. Sociological and ecological factors in technology adoption: fodder trees in southeast Nigeria. Experimental Agriculture, 25:, 1-10.

Nordblom, T.L., A. Ahmed, K.H. El, and G.R. Potts. (eds). 1985. Research Methodology for Livestock On-farm Trials. Ottawa, Canada: IDRC,

Reynolds, L., A.N. Atta-Krah, and P.A. Francis. 1988. Alley farming with livestock — Guidelines. Ibadan, Nigeria: ILCA, (Largely superceded by this Training Manual).

Smith, O.B., and H.G. Bosman. (eds). 1988. Goat Production in the Humid Tropics. Wageningen, The Netherlands: PUDOC.

Van Eys, J.E., I.W. Mathius, P. Pongsapan, and W.L. Johnson. 1986. Foliage of the legumes *Gliricidia*, *Leucaena* and *Sesbania* as supplement to Napier grass diets for growing goats. Journal of Agricultural Science, Cambridge. 107: 277-233.

4.9 REFERENCES

Blunt, C.G., and R.J. Jones. 1977. Steer liveweight gains in relation to the proportion of time on *Leucaena leucocephala* pastures. Tropical Grasslands 11: 159-164.

Brewbaker, J.L. 1987. *Leucaena:* a multipurpose tree genus for tropical agroforestry. In: H.A. Steppler and P.K.R. Nair (eds). Agroforestry a decade of development. Nairobi, Kenya: ICRAF.

Duguma, B., B.T. Kang, and D.U.U. Okali. 1988. Effect of pruning intensities on three woody leguminous species grown in alley cropping with maize and cowpea on an alfisol. Agroforestry Systems 6: 19-35.

ILCA (International Livestock Centre for Africa) 1987. ILCA Annual Report 1986. Addis Ababa, Ethiopia.

ILCA (International Livestock Centre for Africa) 1988. ILCA Annual Report 1987. Addis Ababa, Ethiopia.

Jones, R.J., and R.M. Jones, (1982). Observations on the persistence and potential for beef production of pastures based on *Trifolium semipilosum* and *Leucaena leucocephala* in sub-tropical coastal Queensland. Tropical Grasslands 16: 24-29.

Perez, J., and F. Melendez. 1980. The effect of height and frequency of defoliation on formation of buds of *Leucaena leucocephala* in the state of Tobasco, Mexico. Tropical Animal Production 5: 280 (Abstract).

UNIT 5

On-Farm Research

Unit 5: On-Farm Research

Main Contributor: A. N. Atta-Krah[1]

5.0 PERFORMANCE OBJECTIVES

Unit 5 is intended to enable you to:

1. Understand the basic characteristics of on-farm research (OFR) and identify the key elements in such research.
2. Differentiate between three different kinds of OFR and describe the main activities involved in each.
3. Describe three major roles played by OFR in the research and development process.
4. Compare and constrast the main purposes of experimental OFR and developmental OFR.
5. Explain the possible relationships between farmer and researcher during the experimental and developmental phases of OFR.
6. Discuss the relative importance of OFR in research and development on different types of technologies.
7. Demonstrate familiarity with basic recommendations for extension of alley farming.
8. Explain the approach researchers should take to on-farm adaptations, and cite examples of on-farm adaptations made to alley farming.

5.1 INTRODUCTION

In alley farming research projects, it is highly desirable to initiate on-farm research activities as early as possible. Naturally, before alley farming experiments can move on-farm, a certain amount of time will be devoted to purely on-station research. This is necessary for screening and evaluation of multipurpose trees, and for

[1] Portions of Section 5-6 are taken from D. Rocheleau, F. Weber, and A. Field-Juma, 1988 Agroforestry in Dryland Africa (ICRAF, Nairobi).

experimentation with management practices. However, AFNETA's strategy is for collaborating institutions to begin on-farm work as soon as researchers have found a "best-bet" prototype for local agroecological conditions.

This unit begins by defining on-farm research (OFR) and explaining the important role of OFR in the testing and development of alley farming systems. It then describes the various types of OFR which alley farming research projects may entail. Detailed methodological guidelines and experimental designs are not provided here, but may be found in the Annex and in Volume 2.

As part of AFNETA's Core Course in Alley Farming, this unit restricts its coverage to *experimental* and *developmental* OFR. These are the types of OFR that are directly involved in alley farming research projects such as those supported by AFNETA. However, it is assumed that researchers have conducted on-farm surveys at an earlier stage. Such *diagnostic* on-farm work is necessary to demonstrate the potential relevance of alley farming in the local area. For example, a station or a ministry may have found through on-farm surveys that local farmers face constraints such as declining soil fertility, soil erosion, poor livestock nutrition, and/or land scarcity. Such findings would justify research into alley farming or other technologies that could address the constraints.

The pre-experimental type of on-farm activity is covered in the technical papers on Diagnosis and Design methods and socio-economic surveying (Volume 2).

5.2 DEFINITION OF ON-FARM RESEARCH

On-farm research is an indispensable tool for developing and validating alley farming technology. On-farm research (OFR) can be defined in its simplest terms as research carried out on farmer's fields and in a farmer's environment. From this simple definition, one can identify four key elements in OFR. These are:

- the farmer,
- the farmer's land,
- the farmer's involvement, and
- the farmer's environment.

The Farmer

In OFR, it is essential to specify the type of farmer for which a particular intervention is aimed, whether for development or for testing. Thus if one is developing a technology for low-resource-base, smallholder farmers, it will be incorrect to sample commercial, large-scale farms for the OFR. Equally, for a technology which requires use of costly inputs — seeds, fertilizer, herbicide, insecticide, etc., — one would have to deal with medium and large-scale farmers who could afford the essential inputs for the technology, rather than deal with smallholder, low-resource farmers.

The "type of farmer" issue is not linked only to resource base, but may also be linked to the production system. For example, in developing a fodder intervention package, it would be necessary to look for a farmer community where both livestock and crop production are important, so that the technology will be relevant. The central issue, therefore, is to define and describe the type of farmer for which the technology to be developed or tested is appropriate and relevant.

The Farmer's Land

Any experiment carried out on a plot of land outside the experimental station could be described as off-station research, but not all such research qualifies as on-farm research. For research to be classified as on-farm, it should be carried out on a plot of land belonging to the farmer and within the farm environment of the farmer. Off-station research is, therefore, not synonymous with on-farm research, though all on-farm research is by definition "off-station."

The Farmer's Involvement

The nature of farmers' involvement in any OFR activity is very important as it influences the interpretation of output and results obtained. OFR scientists seek varying degrees of farmer's involvement in OFR. The exact nature and degree of farmer involvement is determined by the objective of the OFR and the nature of the research in terms of components, systems, or technologies being assessed. The degree of farmer involvement also has an effect on the design of the experiment and the interpretation of results obtained.

The four possible ways in which farmers are usually involved in OFR are:

- landlord/tenant relationship,
- passive on-looker involvement,
- active involvement - researcher controlled, and
- active involvement - farmer controlled.

These relationships are discussed under Types of OFR, below (Section 5.4).

The Farmer's Environment

The farmer does not live as an independent entity. He lives within a family structure, which in itself is embedded within a community structure. Thus, the farmer's input, assessment, and eventual adoption of a system will have to be viewed and assessed within the framework of the community in which the farmer operates. The sociocultural, anthropological, and economic environment within that community will have to be taken into account in the design of the technology, in its testing, and eventually in the assessment of its acceptability to farmers.

The second aspect of the farmer's environment has to do with the cropping and farming system in which the farmer operates and the bio-physical base within which the farming activity goes on. For example, farmers' fields may have many more problems associated with soil fertility and drainage than the research station fields where on-station experiments have been conducted. Farmers may also be practicing a much more complex cropping system than is used in on-station trials. All these factors underline the need for OFR, and the need to take into account the farmer's environment in the design and testing of technologies.

5.3 WHY DO ON-FARM RESEARCH?

While some amount of time devoted to purely on-station research will be necessary, (in order to screen and evaluate multipurpose trees, and to experiment with management practices), quick initiation of on-farm research will help the research and development process. Within the context of the AFNETA project, on-farm research plays essential roles in the following areas:

- testing and validation of alley farming technologies under local farmer's conditions

- development and adaptation of alley farming technologies for local farmers' conditions

- demonstration and extension of alley farming technologies in local farming communities.

Research should be aimed at solving farmers' problems and at involving farmers in the research process quite early on, rather than involving them as passive recipients at some future date.

5.3.1 Testing and Validation

In actual farm conditions, the best-practice on-station technology rarely performs at the same level. On-farm research is commonly used as a means to ensure that technologies developed on-station will be relevant to the problems and priorities of the targetted client adopters. In the case of alley farming, the target adopters are typically resource-poor small farmers.

To validate on-station results, OFR is carried out to assess the performance of particular systems or technologies on-farm, with or without the farmer's involvement. Such research will likely lead to the observation of yield gaps or shortfalls (Figure 5-1). Research is then aimed at identifying constraints causing the gaps and eliminating or narrowing the gaps.

On-farm trials allow assessment of the system according to a broad range of criteria. Analysis of such trials should be based not only on productivity and profitability, but on all other factors that are likely to influence the acceptability of the system to the farmer. These may include farmers' resources, the community's economic and social infrastructure, etc.

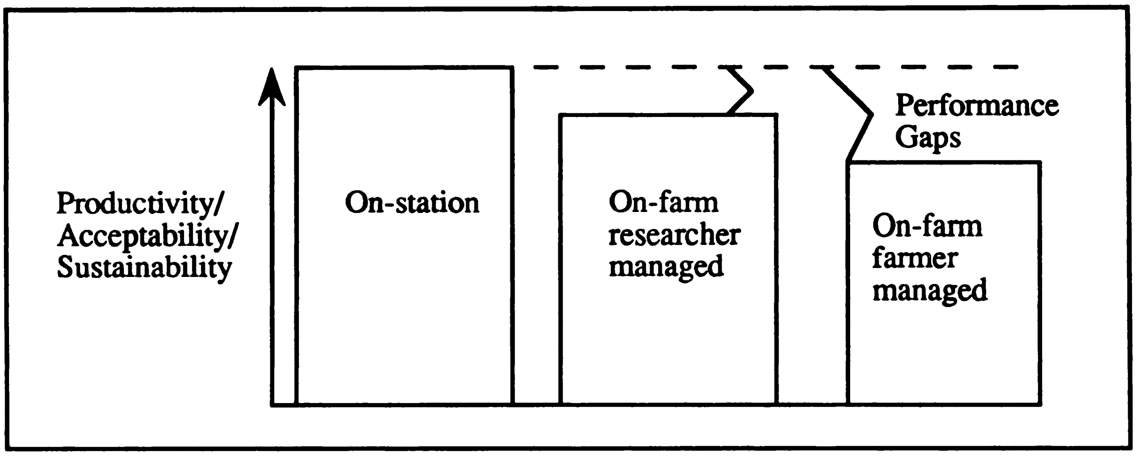

Figure 5-1. Comparison of technology performance on-station and on-farm with different levels of farmer involvement.

5.3.2 Development and Adaptation

On-farm research is often used to generate new or modified technologies. Moving to farmers' fields and interacting with farmers allows the researcher to have an appreciation of the farmers' conditions and problems. It also provides a great opportunity for the identification of problem areas and researchable issues that may arise following farmer use of developed technology. This leads to a continuous process of refining, improving, and re-testing the system.

The length of time required for standardization and adaptation of the technology to various specific farmer situations may be shortened through contributions from the participating farmers. The farmers' own adjustment mechanisms and experiences will be important inputs in the adaptive process. The farmers have an important role to play at this stage of the research, and when possible they should be encouraged to experiment with the system and to suggest improvements.

5.3.3 Demonstration and Extension

For any new technology or technology component to be accepted by farmers, it has to be shown to be superior to the existing system. The most reliable means of proving this is through OFR, in which the farmer is involved and the trial is run within the farm environment. Such OFR trials provide an excellent opportunity to compare the performance of the proposed system and farmer's traditional practice in a reliable way (Figure 5-2).

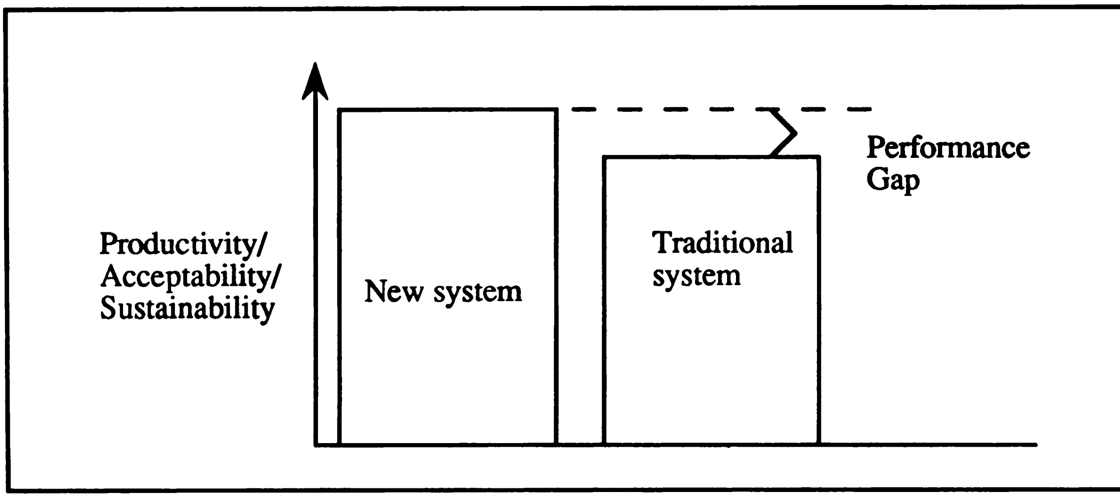

Figure. 5.2 Demonstration of the new systems' improved performance.

When researchers and farmers are testing alley farming in the field, they are also demonstrating the system to the local community. On-farm research thus creates links with extension in at least three ways. Firstly, if on-farm research clearly **demonstrates the viability of the technology**, it may create a "neighbourhood effect," whereby innovation waves spread outward from the research sites. Since on-farm research is likely to be conducted in many locations across the region, the innovation waves will spread from many centers and thus speed up both generation and diffusion of the technology. Moreover, horizontal (farmer to farmer) diffusion is likely to take place, due to lateral learning within each research location.

Secondly, OFR promotes **collaboration with extension and development agencies** which helps in improving the efficiency of the technology generation and diffusion process. Involvement of extension and development agencies as partners and participants in the technology generation process will bring them directly into contact with the farmers. It will also acquaint them with the salient features of the technology while it is being generated. This is a step ahead of the more typical situation where such agencies have to wait until some best-practice technology package is made available to them for dissemination.

Thirdly, the OFR stage may test the **suitability of the existing institutional framework** for proper delivery of the technology to the users. For example, in most countries, crop, livestock, and forestry extension services are independent with little collaborative activity. Moreover, the crop extension service tends to be much better organized than the other two. Since the scope of alley farming cuts across all three fields, appropriate mechanisms could be developed at the technology generation stage to integrate the roles of these various agencies in the diffusion process. Mechanisms for using non-governmental and traditional institutions in the diffusion process such as village associations and local leadership structures, could also be studied at the OFR stage.

5.4 TYPES OF ON-FARM RESEARCH

There are basically two types of OFR:

- Experimental OFR,
- Developmental OFR.

The range of objectives for which OFR may be carried out is very wide. Thus, it is inconceivable that a single OFR activity will embrace all these objectives. It is essential in carrying out OFR to define the objectives clearly. It is important to make a clear distinction between the assessment of a technology for its biological, technical, and economic potential, on the one hand, and assessment for its workability, acceptability, and potential adoptability by farmers on the other. Often, different types of OFR activity are required for achieving different objectives (Figure 5-3). The interpretation of results from different types of OFR should take into account the limitations imposed on the system by the specific objectives and methodologies followed.

AFNETA's guidelines for designing experimental and developmental OFR trials are given in the Annex.

5.4.1 Experimental OFR

This is the more commonly known and practiced of the two types of OFR. It is performed for bio-physical, technical, and economic assessment of alternative systems or treatments within the framework of standard experimental designs. Bio-physical assessment aims at determining the system's biological and physical yield and productivity, while economic assessment inquires into the availability of labor, cash, and other resources for meeting the projected needs of the alternative system, and looks into the level and dependability of profit.

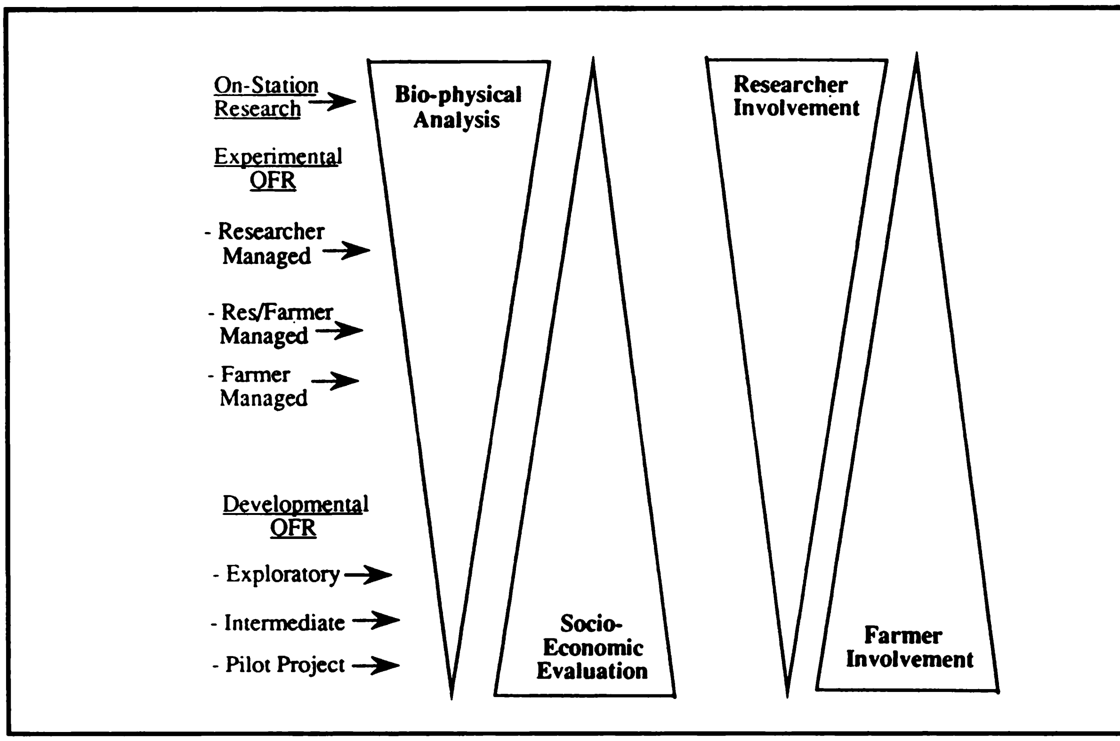

Figure 5-3 Research objectives and levels of farmer involvement vary in the different types of on-farm research.

Experimental OFR trials emanate directly from on-station research. Their structure and design are very similar to those used on-station. Generally, however, on-farm experimentation is kept as simple as possible to ensure effective farmer understanding of issues and meaningful involvement and contribution. Depending on the nature of farmer/researcher involvement in the trials, experimental OFR may be further classified into three different types, namely:

- researcher-managed trials,
- researcher/farmer-managed trials,
- farmer-managed trials.

<u>Researcher-managed Trials</u>

Researcher-managed trials are very similar in structure to on-station trials. The researcher is responsible for directing and implementing the treatments in accordance with the chosen design and methodology of the trial. A single farmer's field could be used for such a trial, though this may be repeated on another farmer's plot (if required).

The farmer and researcher may have a **landlord/tenant relationship,** which represents the lowest degree of farmer involvement. It applies to the situation where a researcher obtains a plot of land from a farmer's holding to carry out an OFR activity in which the farmer has no part to play. The farmer may also have no direct interest in what is going on, and may consider his or her involvement only as having given land (on lease, on loan, or as gift) for research activity.

Alternatively, the farmer may have a **passive on-looker involvement.** In this case also, the farmer makes land available, but has no direct role in the management or operation of the trial. The major difference between this and the landlord/tenant relationship is that in this case, the research is carried out on the same piece of land that the farmer is cultivating. The researcher may, from time to time, invite the farmer to observe particular operations or see some emerging responses. Such a situation usually arises in researcher-managed OFR trials superimposed on existing farmer plots.

Joint Researcher/Farmer-managed Trials

These are trials in which management and operation are the joint responsibility of farmer and researcher (figure 5-4). Such trials need to be made simpler than the researcher-managed trials, since an increased level of farmer's involvement is required. Simplicity insures a better understanding of the trial by the farmer.

The farmer's role may be termed **active involvement (researcher-controlled),** as the farmer is directly involved in carrying out some or all of the management operations in the trial. However, the farmers' contribution is very clearly defined and controlled by the researcher. He is therefore unable to use his initiative, and does what the researcher has programmed for him to do in terms of treatment applications and management requirements.

Farmer-managed Trials

In farmer-managed OFR, the farmer is responsible for carrying out almost all management operations for the trial. An even higher level of simplicity is thus required, and the number of unit plots within a single farmer's field are kept at a minimum to avoid complications for the farmer.

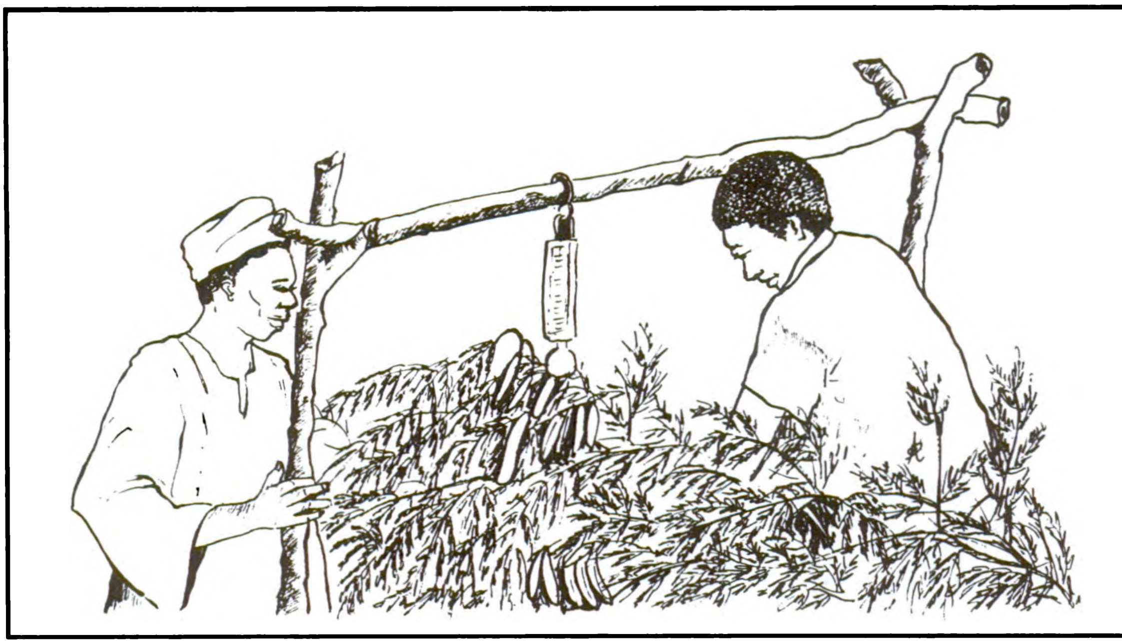

Figure 5-4. Measuring biomass on farm. Researchers and farmers cooperate to achieve common objectives in jointly managed or farmer-managed trials.

The farmer's role is **active involvement (farmer-controlled).** The farmer is made to see the trial as his or her own, and is free to make modifications in the management of the system being tested and to identify problem aspects of the system. The researcher takes on what may be described as an "active on-looker" role in this process, making regular observation of the farmer's performances, responses, attitudes, impressions, and opinions, as well as the biological and technical performance of the system being tested.

Criteria for Adopting Researcher-managed or Farmer-managed Trials

The main consideration for carrying out one or the other type of experimental OFR is the level of knowledge and confidence about the technology in question. Technologies for which sufficient information is not available are generally tested under researcher-managed trials with a high degree of control by the researcher. But technologies for which enough accurate information is available are carried out under researcher/farmer-managed trials or under farmer-managed trials. A rough generalization about the three type of trials is that researcher-managed trials are technology generation trials while the other two aim at technology validation or demonstration.

Figure 5-5. In farmer-managed trials, the farmers are responsible for pruning, mulching, and other aspects of managing an alley farm.

5.4.2 Developmental OFR

This type of OFR activity has received less attention than the experimental type. It involves (1) the introduction of particular systems within the farmer environment and (2) the assessment of the workability of the system and its acceptability by farmers. Developmental OFR operates within a framework of research-extension collaboration. Its main purpose is the extrapolation of the tested results to the target area. An attempt is made to fine-tune the technology and to determine the required support structures prior to wide-scale extension of the technology. Through the developmental OFR process, farmers of the targetted area are gradually exposed to a new technology, and their management of the system is monitored in order to identify problem areas and researchable issues.

Developmental OFR makes use of extension techniques and methodologies for the introduction of the concept or system and development of farmer's awareness. For this reason, developmental OFR requires the joint involvement of researchers, farmers and extension agents.

The farmer's involvement evolves gradually to the point where he or she considers the experiment to be his/her own, and is free to make modifications and adjustments in accordance with his/her own circumstances. For such development-oriented research, the performance parameters are not necessarily crop yield or other biological or technical indicators, but the farmer's level of interest and adoption. It is important to note that farmers' adoption of the technology (and just as importantly, their adaptation and manipulation of technology) is a crucial validation tool in developmental OFR.

Two examples of developmental OFR from Nigeria illustrate the usefulness of the approach, as documented by Kang, Reynolds, and Atta-Krah (1990):

Example 1: The relevance, workability, and social acceptability of alley farming have been shown in southwest Nigeria through a developmental on-farm research process (Okali and Sumberg, 1985: Atta-Krah and Francis, 1987). This process involves actual farmer control of the management and use of the technology and relies on observations of farmer initiative, management, and use of the system, and on adoption analysis. From 60 farmers who established alley farms in the project site in 1984, the system has spread to four adjacent villages, with more than 200 farmers planting alley farms.

Example 2: In southeast Nigeria, where a similar project was undertaken, alley farming was assessed to be of only limited acceptability. This finding was traced to a number of edaphic, sociological, and institutional factors. These include low soil fertility with high acidity levels, incompatibility of woody species tested to established cropping patterns and rotation practices, the division of labor and the decision-making process within the household, and land and tree tenure rules (Francis and Atta-Krah, 1989).

5.4.3 Three Phases in Developmental OFR

There are three phases in the developmental OFR process, namely:

- the exploratory phase,
- the intermediate phase,
- the pilot project phase.

Exploratory Phase

The exploratory phase is the stage where a new system or concept such as alley farming is introduced into a community. This allows the farmers to gain an accurate image and a practical understanding of the system. This exploratory phase thus has a demonstration objective. It begins with the identification of individual farmers within the community with whom the researchers work closely to put the system on the ground. During this phase, researchers' involvement is very high as the farmers perception of the system is almost nil. Only a few farmers (1-5) are selected for these trials; they do not necessarily have to be in the same village.

Intermediate Phase

The intermediate phase begins after the exploratory trials are established and management of the system has commenced. This phase, like the exploratory phase, is also targetted at individual farmers, but requires a greater involvement of the farmer in the establishment and management of the experiment. Farmers participating in the intermediate trials will have a clearer perception of the system because of the existence of the exploratory (demonstration) units which provide a visual dimension for discussions on the system's structure and potential. The number of farmers used in this stage could be 3-5 times the number in the exploratory trials. The exact number is usually determined by resource availability.

Pilot Project Phase

The pilot project phase takes off after the intermediate trials have been conducted and farmers' understanding and capability in management have been sufficiently established. At this point, direct involvement of researchers in management and other farm operations is withdrawn, and the farmer involvement is greatly increased.

The main objective of the pilot project is to place the technology within a community framework and to enable assessment of its relevance, workability, and acceptability by the farmers. More specifically, a pilot project aims at:

- evaluating benefits to farmers and community from the adoption of the new technology,

- assessing institutional and social requirements for the accelerated adoption of the technology,

- identifying constraints and researchable problems in adoption of the technology by individual farmers and the community,

- redesigning the production program as necessary for wide-scale implementation.

During the pilot project stage, the focus is on the community rather than on individual farmers. Participating farmers are responsible for all farm activities and for management of the experimental plots. The involvement of extension agents, which is required to a lesser degree in the earlier stages, also reaches its peak during the pilot project phase. The extension officer becomes the key link between the farmer and the researcher.

5.5 THE IMPORTANCE OF DEVELOPMENTAL OFR FOR COMPOSITE TECHNOLOGIES

The relative importance of the two types of OFR described above is determined by the nature of the technologies to be tested (Figure 5-6). For this purpose, three different types of technologies may be identified:

- **single component technology** (e.g., fertilizer, cassava cultivar).

- **package technology,** consisting of several independent components (e.g., improved seed, fertilizer, and herbicides).

- **composite technology,** consisting of several interacting components (e.g., alley faming).

These different types of technologies differ in their input and management complexity, management and operational flexibility, and also in the waiting period for benefits to appear. Single component technologies are the least complex and can be easily managed with little flexibility required in their proposed operational plans. They also have a short waiting time for responses to be shown. For example, the results of a fertilizer trial can be seen in one cropping season or less.

Composite technologies, like alley farming, lie at the other extreme. They are more complex because they involve several interacting components. They also require a higher degree of management flexibility to allow alternatives objectives to be met. They are usually of a long-term nature and may have a rather long waiting period before benefits can be seen. These factors make OFR on composite technologies a much more difficult task. Package technologies fall in between single component and composite technologies.

The role of OFR as a link between research and extension is much simpler when dealing with single component technologies. For such technologies, the effects show up quickly, and farmers' interest and participation can be expected to rise if earlyresults are promising. An active involvement of the farmer in experimental OFR on such technologies can lead directly to extension work without necessarily passing through the developmental OFR process. This is in line with traditional thinking on the

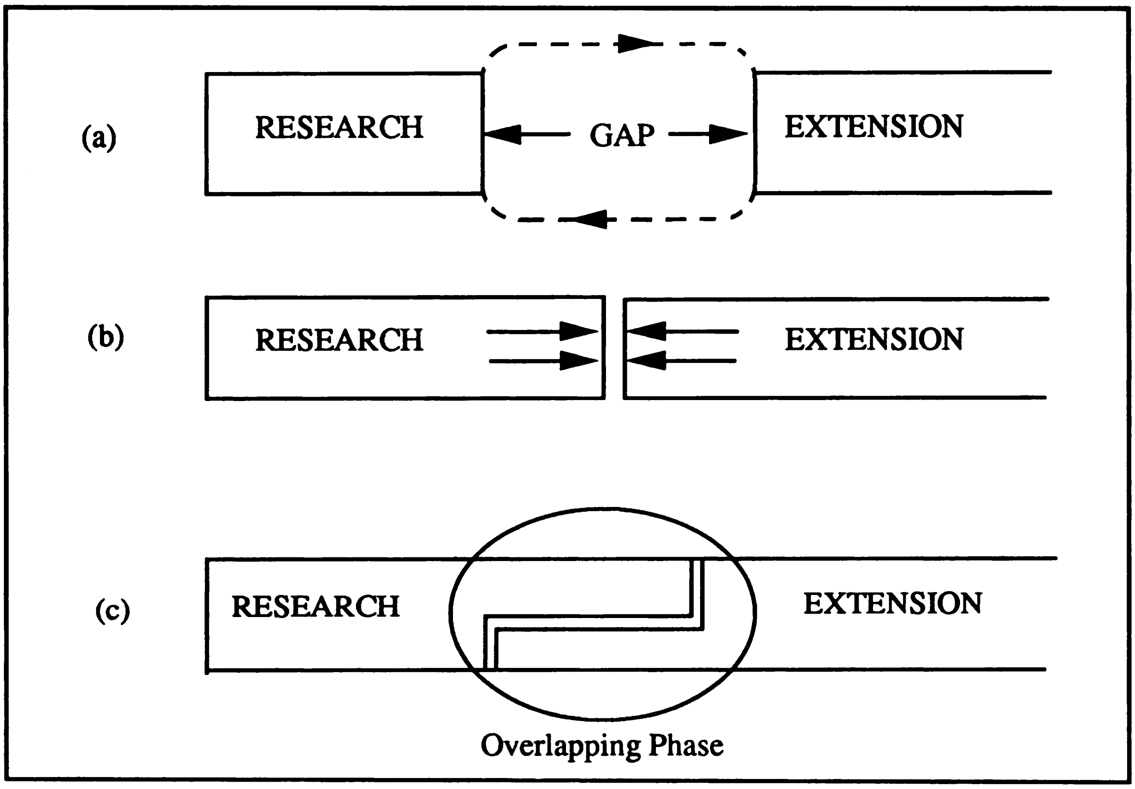

Figure 5-6. Overview of linkage between research and extension

- **(a) Illustrates the gap that usually exists between research and extension in developing countries.**
- **(b) Illustrates a back-to-back research/extension linkage. Suggested for simple technologies such as fertilizer-use.**
- **(c) Illustrates the overlapping phase between research and extension in which the two units operate together in a developmental OFR activity. Suggested for composite technologies such as alley farming.**

research/extension linkage (Figure 5-7). However, the process will depend on the existence of an effective extension service which can link up with the research group for the dissemination of the technology.

The research-extension linkage is more complex in the case of composite technologies. For OFR to lead to extensive adoption and extension, farmer involvement will have to be developed to the point where farmers have management control over the system under trial. In view of the complexity, flexibility, and long waiting time for benefits to show up, composite technologies would need to go through the three stages of developmental OFR.

Developmental OFR may be linked to both on-station research and experimental OFR as illustrated in Figure 5-8. A feed-back mechanism exists among all three processes such that problems identified during developmental OFR can receive further research attention in either on-station or experimental OFR trials.

For composite technologies, the interface between research and extension is more likely to be provided through a developmental OFR approach rather than through experimental OFR. Results from the experimental OFR trials will be worked into the later stages of the developmental OFR process (i.e., the pilot project stage). The direct involvement of extension agents during the developmental phase will facilitate this process. Meanwhile the involvement of the researcher will ensure that problems and opportunities arising as a result of farmer modifications and adaptation are taken into account in further development and fine-tuning of the system.

5.6 RECOMMENDATIONS FOR EXTENSION OF ALLEY FARMING

Alley farming requires the adoption of new management techniques such as tree planting, pruning and management, mulching and cut-and-carry feeding. Experience has shown that, given information and advice, farmers are willing to adopt, and even to experiment with, this new system. The most effective level of extension is at the community level.

The community should be approached through the appropriate leaders, traditional or otherwise. Community meetings will need to be held, at which the potential benefits of alley farming are explained to interested farmers. It is very important to stress to farmers at the outset that the adoption of alley farming does not

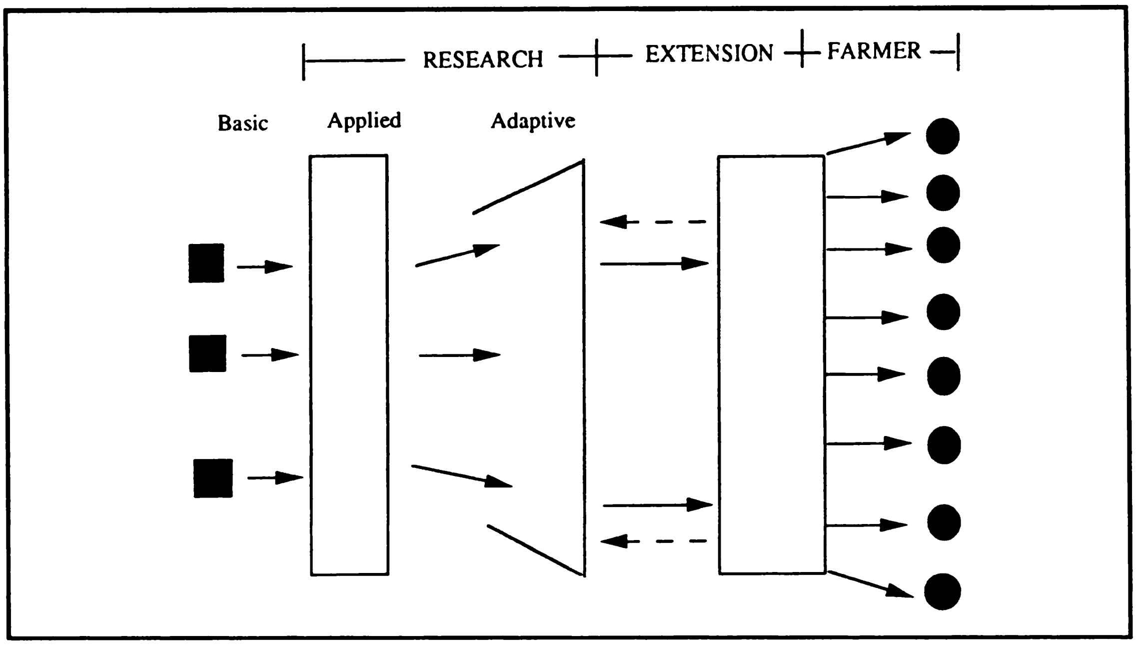

Figure 5-7. The traditional view of links between stages of agricultural research and extension. This scheme is more appropriate for single component technologies such as fertilizers.

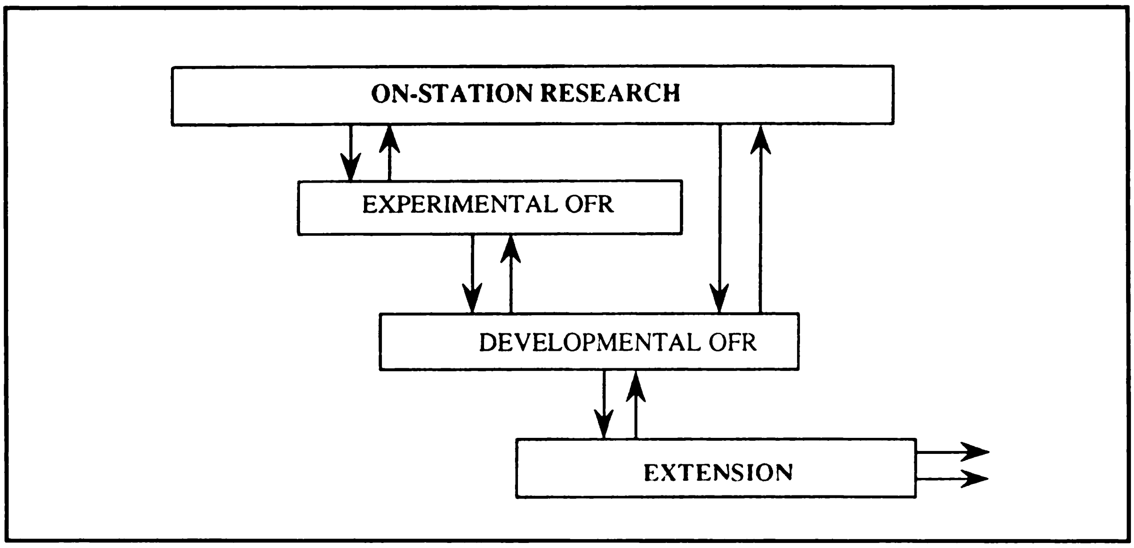

Figure 5-8. Relationship between developmental OFR and other stages of research and extension. This scheme is more appropriate for composite technologies such as alley farming.

imply access to credit or other privileges, unless specific provision for credit, etc., has been made in the extension project.

Posters illustrating the various steps in the establishment process are useful at this stage. However, there is no substitute for farmers seeing alley farms on the ground. Field trips should be organized for would-be alley farmers to see some alley farms — preferably on farmers fields rather than on a research station.

Participatory demonstrations of activities such as planting, pruning, and mulching should also be arranged. Instructions on technical issues, such as arrangement of tree species, intra- and inter-row spacing of the trees, planting depth and planting methods, are best discussed during such demonstrations. However, farmers should be allowed to benefit from the inherent flexibility of alley farming by tailoring it to their own needs, priorities, and preferences.

An extension worker should be based in the village to assist farmers as and when required, and also to monitor activities on the farms. The extension worker should visit farmers and their farms regularly.

5.7 ON-FARM ADAPTATIONS

As mentioned earlier, researchers and extension workers should be alert to adaptations made by farmers that could lead to improvements in alley farming practices. Clearly, this requires a commonsense approach. When a particular farmer does something unusual, the researcher/extension worker should first discover the reason. If the farmer was simply ignorant of recommended practices, and was mismanaging the system, the researcher should educate him or her so as to improve the chances of success.

Figure 5-9. The involvement of extension agencies is essential during on-farm testing and adaptation of alley farming.

However, if the farmer had a rationale for the modification, the researcher should look at the new system carefully, and discuss with the farmer the possible harms and benefits. The farmer may be modifying the system to better achieve his/her own objectives, while not harming crop productivity or long-term sustainability Through this sort of interaction, researchable issues can emerge and suggest new directions for on-station and/or on-farm research.

Some examples of on-farm adaptations are provided in the sections that follow.

Adaptations made by Farmers

Smallholder farmers have priorities and limitations that may affect their approach to hedgerow management. For example, one farmer might decide to prune some trees on the sides to encourage rapid growth of tall trunks with small, high canopies. The prunings can be applied as mulch, and poles can be harvested after the trees reach a useful size, usually in 4 to 10 years. After coppicing, this farmer can lop the trees for leaf mulch or coppice them for more poles.

Another farmer might choose to allow tethered goats to browse on regrowth for mulch in the following cropping season. As another consideration, farmers may vary the timing of hedgerow management tasks to fit in with plowing or weeding schedules. In areas where domestic or wild animals damage the trees in hedgerows, farmers have suggested planting trees in small blocks close to the home. While the leaf mulch then has to be carried to the fields, only a small block of trees has to be fenced. Farmers have tested and will continue to develop many other variations on the standard pattern of alley cropping.

Farmers have combined alley farming with many other practices. For example, farmers participating in agroforestry research projects in Kenya have expressed an interest in combining tree litter from hedgerows, blocks or fencelines with composting or related techniques. In one case, farmers reported adding leaves and twigs of *Euphorbia tirucalli*. *Terminalia brownii* and *Combretum* species to cattle pens for composting. They were interested, not in the structure of alley farming, but in the idea of nutrient cycling by adding leaf litter to the soil.

In many cases, a combination of hedgerows with dispersed trees in cropland can provide additional or better products and a greater impact on surrounding crops than a simple alley farming system. Farmers may wish to combine alley farming with carefully spaced individual fodder trees, such as *Acacia albida,* fruit trees, such as *Persea americana* (avocado) and *Carica papaya,* or trees intended for pole production. Hedgerows may provide a site for individual trees that serve a purpose very different from that of the hedgerow itself.

Alley farming can also complement contour vegetation strips and structural measures for soil and water conservation. In such cases, mulch production complements the erosion-control function, while the hedgerow plants strengthen conservation structures and improve soil fertility in the surrounding fields.

Adaptations made by Researchers in Response to Farmer Preferences

Useful adaptations of alley farming technologies have resulted from observations of farmers' problems and preferences during on-farm trials.

For example, in more than five years of extensive on-farm trials, IITA and ILCA have collected information on farmers' behavior during the establishment phase of alley farming. Small farmers have often proved to be sufficiently intrigued by the idea of using shrubs to improve soil fertility and yields to try the alley system. Their initial interest, however, has not always translated into the extended effort needed to protect and maintain the young hedgerows. Nor are the farmers always motivated to abandon familiar cropping patterns. Some busy farmers, for example, put off establishing hedgerows until after they have planted their crop. Late planting increases the probability that young hedgerow plants will be damaged during weeding.

To keep farmers from getting discouraged, IITA and ILCA researchers have worked on developing alley systems in which the hedgerows provide early, direct, and significant economic benefits; and in which future economic benefits are large and certain enough to justify the farmers' patience. For example, agronomists are testing systems in which perennial cash and food crops, such as oil palm and plantain, are planted in the same hedgerows with leguminous trees. Assurance of an early yield of perennial crops has encouraged farmers to plant annual crops in their alleys and to maintain the alleys during the first two to four years, until the system effects a visible improvement in yields of annual crops.

At some sites, on-farm research has shown that farmers do not favor a close association of crops with hedgerows. Such observations have stimulated research into alternative spatial arrangements, in which wider (double) hedgerow are spaced further apart. This may lead to more competition between hedgerow plants, but will reduce direct competition between the hedgerow and the crops. This spacing can also be used to accommodate higher hedgerows with larger trees interspersed.

5.8 FEEDBACK EXERCISES

All answers can be found in the text and figures of Unit 5.

1. Which one of the followings represents the true definition of OFR?
Circle the correct answer.

- Research carried out on a plot of land outside the experimental station.
- Research carried out on-station with farming systems perspective.
- Research carried out on a farmer's fields in a farmer's environment.
- Research carried out on-station with farmer's involvement.

2. A farmers' involvement in OFR could be one of four types, as given below:
   i) Landlord/tenant relationship.
   ii) Passive on-looker.
   iii) Active involvement - researcher controlled.
   iv) Active involvement - farmer controlled.

   From the viewpoint of a researcher, which one of the above would be labeled as the "most passive" and "most active" involvement ?

3. The following five statements concern experimental guidelines for MPT screening and evaluation. Circle T for true statements or F for false ones:

i)	OFR is a means of ensuring the relevance of technologies developed on-station	T	F
ii)	OFR is used only for technology validation but not for adaptation or extension.	T	F
iii)	OFR is often used to demonstrate new technologies to farmers.	T	F
iv)	OFR can indicate the suitability of existing institutions for delivery of the technology to users.	T	F

4. There are two types of OFR, namely, experimental OFR and developmental OFR. Indicate which of the following activities fall under experimental OFR (Exp.), which under developmental OFR (Dev.), and which under both.

• Tests the biological and technical feasibility of the technology.	Exp.	Dev.
• Demonstrates the value and feasibility of the alternative technology over large areas involving many farmers.	Exp.	Dev.

- Determines the social and institutional requirements for adoption of the technology. Exp. Dev.
- Tests tbe economic viability of the technology. Exp. Dev.
- Fine-tunes the technology. Exp. Dev.

5. a.) The pilot project phase in developmental OFR is normally preceded by two other phases. What are these phases?

- ______________________________
- ______________________________

b.) A pilot project is carried out with certain specific objectives. Name at least three.

____

____

____

6. Give one example of each of the following three types of technologies:

i) composite technology: ______________________________

ii) package: ______________________________

iii) single component: ______________________________

7. Imagine you are conducting a developmental OFR project. Most of the farmers have planted single hedgerows at 4 meters spacing, according to your recommendations.. One of them, however, has decided to plant double hedgerows, spaced 8 meters apart. How will you respond to this farmer's "deviation"?

5.9 SUGGESTED READING

Atta-Krah, A.N., and P.A. Francis 1987. The role of on-farm trials in the evaluation of composite technologies: The case of alley farming in southern Nigeria. Agricultural Systems 23 (2): 133-152.

Amanor, K. 1990. Abstracts on farmer participatory research. ODI Agric. Admin. Unit Paper No. 10. Regent College, England: Overseas Development Institute.

Farrington, J., and A. Martin. 1988. Farmer participation in agricultural research: a review of concepts and practices. ODI Agric. Admin. Unit Paper No. 9. Regent College, England: Overseas Development Institute.

Merrill-Sands, D., and J. McAllister. 1988. Strengthening the integration of on-farm client-oriented research and experiment station research in National Agricultural Research Systems: Management Lessons from Nine Country Case Studies. OFCOR Comparative Study Paper No. 1. The Haque: ISNAR.

Merrill-Sands, D., P. Ewell, S. Biggs and J. McAllister 1989. Issues in institutionalizing on-farm client-oriented research: A review of experiences from nine National Agricultural Research Systems. Quarterly Journal of International Agriculture 28 (3/4): 279-300.

Nordblom, T.L., Awad El Karim, Hamid Ahmed, Gordon R. Potts. 1985. Research methodology for livestock on-farm trials. Ottawa, Canada: IDRC.

5.10 REFERENCES

Atta-Krah, A.N., and P.A. Francis 1987. The role of on-farm trials in the evaluation of composite technologies: The case of alley farming in southern Nigeria. Agricultural Systems 23 (2): 133-152.

Francis, P.A., and A.N. Atta-Krah. 1989. Sociological and ecological factors in technology adoption: Fodder trees in southeast Nigeria. Experimental Agric. 25: 1-10.

Kang, B.T., L. Reynolds, and A.N. Atta-Krah. 1990. Alley Farming. Advances in Agronomy 43: 315-359.

Okali, C., and J.F. Sumberg. 1985. Sheep and goats, men and women: Household relations and small ruminant development in southwest Nigeria. Agricultural Systems 18: 39-59.

UNIT 6

Socio-economic Assessment of Alley Farming

Unit 6: Socio-economic Assessment of Alley Farming

Main Contributors: M. Avila, M. A. Jabbar

6.0 PERFORMANCE OBJECTIVES

Unit 6 is intended to enable you to:

1. Discuss the contributions which social science can make at the various stages of alley farming research.

2. Recall a range of information gathering tools for socio-economic assessment, as well as the strengths and weaknesses of each tool.

3. Demonstrate familiarity with the "farming system" and its various subsystems as units of socio-economic analysis.

4. List the key questions in socio-economic evaluation of a new technology.

5. Discuss the role of five major socio-economic factors affecting adoption of alley farming by farmers, namely: land and tree tenure systems, labor requirements, management complexity, differential social prospects, and overall profitability.

6. Discuss the importance of three key issues related to the diffusion of alley farming across Africa, namely: recommendation domain, public support, and international cooperation.

6.1 INTRODUCTION

Realization of the potential benefits of alley farming will depend on the speed and completeness of the adoption and diffusion of the system among potential users. Diffusion and adoption refer to two distinct processes. The *diffusion* of an innovation means the total process by which an innovation spreads out among farmers until a large number of them have adopted it. *Adoption* concerns the behavior of individuals in relation to the use of technology, more particularly their reasons for taking up use of the technology at a point in time. Understanding and improving the prospects for diffusion and adoption of alley farming depend upon effective socio-economic assessment.

This unit describes the way in which the social sciences contribute to the testing and development of alley farming. It presents the farming system as an appropriate framework for socio-economic assessment of alley farming. Finally, it discusses the major socio-economic issues affecting the diffusion and adoption of the technology.

The reader will find additional information on research tools for socio-economic assessment in Volume 2.

6.2 CONTRIBUTIONS OF SOCIAL SCIENCE TO ALLEY FARMING RESEARCH

The international research literature contains many examples of effective contributions made by social science in technology development. The presence of social science methods and perspectives as part of an interdisciplinary strategy can be especially productive in the case of alley farming research.

6.2.1 Areas of Effectiveness

The particular areas in which social science can be effective are:

1. **Involvement of farmers, households, and communities** as effective participants in the design, evaluation, and extension of alley farming systems.

2. **Definition of recommendation domains** based on (a) household considerations such as need assessment, gender and age responsibilities, household/community relationships, and (b) socio-economic factors such as market prices of inputs, labor supply and demand, and regional development priorities.

3. **Integrated analysis** of biophysical and socio-economic indicators with respect to (a) the existing production systems and (b) the proposed alley farming systems;

4. **Identification and analysis of social constraints** to wide-scale adoption of alley farming;

5. **Design of appropriate strategies** for community organization and mobilization of resources to promote the technology.

6. **Determination of the socio-economic impacts** of technology innovations, and analysis of their implications for further research.

This list shows that socio-economic assessment can play a role in every stage of an alley farming research project. Researchers should avoid the traditional practice, in which socio-economic assessment occurs only in the first and the final stages of technology development (Figure 6-1).

Ideally, socio-economic assessment will be carried out as part of an multi-disciplinary research effort. There could be three to five members on the research team, including at least one social scientist. Their first joint assignment would be to conduct a survey at the village level. This exercise teaches the team to work together and to understand farmers' perspectives.

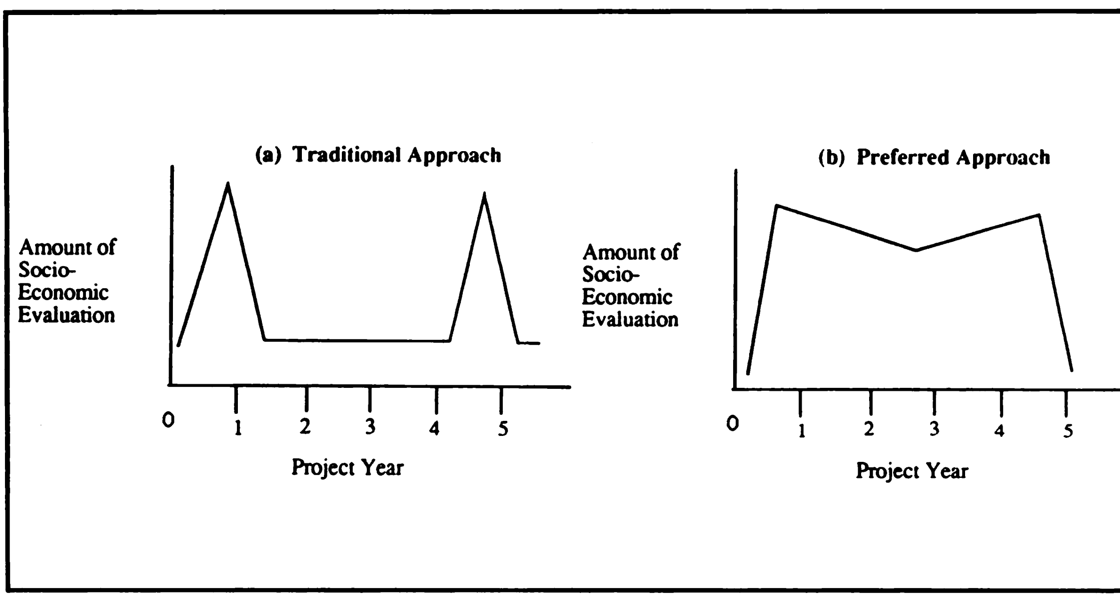

Figure 6-1. The role of socio-economic evaluation in R & D projects:

(a) In the traditional approach, socio-economic assessment occurs only during the preparatory survey and the concluding technology impact study.

(b) In the preferred approach, socio-economic considerations are actively taken into account throughout the research process.

In small projects, fielding such a team may not be feasible. However, even a single scientist who keeps socio-economic as well as bio-physical concerns in mind can constitute a one-man or one-woman multi-disciplinary "team." Socio-economic assessment does not have to be highly technical. A range of information gathering

Table 6-1. Strengths and weaknesses of different information gathering tools for socioeconomic assessment. (After Horton, 1990.)

Tool	Strengths	Weaknesses
Literature review	Helps prevent "reinventing the wheel"	Requires time and access to good libraries
Maps, statistical publications	Provide background data on agricultural sector	May be inaccurate or too "macro"
Informal survey	Provides rapid overview of land use and farming practices	Allows little quantification and outsiders may consider data "soft"
Direct observation	Helps avoid problems of farmer recall and interpretation of verbal responses	Logistical (transport) problems and small sample size
Formal survey	Quantification and large sample size	Costly, time-consuming and computer-intensive
On-farm experiment	Allows technologies to be tested under farmer conditions	Very costly, small sample size, requires at least one full crop season, logistical problems

tools with varying degrees of complexity are available to suit the needs and resources of researchers (Table 6-1).

Simple methods can be quite useful, such as including local farmers in discussions of alley farming's potential, or inviting them to a research station to comment on MPT and management trials. Making a labor calendar of farming activities throughout the year is an example of a relatively straightforward but effective analytical method.

6.2.2 Socio-economic Investigation in AFNETA Research

The AFNETA/NARS collaborative research program provides an example of the role of socio-economic investigation in alley farming research.

Each new AFNETA/NARS project beings with a socio-economic survey. The aim is to begin serious investigation of the critical socio-economic determinants which will ultimately bear on the adoption of alley farming in the project's mandate area. The research teams are expected to acquire a thorough and detailed understanding of traditional systems as practiced by farmers at the various sites, to identify the farmers' conceptions of local constraints and opportunities. The exercise should result in an assessment of potential entry points for agroforestry technologies generally, and alley farming in particular. Additional objectives are to ensure that the research team is farmer-oriented from the start, and to instill in each team the spirit of inter-disciplinarity.

AFNETA favors use of tools of assessment that are simple and quick, can be used in an interdisciplinary manner, and can produce results within a short period of time, with minimum resources. General tools include the following: literature reviews; interviews; short, highly focused questionnaires; and direct observation. Special tools include seasonal calendars (e.g., of rainfall, labor use, prices), historical calendars of past and future land use, and sketch maps or transects to show landuse patterns.

The AFNETA strategy recognizes that socio-economic assessment does not begin and end with a single survey. Investigation of the socio-economic determinants is expected to continue thoughout the life of a project. Its importance grows as the research moves on-farm for monitoring and evaluation of alley farming technologies. Details of AFNETA's current requirements and recommendations for socio-economic investigation are published in separate network documents.

6.3 FRAMEWORK FOR SOCIO-ECONOMIC ANALYSIS

6.3.1 The Farming System

Any agroforestry technology — and alley farming is no exception — is a means for farmers to achieve their goals and objectives. Thus, to design and evaluate appropriate technologies, it is indispensable to understand the environment in which farmers exist and make decisions. Farmers are part of a social milieu which influences their behavior, aspirations, and decision-making processes. Therefore, effective development and implementation of a new technology require a sound understanding not only of the biological systems involved but also of the human systems.

The appropriate unit of analysis for alley farming technology is the farming system (Figure 6-2). A farming system comprises sub-systems of household, agricultural production, and other on-farm and off-farm activities. Within the household, there is the household head, whether male or female (implicitly referred to

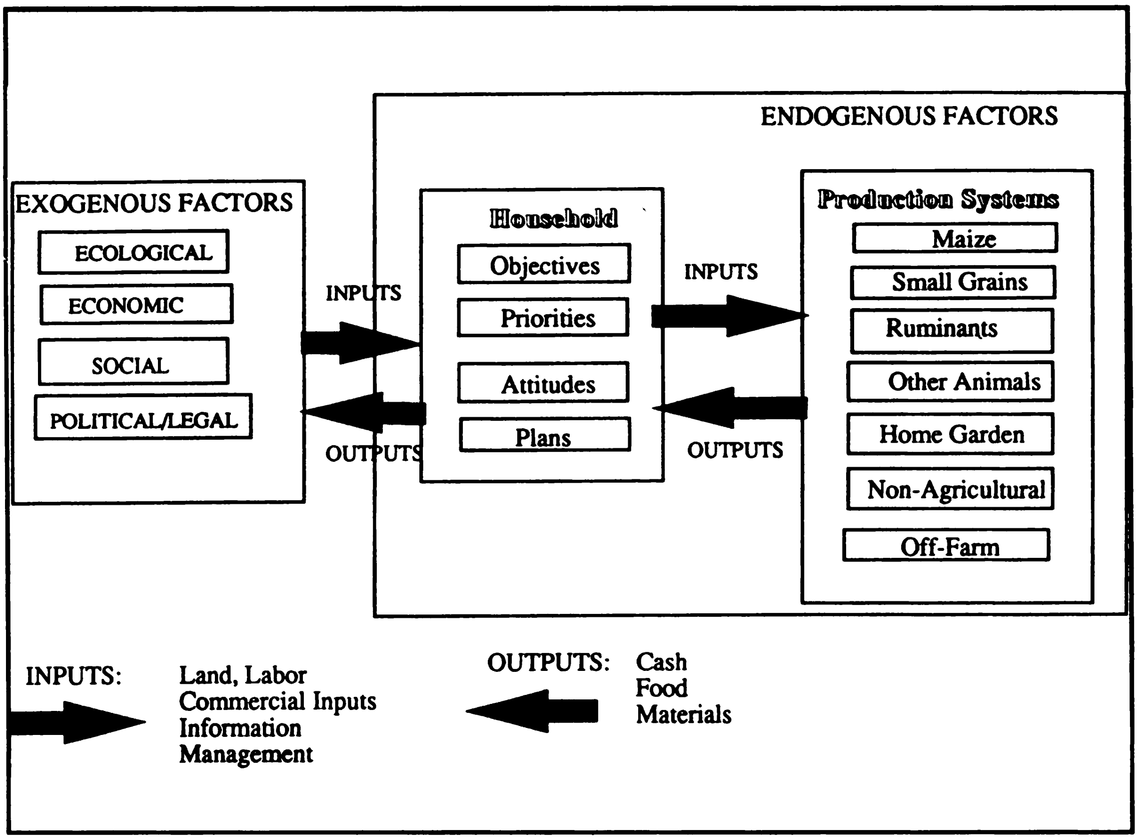

Figure 6-2. A small farming system, showing relationships between the household, production systems, and external socio-economic factors.

as the farmer, the beneficiary of technology), as well as the other members of the immediate or extended family. The household system provides purpose and organization to the multiple activities, specifically in decisions related to establishing priorities, allocating resources, implementing activities, utilizing and distributing outputs, and assessing the overall performance of the farming system. Furthermore, it is the household which organizes and manages all relationships of the farming system with the external environment.

Household goals and priorities deal with physical and psychological needs, which may be summarized as: security of basic needs such as food, clothing and shelter; generation of income and favorable cash flow; conservation and increase of the resource base; recreation and leisure; and recognition and acceptance in the community. There are differences in goals among members of a household. For example, the objective of food security for some members (e.g., producing enough beans, maize and cassava) may compete with or complement the objective of cash generation for other members (e.g., buying land and animals, paying children's school fees).

The resources employed by the household to achieve its objectives are land, labor, capital, and management. These differ in quantity, quality and suitability, depending on location, timing, and/or source. For example, not all plots of land are the same in terms of how and when they can be used. The quantity and quality of *labor* will vary depending on which member of the household is providing it, (e.g., mature male, young female, or very old person), the type of activity to be performed, and traditional customs regarding gender and age-group duties. *Capital status* refers to investments (infrastructure, equipment, tools, animals), operational capital (cash in hand, savings, off-farm employment), and outstanding debts. The ***management resource*** is the ability to make informed decisions on the organization, planning, and implementation of farm activities, and to monitor, evaluate, and learn from successes or failures. The management resource is correlated to the age, education, and experience, of the managers.

A farming system usually includes a mixture of on- and off-farm enterprises due to the household's need to diversify, spread and reduce risks, and to try to optimize use of scarce resources. This makes the analysis of individual enterprises difficult, if not impossible. Therefore, the major task for farming systems analysis (and for technology analysis) is to identify relevant subsystems or sets of enterprises that "make management sense" — particularly from the perspective of resource allocation and resource use efficiency. A production system defined on the basis of land use will probably be a suitable technical unit for defining and analyzing crop, livestock, and/or tree interactions.

The household belongs to larger communities such as village, ethnic group, and/or nation. Emanating from these relationships are societal rules, expectations and institutionalized patterns of behavior that must be adhered to by every member of the community. These rules and patterns extend to the control and use of resources (land, trees, livestock, etc.,) gender and age group rights and duties, community obligations, concepts of wealth, etc. Thus, the social environment shapes and influences the behavior, priorities, and aspirations of the household and the farmer.

6.3.2 Key Questions in Socio-economic Evaluation

<u>Farming Systems Analysis</u>

The adoption potential of a new technology is evaluated in the context of a farming system. To be specific, the following questions should be answered for analysis of alley farming technology:

1. What is the recommendation domain for alley farming? A recommendation domain defines the types of farming systems that are important for the successful introduction and management of a technology. These target farming systems should be defined at least in terms of the chief characteristics of the household, available resources, and production systems.

2. Can one introduce multipurpose trees (MPTs) with crops and/or animals and achieve better economic efficiency in terms of using the scarce resources of the target farmers/households? What and how do the farmers and households gain or lose?

3. What economic complementarities or conflicts with other production activities (e.g., use of labor, cash) are likely to arise within the farming system as a result of the introduced technology?

4. How and to what extent does the alley farming technology reduce variability of crop or livestock performance due to risk and uncertainty factors?

5. Who in (a) the household and (b) the community will make the decisions and implement the changes associated with the technology? Who stands to benefit from the increased production or productivity? Who stands to lose? How does the technology contribute to the realization of the goals of the farmers *vis-à-vis* their status in the community? Are there any potential conflicts with usual customs, for example, those affecting tree or land management and use?

6. Which national economic or development policies, institutional regulations, and/or infrastructural support and services are likely to facilitate or impede the potential application of the technology by farmers?

By seeking answers to these questions, researchers will identify the critical socio-economic determinants for the design and evaluation of the alley farming technology. Because answers depend on the specific situation of the farming system during a given period, socio-economic analysis is location- and time-specific. For this reason, extrapolation or prediction of such results over a range of farming systems should be done with the utmost care.

Cost-Benefit Analysis

To assess the acceptability of the alley farming technology, it is essential to specify its structural and functional aspects, namely: species, propagation, spacing, establishment, fertilization, weeding, plant protection, harvesting, etc. On this basis, one can answer the following questions:

1. What are the resource requirements for all operations?

2. What is the magnitude of real benefits in relation to the farmer's objectives?

3. What are the net returns per unit of land, labor, and/or cash inputs, in the short-term and long-term?

4. To what extent can the technology's benefits be predicted under favorable and unfavorable conditions?

5. What is the anticipated time scheduling for successful establishment of proposed changes and realization of benefit streams?

Such information is derived from both on-station and on-farm research. If only on-station results are used, there tends to be an unintentional effect of overestimating the real benefits and of underestimating the real costs of the technology for the farmer. The most serious constraint to analysis is the probably current scarcity of scientific information on many structural and functional aspects of alley farming.

6.4 ADOPTION OF ALLEY FARMING : FIVE MAJOR ISSUES

Researchers at IITA, ILCA, ICRAF, national programs, and external institutions have been conducting socio-economic assessments of alley farming in Africa since the early 1980s. There is still a great deal of work to be done in this important field of research. However, experience so far has identified the major factors that should receive prominent attention.

A later section (6.5) will cover the issues which relate to the diffusion of alley farming across sub-Saharan Africa. This section (6.4) presents five major socio-economic factors which determine whether individual farmers and communities choose to adopt alley farming technology, namely:

- land and tree tenure,
- labor requirements,
- management complexity,
- differential social prospects for adoption, and
- profitability.

6.4.1 Land and Tree Tenure Systems

Alley farming involves planting trees in addition to annual crops. Tree planting may be subject to special rules. Some people may not be allowed to plant trees or may need to get the permission of another person before planting. These rules vary from region to region and even from village to village, so it is impossible to generalize about them. However, researchers and extension workers should consider the following factors when advising farmers on alley farming (or on tree planting for other purposes):

1. Different land-tenure rules may apply to different categories of land. For example, in many parts of southeast Nigeria, compound land is distinguished from other farmland, and within farmland, "near fields" from "distant fields". While an individual householder will usually be allowed to plant trees around his own compound, this may not be the case with other categories of land.

2. The various members of a household (adult males, adult females, children) may have different kinds of rights over land. In many areas, women are not considered to be owners of land, and may need permission from their husbands before planting trees. However, this need not prevent them from practicing alley farming.

3. People renting land, whether they are from the same community or from outside the community, may have only short-term rights over land, and therefore, may be unable to plant trees. In other cases, tenants are able to plant trees if they obtain the landowner's permission.

4. In some areas, the community or the extended family may exercise control over the use of land. Land (or some types of land) may be shared out annually by

the group, so that the individual farmer will be unlikely to have the same piece of land in the next season. In other cases, the community may dictate the cycle of land rotation. In either situation, the farmer will have little incentive to plant trees, even if he is allowed to, because it is unlikely that he or she will gain the long-term benefit.

The issue of tree tenure is separate from that of land tenure. Rights over trees are often distinct from rights over land. According to Fortmann (1985), issues under tree tenure include the right to own or inherit trees, the right to plant trees, the right to use trees and tree products, the right to dispose of trees, and the right to exclude others from the use of trees and tree products. These various rights differ widely across cultural zones and have a major influence on the social acceptability of alley farming and other agroforestry interventions. In some areas, planting a tree may give the planter rights over the land on which it is planted. In such situations, planting of trees by people with temporary claims to land is usually met with suspicion and opposition by landowners.

6.4.2 Labor Requirements

The main cost of alley farming to the farmer is the extra labor involved in establishing trees and pruning the hedgerow trees. Estimations of labor requirements fall in the range of 40 to 85 hours/ha/pruning in a four-meter alley system. One to three prunings may be required per cropping season. Some extra labor may also be involved in carrying foliage to animals.

These labor costs may be partially or completely offset because alley farming reduces the need for labor for clearing new land. Additionally, alley farming may reduce labor for weeding and for collecting animal feed from the bush. If the alley farm is established by direct seeding, the labor requirements for planting are small (in wetter environments).

Available information on the labor requirment for alley farming is scanty and variable. However, in general, the system appears to require less total labor than conventional bush-fallow farming. The labor costs and the net returns to labor are major determinants of the overall profitability of alley farming. Labor costs may become an important concern if the additional labor has to be hired and/or supplied by the household at peak labor periods in the agricultural calendar.

Figure 6-3. A major labor requirement in alley farming is for regular pruning of the hedgerow trees.

6.4.3 Management Complexity

Alley farming is a composite technology involving trees and/or food crops grasses and/or animals. It is thus a fairly complex and management-intensive technology, requiring careful planning, timely implementation, and close supervision. For both tree and crop components, it is essential to obtain good planting materials, establish them in the right season, use an appropriate combination of plant spacings, manage them to reduce competition (e.g., shading, water use), monitor pests and diseases, protect trees in the off-season (especially against small stock), make sure that MPTs do not invade the alleys, etc. If the farmer does not manage the components properly, he or she may experience serious problems. Such regimes probably require progressive farmers with good management skills or farmer training before implementing the technology. Even extensionists may experience problems with alley farming because it requires a multi-commodity/multi-disciplinary systems strategy.

Tree management, in particular, may present some difficulty to farmers. Although farmers are familiar with the management of trees under the bush-fallow system and plantation tree crops, tree management under alley farming may involve a number of innovative activities, namely:

- planting and establishing trees within arable farms;
- managing the trees for optimum productivity to provide mulch and fodder;

- cutting and carrying foliage to feed animals;
- altering land use and rotation patterns.

Learning these innovations may require time and effort, affecting the speed and ease of adoption.

6.4.4 Differential Social Prospects for Adoption

The issue of social security and equity should always be considered when the introduction of a new technology is planned. What will be the impacts of alley farming technology on the roles, priorities, and opportunities for men, women, and children in the household and community? What will be the prospects of adoption by different types of households and farmers (e.g., resource-rich, resource-poor, women farmers). While it is unfair to expect any technology *per se* to adequately address these socio-political concerns, alley farming can be expected to have different effects on various types of households. It is essential to identify them early in the process of technology development.

For example, levels of education, both formal and informal have been found to influence technology adoption through four effects:

- **the innovation effect**, whereby better educated farmers know the why, what, when, and how of the technology, its cost and benefits, and where to look for information and capital;
- the **allocation effect**, whereby optimal choices in the use of available resources are made;
- the **worker quality effect**, whereby tasks are performed better;
- the **externality effect**, whereby others are helped to learn and adopt.

A generation of adoption studies have emphasized the role of education in adoption. Even where larger farm size and greater extension contact were found important variables in adoption, both of these variables were found to be highly correlated with the level of education.

Experience with the Green Revolution in Asia shows that, although the technology packages were originally characterized as scale-neutral, large farms became early and major adopters. Thus, a technology may itself be scale-neutral, but returns to scale may prevail in adoption, because of the ability of the large farms to spread learning and acquisition costs over a larger volume of output.

Large farmers usually have better access to information and capital because of their better education and greater contact with the supply sources related to the technology. They can become the early adopters and derive the benefits of early adoption such as premium returns and capitalization of those returns in increased investment. Unless special programs for information dissemination to the resource-poor farmers are promoted, such farmers are likely to remain as laggards and miss the benefits of a new technology.

6.4.5 Overall Profitability and Acceptability

When all the costs and benefits are taken into account, is alley farming profitable? This critical issue has received increasing attention from researchers in recent years. They have examined the profitability question from two perspectives: the costs and benefits for the farmers, and those for society as a whole.

Small-scale farmers tend to be most concerned with the short- and medium-term costs and benefits. Alley farming increases their crop yields and animal productivity. It also allows them to extend the cropping period, reducing the area of land that would be needed under the bush fallow system. Alley farming does not require capital outlayother than for seed. Because it reduces, or eliminates, the need for fertilizer, it may actually result in a saving of short-term capital. The extra costs of alley farming must be balanced against these benefits and savings. The major cost factor, as mentioned previously, is increased labor.

Research has shown that alley farming with crops only (no livestock component) is more profitable than traditional bush fallow rotation. The calculations assume a foliage yield of three tonnes of dry matter per hectare and a labor input for pruning of 18 person-days per year. Studies have found the net value of alley farming to be 14 to 59% greater than the bush fallow system. Alley farming with a livestock component will be profitable if it increases net output by 20-30% for sheep and 30-40%for goats – assuming that 25% of the hedgerow foliage is fed to the animals. The attractiveness of alley farming to farmers under appropriate conditions has been

Figure 6-4 Profitability analysis. Alley farming can profit small farmers by, for example, boosting crop and livestock productivity, reducing or eliminating fertilizer purchases, and allowing extended cropping periods.

demonstrated by the spontaneous spread of the technology from pilot project areas, for example, in southwest Nigeria.

Tangible benefits of alley farming are not always apparent to farmers in the establishment phase. During carefully managed on-station trials by trained personnel, IITA's prototype maize/cowpea system begins to improve yields significantly in the second year. Under less favorable conditions on actual farms, however, the improvement usually does not show until the third year after the hedgerows have been planned. The trees have to be established and well-maintained for roughly 10-15 years in order to derive significant long-term benefits. The tree can also provide indirect benefits, such as in yam staking (Table 6-2). This initial time lag may pose a constraint to small farmers. Even when they have a pressing need to conserve soil fertility, their

Table 6-2. Economic returns to yam staking in the Guinea savanna, Benue State, Nigeria (IITA, 1983). The profitability of alley farming improves in areas where tree products such as stakes or fuelwood have a high value.

	Yield (t ha^{-1})[a]		Yield increase		Value of yield increase	Benefit/
Village	Staked	Unstaked	(t ha^{-1})	(%)	(naira ha^{-1})[b]	cost ratio[a]
Yandev 1	25.5	6.9	18.6	269	3627	10.4
Yandev 2	12.1	7.1	5.0	70	990	2.8
Amaladu	20.0	11.0	9.0	81	1782	3.1
Nyikwagh	33.5	17.7	15.8	89	3128	8.9
Abari	19.4	10.5	8.9	85	1762	5.0
Zakibiam 1	27.7	20.8	6.9	33	1366	3.9
Zakibiam 2	18.0	17.0	1.0	6	198	0.6
Isherev	30.5	23.0	7.5	33	1485	4.2
Average	23.3	14.2	9.1	83	1801	5.1

(a) Benefit cost ratio is derived by dividing the values of increased yield by the cost of cutting and carrying *leucaena* stakes

(b) 1 naira = $1.40 (1983 rates).

staying power for the initial period may need to be enhanced through incentive structures such as soft credit. Farmers have indicated their willingness to plant trees under three conditions:

1. Ability to secure tree seedlings at no cost;

2. Possibility of interplanting trees with food crops without adverse effects on crop yields;

3. Possibility of earning some income from the trees (e.g., sale of stakes).

Recent research in Nigeria and elsewhere has shown that socio-economic acceptability relies very heavily on cost-sharing devices between government and rural farmers, as well as on the availability of an active and persistent extension service, and the potential for some direct economic output from the trees in the system.

The benefits to society as a whole are mainly long-term in nature: resource conservation for future generations, stabilized and sustainable food and livestock production systems, reduced reliance on imported chemical fertilizer and/or protein feeds, a stronger rural economy. The long-term benefit of alley farming for soil conservation may not be easily apparent, particularly if land is not scarce. This is because soil degradation occurs slowly, so its implications are also understood slowly. Researchers have argued that policy makers should consider the benefits of alley farming in a national context when deciding whether or not to subsidize adoption of the technology by farmers.

6.5 DIFFUSION OF ALLEY FARMING: THREE MAJOR ISSUES

6.5.1 Recommendation Domain

At the present state of knowledge, alley farming can be recommended with confidence for areas with rainfall over 1200 mm with a bimodal distribution and a soil pH of over 5.2. This recommendation domain reflects the conditions in the areas where it has received most research attention.

The recommendation domain is rather small in relation to the total area of tropical Africa where land pressure, soil degradation, and erosion are serious problems requiring urgent solution. Alley farming is a highly promising low-cost technology for these areas to ameliorate the soil problems and to provide food for people and feed for livestock. However, there is a high degree of diversity within the tropics in relation to resource endowment, and physical, environmental, and institutional conditions. If alley farming is to be considered a potential solution for the problems of this vast region, it has to be developed into a highly robust technology adaptable to these diverse conditions.

Adaptive research is thus a prerequisite for broad diffusion of alley farming. As discussed in Unit 3, the major thrust of current alley farming research in Africa is testing and adapting the current humid-zone, non-acid soil prototype in all agroecological zones and in numerous countries. Such adaptive research constitute the primary objective of AFNETA's program of collaborative research with national agricultural research systems (NARS). It is also a research objective at IITA, ICRAF, and ILCA. These efforts are expected to lead to the development of stable alley farming prototypes for subhumid, semi-arid and highland areas, and for acid soils. As the research emphasis shifts to on-farm investigation (a process that has already begun), the prototype models will be further fine-tuned to suit varying socio-economic conditions within the agroecological zones.

An integral part of this process will be the thorough testing of alley farming using a wider set of food crops. The best-practice technology on station for the tree/crop system has been developed with maize, a shallow-rooted crop. In the humid tropics, maize is not the most important crop. Cassava, yam, cocoyam, and a variety of other crops and vegetables are grown in mixed cropping systems rather than as sole crops. The problems and potentials of establishing alley farms and their performances under such complex cropping systems are not yet adequately known. Accordingly, no precise recommendations are available for farmers to grow crops other than maize. This might prove a bottleneck in the adoption of alley farming technology by farmers who might be interested in root and tuber crops, plantain, etc.

6.5.2 Scientific, Institutional, and Public Support

Public support is necessary for successful promotion of alley farming among farmers. Champions, promoters, and sponsors will be needed at various levels. Seven important issues requiring public support are listed below:

1. Incorporation of alley farming in the priority research agenda of universities and research institutions;

2. Inclusion of concepts and practices of agroforestry, including alley farming, in the teaching curriculum of universities, colleges, and schools of agriculture which turn out future extensionists and development agents;

3. Creating institutional and legal frameworks for providing incentives to farmers;

4. Launching special programs for raising public awareness about the long-term consequences of soil degradation and the role of alley farming in alleviating the problem;

5. Modifying land tenure systems to suit the adoption of alley farming. Since returns to investment in alley farming will accrue over a long period, farmers require a long-term, secure right of cultivation to make necessary investments in alley farms;

6. Making special provisions for subsidies, tax concessions, cost-sharing, and soft credits for those situations where initial personal benefits of alley farming to farmers are few but the social benefits are many. The farmers may have to be paid to "love the land" so as to maintain its future productivity, because even when the farmer is the owner of the land, he may not see far into the future.

7. Ensuring that adequate institutional infrastructure is in place to promote and support the technology. A long-term commitment to extension work will be required from governmental or non-governmental agencies. Infrastructure for the procurement, storage, treatment, and propagation of MPT seeds and seedlings is especially critical.

The degree of public support for these issues will depend on the public perception of the importance of alley farming and the urgency of the problems it addresses, including soil degradation and land scarcity. One important factor that influences public support for a new agricultural innovation is the national policy on food self-sufficiency. If food importation rather than the development of domestic agriculture is the accepted public policy, alley farming is unlikely to get any attention.

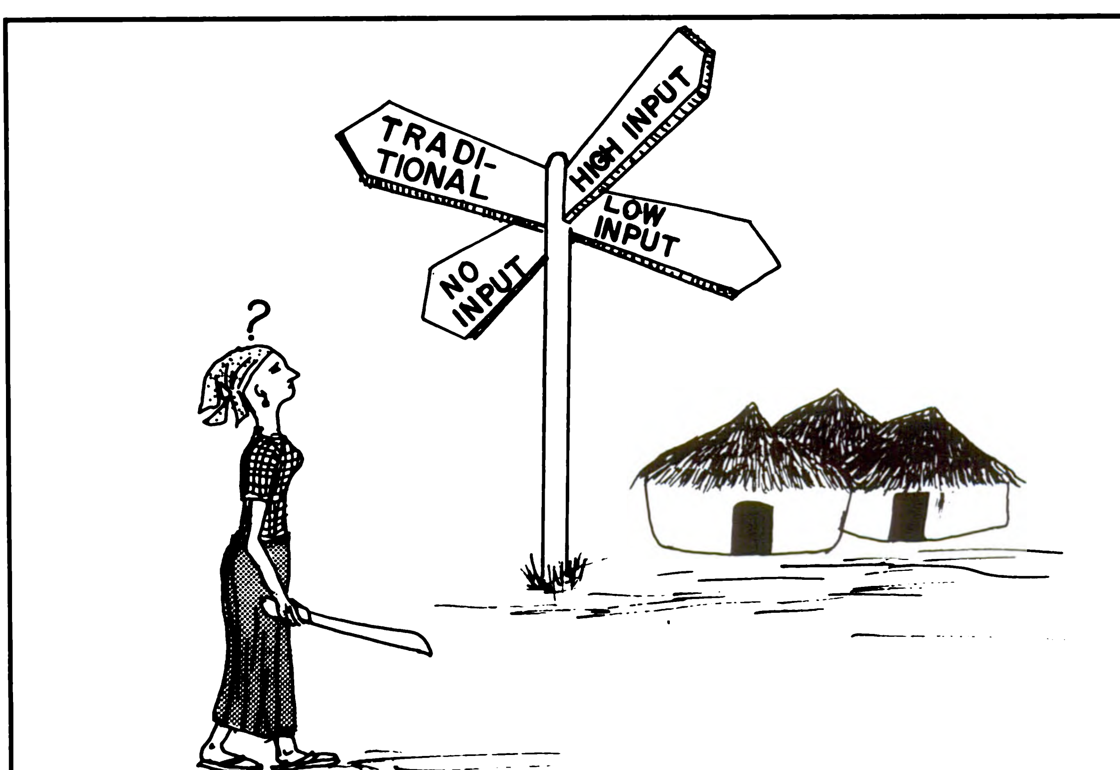

Figure 6-5. Diffusion of alley farming depends on the public's perception of agriculture's most urgent problems and knowledge of the possible solutions.

Public perception is partly derived from the stock of knowledge in a country. A strong intellectual commitment to alley farming would help to mold public perception in its favor. Agroforestry and alley farming are new sciences, and as yet, many scientists, technicians, and administrators in agriculture have not accepted the concept of growing trees to benefit crops.

6.5.3 International Cooperation

Given the size, complexity and geographical coverage of the problem, a high degree of international support and cooperation in research, extension, and capacity-building will be required for successful diffusion of alley farming. Collaboration among IITA, ILCA, and ICRAF in promoting AFNETA is a good example of such an effort.

AFNETA is playing a pioneering role in technology diffusion by promoting collaborative research, providing experimental seeds and other materials, and helping information exchange through various means (newsletter, publications, seminars, workshop, training). However, networks such as AFNETA and the ICRAF-supported Agroforestry Research Network for Africa (AFRENA) are rather small and necessarily limited in scope. Eventually, national governments and institutions will need to play a much larger role.

6.6 FEEDBACK EXERCISES

All answers can be found in the text and figures of Unit 6.

1. a.) List five ways in which social science can contribute to alley farming research:
   1. ______________________________
   2. ______________________________
   3. ______________________________
   4. ______________________________
   5. ______________________________

   b.) Imagine you are designing a five-year alley farming research program, following the research strategy outlined in Unit 1, Section 7. List all possible points at which socio-economic assessment could make a significant contribute to the program.

2. a.) Table 6-1 provides information on six different information gathering tools. Which would be most useful when time and money are especially scarce? Which would be most appropriate in the early stages of a research program? In the later stages?

   b.) Name at least two methods for gathering relevant socio-economic information that are not mentioned in Table 6-1.

3. The following statements concern farming systems concepts. Circle T for true statements or F for false ones:

i)	A farming system does not contain any sub-systems because it is the smallest possible unit of socio-economic analysis.	T	F
ii)	Exogenous economic factors provide inputs to each household. They also receive certain outputs from each household.	T	F
iii)	"Capital status" refers to a village's access to the capital city.	T	F
iv)	Production systems defined on the basis of land use are more convenient units of analysis than household enterprises.	T	F

4. List five major socio-economic factors which determine whether farmers adopt alley farming technology, and briefly cite an example of each factor:

Issue 1: ______________________________
Example: ______________________________
____

Issue 2: ______________________________
Example: ______________________________
____

Issue 3: ______________________________
Example: ______________________________
____

Issue 4: ______________________________
Example: ______________________________
____

Issue 5: ______________________________
Example: ______________________________
____

5. Alley farming has been designed to help smallholders in addressing problems of soil degradation, land pressure, and soil erosion. Recall that the system can be recommended with confidence for areas with rainfall over 1200 mm with a bimodal distribution and a soil pH of over 5.2. Adaptive research efforts are

underway to expand the recommendation domain into areas with drier climates and/or more acidic soils.

Based on what you have learned about alley farming, indicate the geographic area or areas, land use system(s), and target farmers in your country or neighboring countries which would appear to have high adoption potential. For example, a Kenyan might write "Embu District" as a possible high-potential area, "Coffee/banana/maize intercropping with stall-fed cattle" as a land use system, and "Cash-poor farmers with < 1 ha" as target farmers.

Area(s): ______________________________

____

____

Land use system(s): ______________________________

____

____

Target farmers: ______________________________

____

____

6. Section 6.5.2 in the text cited seven measures for promotion of alley farming. Referring to the high-potential adopters you suggested in question 5, can you suggest actions by governmental or non-governmental agencies that – in your opinion – might best enhance the prospects of alley farming in your country or region?

7. Write the full form of the following acronyms.
   1. AFNETA ______________________________
   2. IITA ______________________________
   3. ICRAF ______________________________
   4. ILCA ______________________________
   5. NARS ______________________________

6.7 SUGGESTED READING

Arnold, J.M. 1987. Economic considerations in Agroforestry. In: Steppler, H.A. and P.K. Nair, (eds). Agroforestry: A Decade of Development, ICRAF, Nairobi.

Atta-Krah, A.N., and P.A. Francis. 1987. The role of on-farm trials in the evaluation of composite technologies: The case of alley farming in Nigeria. Agricultural Systems, 23(2), 133-52.

Francis, P.A., and A.N. Atta-Krah. 1989. Sociological and Ecological Factors in Technology Adoption: Fodder Trees in South-east Nigeria. Experimental Agriculture, 25:1-10.

ILCA (Iternational Livestock Centre for Africa) 1987. Final Report to the Federal Livestock Department, Federal Military Government of Nigeria. FLD Grant Sept. 1986-Sept. 1987. Ibadan, Nigeria: ILCA Humid Zone Program.

Kaimowitz, David (ed), David (ed), 1990. Making the link - Agricultural research and technology transfer in developing countries. Westview Press, Boulder, Colorado, U.S.A.

Kang, B.T. 1989. Alley cropping/farming: Background and general research issues. Paper presented at AFNETA inaugural meeting, IITA, lbadan, Nigeria, 1-3 August.

Lindner, R.K. 1980. Farm size and the time lag to adoption of scale neutral innovation. Mimeo. Report. Adelaide: University of Adelaide, South Australia.

Mahajan, V., and R.A. Peterson. 1979. Integrating time and space in technological substitution models. Technological Forecasting and Social Change, 14(1), 231-41.

Ngambeki, D.S., and G.F. Wilson. (undated). Economic and on- farm evaluation of alley farming with *Leucaena leucocephala, 1980-83*. Activity Consolidated Report. IITA, Ibadan, Nigeria.

Rogers. E.M. 1983. Diffusion of innovations, 3rd Ed. Macmillan and Co., New York, U.S.A.

Rogenberg, N. 1982. Inside the black box: Technology and Economics. Cambridge University Press, Essex, U.K.

Ruttan, V.W. 1977. The green revolution: Seven generalizations. International Development Review, 19, 16-23.

Thirtle, Collin G., and Vernon W. Ruttan. 1987. The role of demand and supply in the generation and diffusion of technical change. Harwood Academic Publishers, London, U.K.

Vogel, W.O. 1989. Economic returns of alley farming. In: B.T. Kang and L. Reynolds (eds.), Alley farming in the humid and subhumid tropics. IDRC, Ottawa, Canada.

Walker, T.S. 1987. Economic prospects for agroforestry interventions in India's SAT: implications for research resource allocation at ICRISAT. Resource Management Programme, Economics Group, Progress Report 79. ICRISAT, Patancheru, India.

6.8 REFERENCES

Horton, D. 1990. Tips for planning formal farm surveys in developing countries: IITA Research Guide 31. Ibadan, Nigeria.

Fortmann, L. 1985. Tree tenure. An analytical framework for agroforestry projects. Paper prepared for conference on land tenure and agroforestry, Nairobi, Kenya, May 1985.

IITA (International Institute of Tropical Agriculture) 1983. IITA Annual Report, Ibadan, Nigeria.

APPENDICES

Appendix A: Inoculation Techniques

Main Contributor: K. Mulongoy

As discussed in Unit 3, inoculation of legume seeds with a compatible rhizobium strain may be required if a hedgerow species is being introduced for the first time in an area. This appendix provides information on how to inoculate the seeds of leguminous plants to ensure establishment of the hedgerows and to maximize biologically fixed N_2.

Source of Rhizobia Inoculant

The rhizobia to be used for inoculation may be isolated by the researcher himself from nodules, dried root material, or soil, or be requisitioned from a *Rhizobium* culture collection. In either case the culture will require further growth and multiplication until there are sufficient bacterial numbers present for inoculation.

Alternatively, inoculant can be purchased from a commercial producer. In this instance it is desirable to select commercial inoculant of the highest quality possible. The minimum number of viable bacteria accepted in peat cultures as prescribed by the Australian Inoculants Research and Control Service is 10^9 rhizobia per gram at manufacture and 10^8 per gram at the time of inoculant expiry with less than 0.1% contamination.

Inoculant for *Leucaena* is obtainable from the Nitragin Company in the United States (Address: 3101 W. Custer Ave., Milwaukee, Wisconsin 53209, USA).

How to Handle Rhizobia Cultures

Some general principles apply whatever the technique chosen for obtaining the culture:

- If uninoculated control treatments are included in an experiment, they should always be handled before treatments in which the seed is inoculated. This reduces the risk of contamination and subsequent nodulation of the controls.

- Inoculation levels should always be as high as feasible within the objectives of the experiment. The presence of large numbers of inoculant rhizobia reduces the scope for contamination and nodulation by naturally occurring rhizobia or strains from other inoculation treatments.

- Rhizobia are mobile organisms and are easily transferred accidentally by water movement, humans, or animals from treatment to treatment or plot to plot. Awareness of this is needed in setting up an experiment, weeding plots, and even in walking across plots. Fencing should be set up around plots to exclude animals.

- Rhizobia are incompatible with many agrochemicals applied as seed dressings. Even a fertilizer such as superphosphate can be toxic to rhizobia when put in direct contact with inoculated seed, because superphosphate is very acidic.

- Rhizobia can easily be killed by heat. The inoculant therefore must be kept in a cool place before use. Environmental temperature at sowing, however, is also important. Some 4.6% of a soybeam inoculant can be recovered from the soil 24 hours after sowing at 28°C; but only 0.2% or less might survive when sowing is done at 38°C.

Standard Laboratory Method at IITA for Peat Inoculant

Step 1: Preparation of Inoculant

Materials

- Packet of milled peat (50 g) previously sterilized with gamma rays

- *Rhizobium* broth culture

Method

1. Inject (with sterile syringe) 25 ml of broth culture to raise moisture content of peat to 60% (i.e., 1 part broth, 2 parts carrier).

2. Using adhesive label, seal the puncture in the peat packet caused by the syringe.

3. Manipulate the packet before the absorption of gas shrinks the packet. Incubate the packet at which is the +26°C to let *Rhizobium* population increase to e.g. 10^8, 10^9 cells/g.

Step 2: Seed Inoculation

Materials:

- Rhizobium inoculants
- Legume seeds
- Nitracoat (60g/100 ml), gum arabic, or sucrose (10%)

Method:

1. Mix 10g of peat inoculant with 20 mlof Nitracoat
2. Use 8 ml of this slurry for 1 kg of seeds. For example, for 25 g of seeds, prepare 6 g in 10 ml of Nitracoat and 5 g of Inoculant. Mix 5 g of inoculant with 10 ml Nitracoat (slurry) to inoculate 25 g of seeds with 0.2 ml of the slurry.

Field Inoculation Method

Materials:

- Commercial Inoculant Packet
- Legume Seeds
- Sugar
- Bottle (approx. 1-liter)
- Bucket and Basin
- Paper or cloth

Method:

1. Take clean water in an empty bottle, add a tablespoonful of sugar and shake well to dissolve.
2. Take a bucket full of clean seeds (approx. 15 kg seeds).
3. Empty the seeds into a clean basin.
4. Pour the water onto the seeds.
5. Mix seeds well with water so th at each seed is wetted.
6. Empty the contents of the inoculant packet on to the wetted seeds.

7. Mix the seeds thoroughly so that each seed is uniformly coated with the inoculant.

8. Cover the inoculated seeds with paper or cloth to protect from direct sunlight.

9. Sow the seeds immediately in a moist, well prepared field.

Appendix B: Seed Production of *Leucaena* and *Gliricidia*

Main Contributors: A.N. Atta-Krah, P.A. Francis, L.Reynolds

The basis of good hedgerow establishment in alley farming is high quality seed. *Gliricidia* seed can be collected from mature plants where these are available, but local *Leucaena* is the shrubby, weedy type and should be avoided. Seed of better cultivars can be obtained from appropriate sources (see Unit 2). Where large quantities of seed are needed each year for distribution, seed of the two species will have to be produced.

Establishing a Seed Ochard

Leucaena and *Gliricidia* seed orchards should be planted on fertile land. *Leucaena* should be planted at spacing of 2 x 2 m (2500 trees per ha) and *Gliricidia* at 3 x 2 m (approx. 1660 trees per ha). This requires about 250 g of *Leucaena* seed or 200 g of *Gliricidia* seed per ha. *Leucaena* flowers 7-9 months after establishment and can produce good quality seed even in the first year of growth.

If left uncut during the establishment year, some *Gliricidia* trees in a block may flower towards the end of the first dry season, after about 8 months of growth. This flowering is, however, unreliable as most of the flowers drop without forming pods. The first effective flowers will be produced approximately 18 months after establishment during the second dry season. For seed production, *Gliricidia* trees should be pruned prior to the first dry season to induce branching and increase flowering and seed production loci on the trees. Thereafter, they should not be cut again, because cutting delays flowering and reduces seeding. Mature pods form 6-8 weeks after flowering in *Gliricidia* and 10-12 weeks after flowering in *Leucaena*.

Seed Collection and Handling

Although *Leucaena* and *Gliricidia* generally produce highly viable seeds, improper handling and storage can lead to loss of viability and poor germination, especially in *Gliricidia*.

Seeds of the two species should be picked at different stages of growth. *Leucaena* pods can be left to dry on the trees before picking, while *Gliricidia* pods must be picked before they are completely dry, to avoid seed loss from pod shattering. After collection, pods are sun-dried. The seeds can be extracted by either manual or mechanical threshing and cleaning. Different batches of seed should be tested for germination and then stored in air-tight containers. The seeds should be stored in a refrigerator (+4°C). For short periods (up to 3 months), they can be stored in a cupboard at room temperature. Storage in a deep-freeze (-4°C) or at room temperature for periods of more than 4 months reduces viability of *Gliricidia* seeds.

Leucaena seed is hardier than *Gliricidia* seed and therefore stores better. Dry *Leucaena* seed in air-tight containers can be kept at room temperature, in a deep freezer or in a refrigerator. The seeds have good viability maintenance (up to 90%) after a year's storage. Seed dormancy is maintained under these conditions and seeds have to be scarified prior to germination (see Unit 2). Subsequent drops in viability are slight and gradual.

Appendix C: Contour Planting Techniques

Main Contributors: A.N. Atta-Krah, P.A. Francis, L. Reynolds

Introduction

In alley farming on sloping land, hedgerows should always be planted along contour lines. This appendix describes techniques which can assist researchers and farmers to plant along contours. During on-station trials, researchers may wish to use more sophisticated procedures and equipment. However, the following techniques would normally be appropriate for on-farm trials.

Planting on Gently Sloping Land

On ridged or heaped land, the trees should be planted on one side of every fourth or fifth ridge (or line of heaps). Ridges should run across the slope to minimize soil erosion.

On un-ridged, gently sloping land, tree rows can be aligned using the following method:

- Determine the direction of slopeof the land. Plant across the slope, starting from the top of the slope.
- Place a long stake at either end of an imaginary contour at the top of the slope. Where the distance between the two poles is long (over 40 m), or where there are obstacles between the two, making it difficult to see one pole from the other, place a third in between.
- Start planting from one end of the row. Spacing between tr ees should be about 25 cm. (In subhumid regions, the trees should be 50 cm apart.)
- When the entire row has been planted, the distance to the next row can be estimated by taking four or five strides down the slope from each pole, moving the poles to these new positions. The poles define the path of the new row.
- Plant along this new row as before.
- Continue until the entire field is planted.

Using an A-Frame to Plant on Steep Slopes

If the land slopes steeply (e.g., on hillsides) the contour line should be determined more accurately than can be achieved by eye alone. The first step is to make a simple A-frame, and then use it to follow the contour line across the slope. Trees are then planted as described for gently sloping land.

The A-frame can be made using simple materials. You will need two pieces of wood or bamboo about 120 cm long and one piece about 60 cm long, a carpenter's level or 60 cm of string, a stone to be made into a pendulum, and nails or string to fasten the A-frame together (Figure 1). Follow these steps:

- Nail or tie the two long pieces of wood together at one end.
- Set the "legs" of the frame on level grond so that the "feet" are one meter apart.
- Fasten the short piece of wood to the legs to make an "A".
- Using the carpenter's level, check that the crossbar is level, and connect the carpenter's level to the crossbar. (If you will use a pendulum, hang the string from the top of the "A" and put the A-frame on level ground. Mark where the string crosses the croossbar).

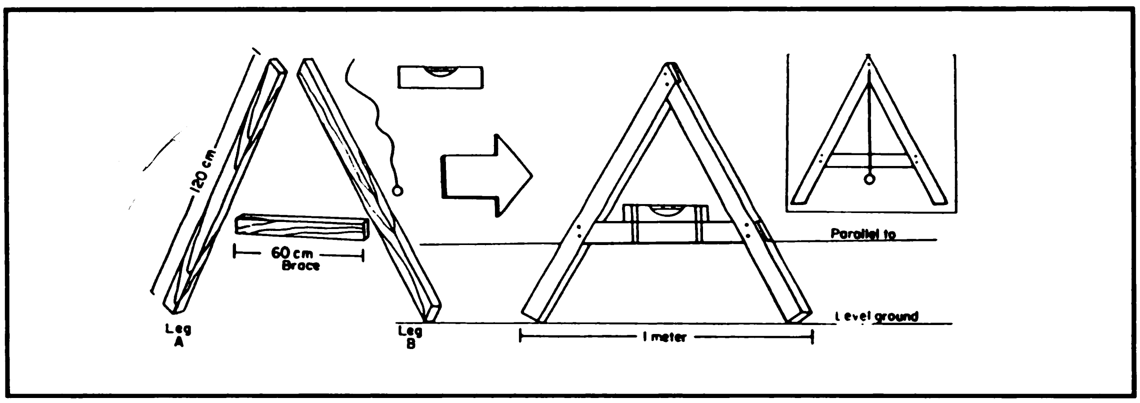

Figure1. Making the A-Frame.

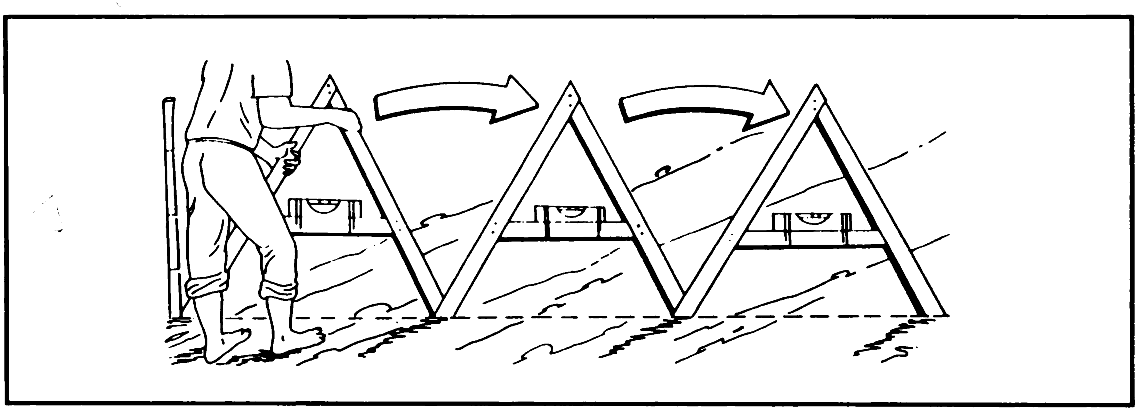

Figure 2. Finding the contour.

Appendix D : Productivity Indices for West African Dwarf Breeds

Main Contributors: A. N. Atta-Krah and L. Reynolds

The following quantitative performance data are for West African dwarf breeds under traditional systems. Sheep are almost twice as productive as goats, and free-roaming goats are, in turn, twice as productive as confined ones. As with other species, litter size, birth weight and survival rate increase up to the fourth or fifth parturition, and fall slowly thereafter.

Liveweight: Mature males are heavier than mature females, with average weights of 30 kg for sheep and 20 kg for goats.

Litter size Average litter size is 1.2 for sheep and 1.5 for goats.

Gestation period: About 5 months for both species.

Parturition interval: 9-10 months for sheep and 8-9 months for goats.

Mortality rate: In village flocks mortality rates are high, ranging from 30-60% up to 12 months, and around 10% thereafter.

Age at first conception: 12 months.
Age at first parturition: 17 months.

Growth rate of offspring to weaning: About 70 g per day for sheep and 35 g per day for goats. Single offspring grow faster than twins, and males grow faster than females.

Appendix E: Farmer Equivalents for Measuring Units

This training manual uses metric units of length, area and weight in its recommendations for alley farming practices. It is often not possible under field conditions for farmers to judge these measures exactly. They are therefore to be taken as guidelines, and the following methods of approximation may be helpful.

Length: 1 meter (m) = one pace
25 centimeters (cm) = distance from heel to toe on a foot
2 centimeters = width of one thumb

Area: 1 hectare (ha) = 100 paces x 100 paces
0.2 hectares = 100 paces x 20 paces or
50 paces x 40 paces

Weight (fertilizer): 50 kilograms (kg) = one fertilizer bag
100 grams (g) = one small milk tin full of fertilizer
20 grams = one matchbox full of fertilizer

Weight (edible browse foliage):
200 grams dry matter (g DM) = 2 branches of *Leucaena* and 2 branches of *Gliricidia*, each about 1 to 1.5 meters long.

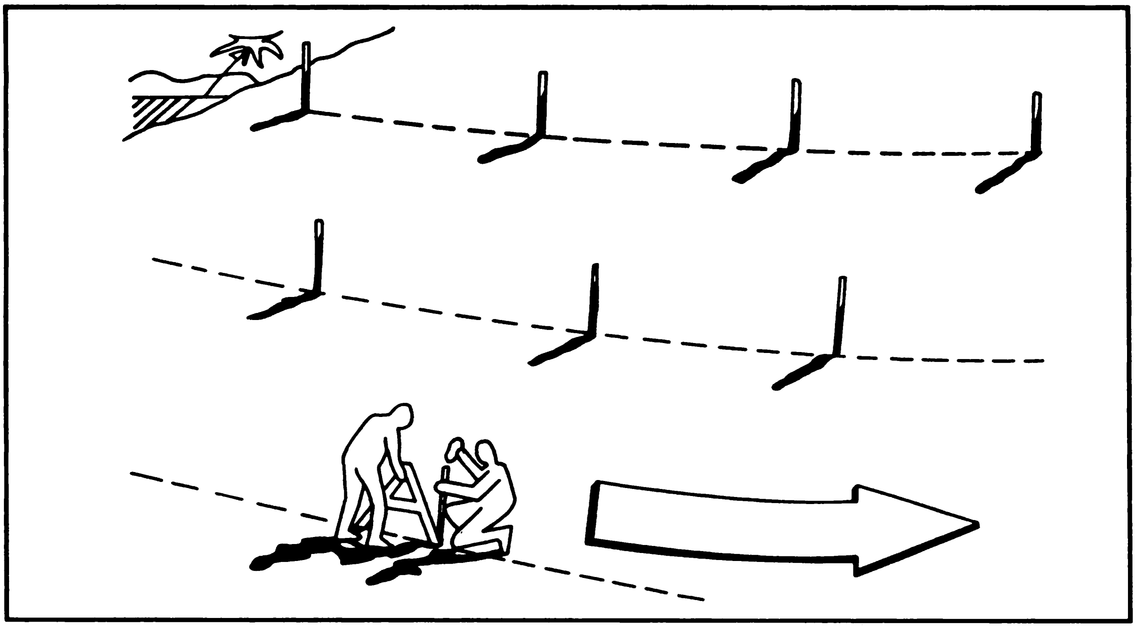

Figure 3. Staking out contour lines.

To use the A-frame, follow these steps:

- Put leg A on the ground and move leg B forward or backward until the bubble in the carpenter's level floats to the centre (or the pendulum swings to the center mark). Mark the position of the legs.

- Move the A-frame, placing leg A where leg B was before, and repeat the process (Figure 2).
- Move across the hillside along the contour, and place a marking stake every 3 to 5 meters (Figure 3).

Additional Erosion Control Measures

In areas where water erosion is a serious concern, alley farming techniques can be combined with terracing and grass planting. For example, one ongoing AFNETA project is experimenting with a hillside terracing system in which fodder grasses are planted on the upper bunds of the terraces while trees are planted on the lower bunds. Indvidual stands in the hedgerows are left uncut for added stability (Figure 4).

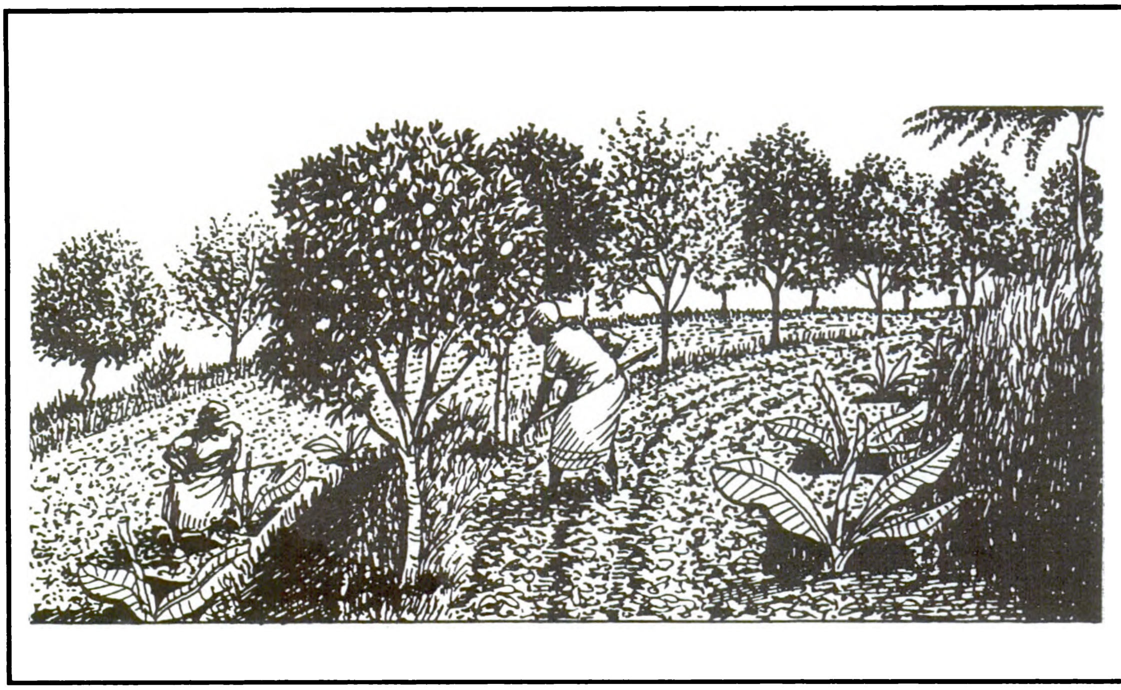

Figure 4. **Experimental hillside terraces combining fodder grass, tree hedgerows, and arboreal trees.**

Appendix F: Glossary of Terms

Main Contributors(*) D. Rocheleau, F. Weber, A. Field-Juma and J. Cobbina

Acid (soil) : A soil having a pH of less than 7.0. A soil with a higher pH is called basic or alkaline. Some plants, such as *Leucaena leucocephala*, do not grow well in strongly acid soils (pH less than 5.5). Limestone (a basic rock) is often ground and added to soils to reduce their acidity.

Agroforestry: The deliberate use of woody perennials (trees, shrubs, palms, bamboos) on the same land-management unit as agricultural crop pastures and/or animals. This may consist of a mixed spatial arrangement in the same place at the same time, or a sequence over time.

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

Annual: A plant that grows for only one season (or year) before dying, in contrast to a perennial, which grows for more than one season.

Arid: A climate characterized by so little rainfall that cultivation is only possible if supported by water management. For the purposes of this manual, an arid area has an average annual rainfall of less than 200 mm.

Biomass: The weight of material produced by a living organism or collection of organisms. The term biomass is usually applied to plants. It may include the entire plant, or it may be qualified to include only certain parts of the plant, e.g,. above-ground or leafy biomass. Biomass is expressed in terms of fresh weight or dry weight.

Browse: The buds, shoots, leaves and flowers of woody plants which are eaten by livestock or wild animals.

Contour: Line joining all places at the same height above sea-level. Used on maps to indicate change in elevation, or the slope of land.

Coppicing: Cutting certain tree species close to ground level to produce new shoots from the stump. Also occurs naturally in some species if the trees are damaged.

Crown: The canopy or top of a single tree or other woody plant that carries its main branches and leaves at the top of a fairly clean stem.

Cutting: A piece of a branch or root cut from a living plant with the objective of developing roots and growing a new plant, genetically identical to the original parent (a clone).

Cut-and-carry: Fodder or other plant products which are harvested and carried to a different location to be used or consumed.

Deciduous: A plant which loses all or a part of its leaves at the end of a season's growth. The opposite of evergreen.

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

(*) Most definitions are from Dianne Rocheleau, Fred Weber, and Alison Field-Juma, Agroforestry in Dryland Africa (Nairobi : ICRAF, 1988, pp. 271-279)

Dormancy: Arrested development of a plant owing to structural or chemical properties of the seed that prevent germination when environmental conditions are favorable.

Edaphic: Pertaining to the influence of the soil upon plant growth.

Extensive: Land use or management spread over a large area where land is plentiful (at least for those who control it). Opposite of intensive.

Exotic: A plant or animal species which has been introduced outside its natural range. Opposite of indigenous.

Fallow: Land resting from cropping, which may be grazed or left unused, often colonized by natural vegetation. Also, the practice of leaving land either uncropped and weed-free, or with volunteer vegetation during at least one period when a crop would normally be grown.

Farming system: All the elements of a farm which interact as a system, including people, crops, livestock, other vegetation, wildlife, the environment and the social, economic and ecological interactions between them.

Fodder: Parts of plants which are eaten by domestic animals. These may include leaves, stems, fruit, pods, bark, flowers, pollen or nectar.

Foliage: The mass of leaves of trees or bushes.

Foliage harvest index: The ratio of foliage dry weight at harvest to total above ground dry weight at harvest.

Forage: Herbaceous plants or plant parts consumed by animals.

Forb: Any herbaceous nongrass plant.

Graze: To feed on grass.

Green manure: Green leafy material applied to the soil to improve its fertility.

Hedgerow: A closely planted line of shrubs or small trees, often forming a boundary or fence. Also called a hedge.

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

Highlands: For the purposes of this manual, any land area with an altitude of 1500m or more.

Intensive: Land use or management concentrated in a small area of land. Opposite of extensive.

Intercropping: Growing two or more crops in the same field at the same time in a mixture.

Interface: The area where there is positve or negative interaction between two entities, such as between a row of trees and a row of crops.

Inoculation: Addition of effective rhizobia to legume seed prior to planting for the purpose of promoting nitrogen fixation.

Land use system: The way in which land is used by a particular group of people within a specified area.

Lop: To cut one or more branches of a standing tree.

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

Mulch: Plant or non-living materials used to cover the soil suface with the object of protecting the soil from the impact of rainfall, controlling weeds or moisture loss and, in some cases, fertilizing the soil.

Multipurpose tree (MPT): A woody perennial which is grown to provide more than one product or service. May refer to trees or shrubs.

Nitrogen-fixing: Relating to a plant that has the ability to convert nitrogen in the air into a form which can be used by plants. This process is performed by another organism that lives within the roots of the plant. In leguminous plants the organism is a bacterium. In other plants, such as *Casuarina* species, it is an actinomycete.

Palatability: Plant characteristics eliciting a choice between two or more forages or parts of the same forage, conditioned by animal and environmental factors that stimulate a selective intake response.

Palatable: Desirable to eat.

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

Pollarding: Cutting back the crown of a tree in order to harvest wood and browse to produce regrowth beyond the reach of animals and/or to reduce the shade cast by the crown.

Pruning: Cutting back plant growth. In this manual, pruning is a general term which includes coppicing, lopping, pollarding or other cutting techniques.

Ration: A 24- hour allowance of feed or mixture of feedstuff making up the animal diet.

Ridge: A long raised strip of earth.

Rhizobia: Species of bacteria that live in symbiotic relationship with leguminous plants within nodules on the plant roots. Rhizobia carry on the fixation of atmospheric N in forms used as nutrients by the host legumes.

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

Rotational grazing: System of pasture utilization embracing periods of heavy stocking followed by periods of rest for herbage growth recovery during the same season.

Seed pretreatment: Nicking, soaking in water, or treating seeds with substances such as insecticides or fungicides to improve germination.

Semi-arid: In this manual, semi-arid refers to a climate with average annual rainfall of 200 to 900 mm. In semi-arid areas, rainfall in some years is insufficient to maintain crop cultivation.

Senesce: To age (particularly of leaves).

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

Shoot: A stem; may also refer to new growth of a plant, usually including a stem.

Slope: The inclination or angle of the land surface, which can be measured as a percent, a ratio, or in degrees or grades.

Soil moisture: Water in the soil, a portion of which is available to plants.

Stockpile: Accumulation of growth of forage for later use.

Subhumid climate: In the tropics, a climate with rainfall averaging 900 to 1200 mm a year and susceptible to drought. Also known as 'grassland' climate.

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

Trace elements: Chemical elements required in small amounts by plants or animals, and measured in milligrams per kilograms or parts per million.

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

Tilth: Physical condition of a soil in respect to its fitness for plant growth.

Woody: Plants which consist in part of wood; not herbaceous.

Yearling: A male or female animal from 12 to 20 months of age.

Zero-grazing: Livestock production systems in which the animals are fed in pens or other confined areas and are not permitted to graze.

ISBN 978-131-074-X

Printed at ILCA, Addis Ababa, Ethiopia