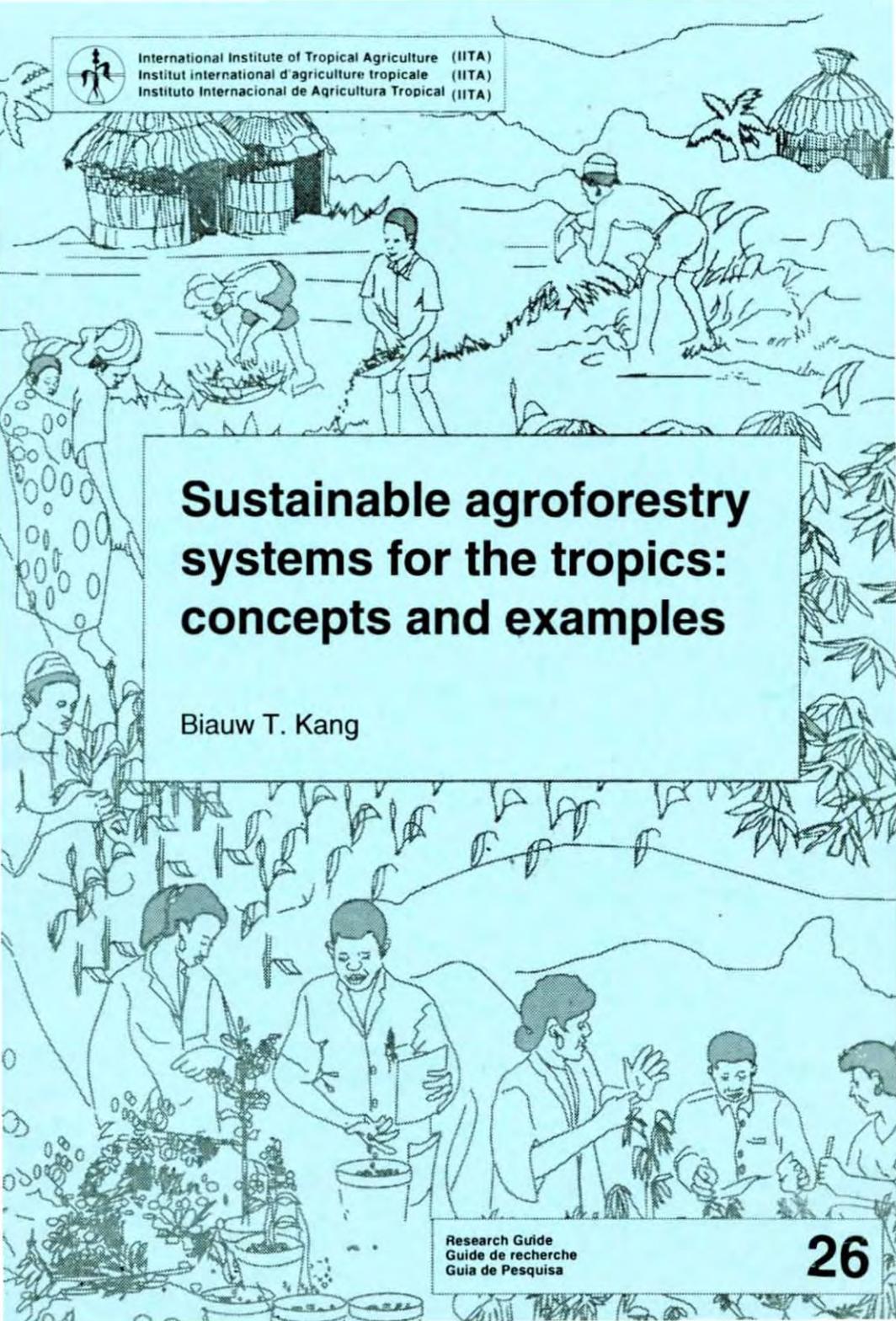




International Institute of Tropical Agriculture (IITA)
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Sustainable agroforestry systems for the tropics: concepts and examples

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Sustainable agroforestry systems for the tropics: concepts and examples

Objectives. This guide is intended to enable you to:

- explain the concept of agroforestry,
- classify agroforestry systems,
- describe the interactions between trees and crops,
- describe four types of agroforestry systems.

Study materials

- Slides of traditional and recent agroforestry systems.
- Real examples of agroforestry systems.

Practicals

- Examine traditional agroforestry systems in nature.
- Classify agroforestry systems in the field.
- Study interactions of trees and crops.

Questions

- 1 In what three main areas do trees and shrubs benefit the farmer?
- 2 In what forms can land be distributed between trees/shrubs and agriculture?
- 3 What are three classes of agroforestry systems?
- 4 What are the characteristics of agrosilvopastoral systems?
- 5 What is an extreme example of temporal agroforestry?
- 6 What are three socioeconomic agroforestry systems?
- 7 What are the interactions between tree and non-tree components?
- 8 What are the beneficial effects of trees on soil fertility?
- 9 What are the effects of trees on soil conservation?
- 10 What is the main objective of the taungya system?
- 11 Why may the term "compound farming" be confusing?
- 12 In compound farming, what features of gardens show the imitation of the natural forest?
- 13 Why are compound farms not static?
- 14 In what sense does alley farming retain the basic features of traditional fallow systems?
- 15 What are the applications of strips of perennial vegetation?

Sustainable agroforestry systems for the tropics: concepts and examples

- 1 Concept of agroforestry
- 2 Classification of agroforestry systems
- 3 Tree and non-tree components - interactions
- 4 Taungya
- 5 Compound farming
- 6 Alley cropping and farming systems
- 7 Strips of perennial vegetation
- 8 Bibliography
- 9 Suggestions for trainers

Abstract. Integration of woody species with annual crops in agroforestry (AF) systems can enhance sustainability of production systems in the humid and subhumid tropics under low-input conditions. Agroforestry has short and long-term protective and socio-economic benefits. The various agroforestry systems can be classified based on the main component of the systems, their structural arrangements, and based also on their functional attributes and socioeconomic scale of management and input use. Stable indigenous and prototype agroforestry systems suitable for humid and subhumid regions are available. However, they need wider testing and use.

1 Concept of agroforestry

Intercropping woody species with annual crops, known as agroforestry (AF), is an old practice. Trees and shrubs are important in the traditional farming systems of the tropics, where woody species form a major component of the bush fallow system and are also widely grown in cropped land. Trees and shrubs benefit the farmer in three main areas:

- direct agricultural benefits (plant stakes, mulching materials, green manure, animal fodder and so on);
- environmental benefits (shade, soil erosion control, nutrient recycling and so on);
- socioeconomic benefits (saleable commodities like fruits, vegetables, nuts, wine, building materials, craft materials and so on).

In agroforestry land use systems, trees and woody shrubs grow together with agricultural crops and/or pasture and livestock. An economic and ecological interaction exists between the tree and non-tree components of the system.

The distribution of land between trees/shrubs and agricultural crops/livestock/pasture may be:

- spatial: land zoned for tree and non-tree components;
- temporal: land used at different times for tree and non-tree components in sequence.

2 Classification of agroforestry systems

Three classes of agroforestry systems are:

- agrosilvicultural: crops and woody perennials,
- silvopastoral: pasture/animals and woody perennials;
- agrosilvopastoral: crops, pasture/animals and woody perennials.

Agrosilvicultural systems. Improved shifting cultivation system; alley cropping (hedgerow intercropping); multistorey cropping; shade trees for plantation crops; mixture of plantation crops; taungya; shelterbelts.

Silvopastoral systems. Fodder banks (multipurpose, leguminous fodder trees and shrubs grown on or around farmlands); living fences of fodder hedges; trees and shrubs on pastures; integrated production of animal and wood products.

Agrosilvopastoral systems. Tree-livestock-crop mixtures around the homestead (compound farming); alley farming, multipurpose trees and hedgerows for browse, green manure, soil conservation; integrated production of trees, pasture and livestock.

In addition to the classification explained above, agroforestry systems could also be classified according to the spatial and temporal distribution of the components (crops, woody perennials, livestock).

Spatial distribution of plant components may result in:

- mixed and dense stands as observed in compound farms;
- mixed stands of trees and crops or pasture as commonly observed in farmers' plots.

The intercropped species can be grown in zones or strips of varying widths.

Spatial or zonal agroforestry varies from microzonal (such as alternate rows of plant components) to macrozonal arrangements (Figures 1-4). An extreme form of the zonal arrangement is the boundary planting of trees on edges of plots for fruits, fodder, fuelwood, fencing, soil protection and windbreak.

Temporal distribution of plants in agroforestry can also take various forms. An extreme example of temporal agroforestry is the shifting cultivation cycle with a separate short cropping cycle and a long fallow cycle or relay cropping of trees with crops.

Still another way to classify agroforestry systems is by productivity and sustainability. This classification takes into account the service role of agroforestry (soil erosion control, shelter belts and so on) in the sustainability of production.

It is also possible to classify agroforestry systems by socioeconomic criteria such as scale of production, level of technology, input, and management.

Three socioeconomic agroforestry systems are:

- Commercial agroforestry systems aim at the production of a saleable output (for example, commercial tree plantations with underplanting of food crops).
- Intermediate agroforestry systems fall between commercial and subsistence scales of production and management.

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- Subsistence agroforestry systems are directed toward satisfying basic needs, and are managed mostly by the owner/occupant and his family. Cash crops, including sale of produce surplus are only supplementary.

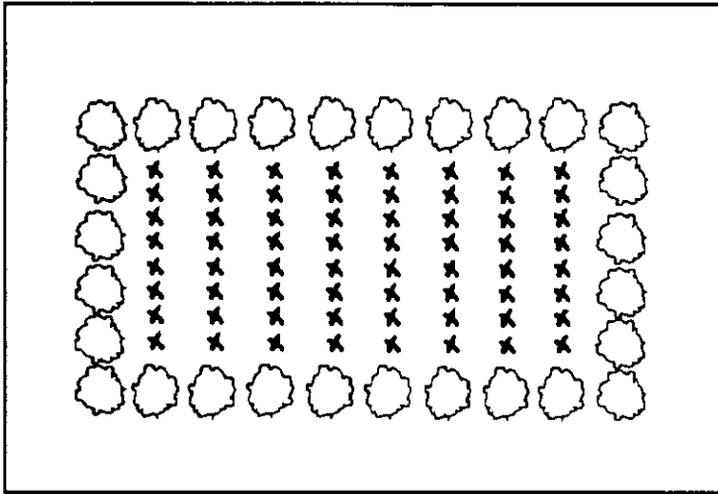
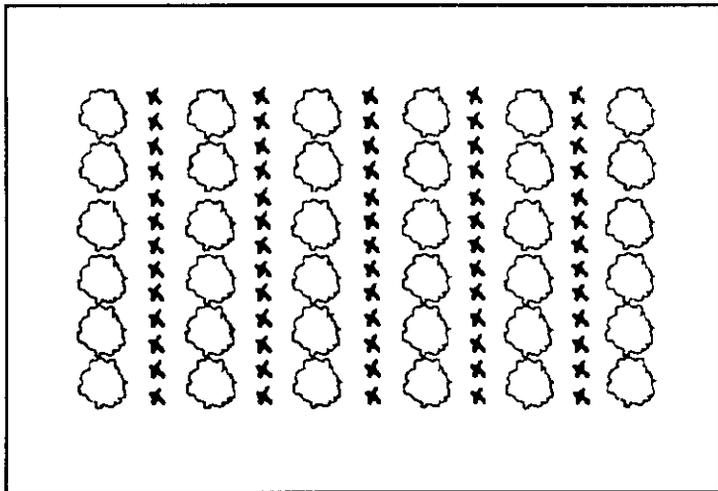


Figure 1. Trees along borders of fields.

Figure 2. Alternate rows of plant components.



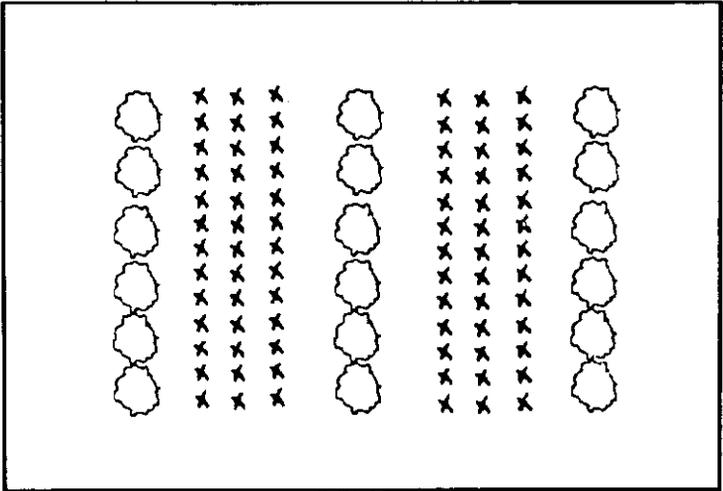
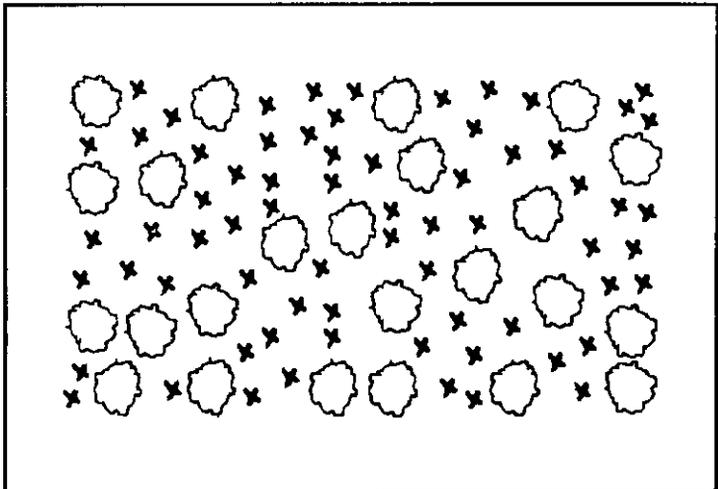


Figure 3. Alternate strips or alley cropping.

Figure 4. Random mixture of plant components.

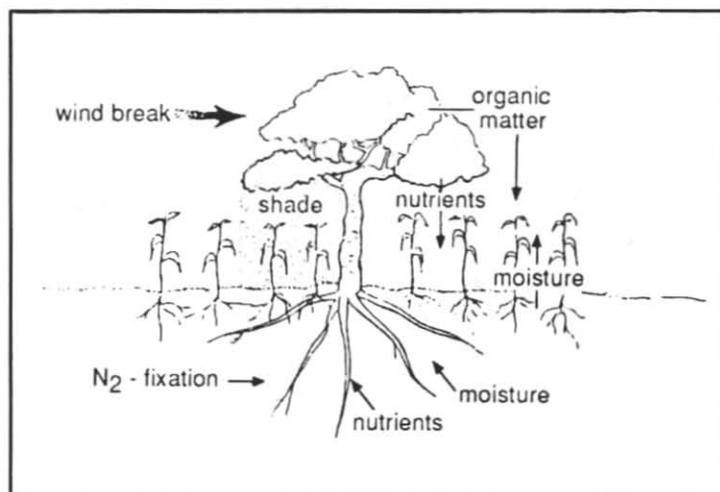


3 Tree and non-tree components – Interactions

Various interactions, taking place between tree and non-tree components through the soil or microclimate, may have favorable or adverse effects (Figures 5-7).

Shading. Shading of the crop by the tree may be adverse, neutral or favorable, (for example, for cocoa) to crop growth. Shade is always favorable to livestock performance in the tropics.

Figure 5. Interactions in agrosylvicultural systems (Young 1988).



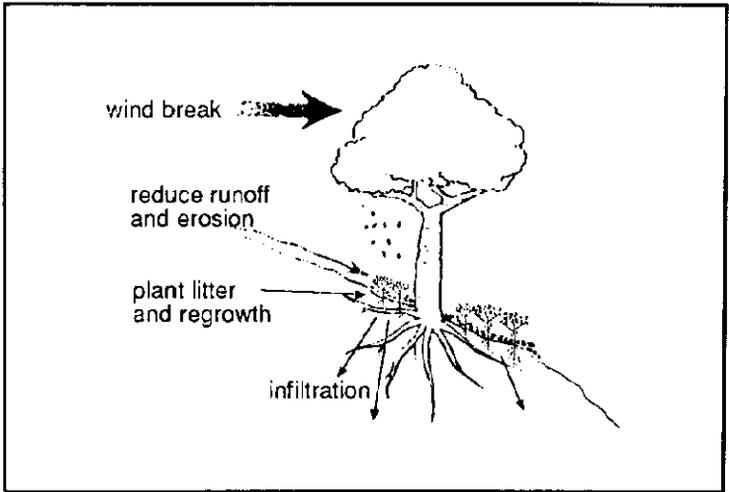
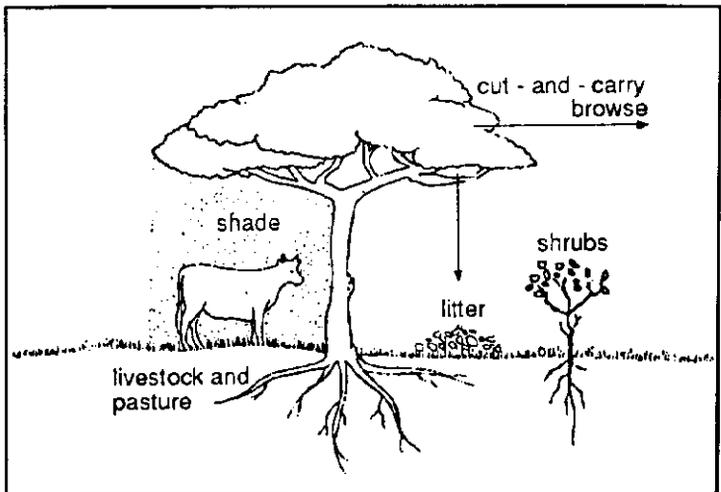


Figure 6. Soil and water conservation.

Figure 7. Silvopastoral system.



Provision of organic matter and nutrients. Trees normally have beneficial effects on soil fertility (as indicated by forest and natural fallows). Trees:

- fix nitrogen;
- increase organic matter from leaf litter and root residues;
- bring up nutrients released by weathering in lower soil horizons;
- trap and recycle nutrients that would otherwise have been lost by leaching, thereby making the plant-soil system more closed.

Effect on microclimate and soil moisture. Through the microclimatic effects of shading and windbreaks, trees can conserve soil moisture; but their roots may also deprive crops of moisture.

Effect on soil conservation. Trees alone do not normally protect against soil erosion, except closely-planted shrub hedges and tree litter. Trees planted on contour strips can stabilize grass strips, bunds, terraces, and at the same time use them productively. Windbreaks can control wind erosion.

Various agroforestry systems are used in the African tropics. Some examples are described in the following sections:

- | | |
|--------------------------------------|-----------|
| • Taungya | Section 4 |
| • Compound farming | Section 5 |
| • Alley cropping and farming systems | Section 6 |
| • Strips of perennial vegetation | Section 7 |

4 Taungya

The taungya system is a temporal agroforestry system which combines production of forestry tree crops and agricultural crops on forest lands. First used in Myonmar, it has been practised for a long time in various parts of the tropics. The taungya system is found in areas where forestry departments are establishing tree plantations.

Food crop production takes place during the period between land clearing and the plantation establishment phase. The system, though hailed as a successful means of combining food and forest production, is often unattractive to farmers. The main objective of taungya is wood production, not food. It persists in areas with high population pressure, where there is adequate government support.

5 Compound farming

Compound farming is another type of stable agroforestry system. The compound farm is an important component of traditional farming systems in tropical Africa. An example is the chagga/home garden of northern Tanzania, where subsistence crops, tree crops, and sometimes cash crops are grown mainly around the homestead.

Other terms used for compound farming are:

- compound farm,
- home garden,
- village-forest garden,
- kitchen garden,
- household garden.

The use of the term "compound farm", unless properly defined, may be confusing. There is no clear standard definition of a compound farm. Michon (1983), gives the following definition of an Indonesian home garden or *Pekarangan*:

"A clean and carefully tended production system just surrounding the house; often with small acreage (one tenth of a hectare), fenced and planted with various plants from herbaceous vegetable species to medium size trees up to 20 m high."

Niñez (1987) defines a household garden as:

"A small-scale production system supplying plant and animal for domestic consumption and utilitarian items either not obtainable, affordable, or readily available through retail markets, field cultivation, hunting, gathering, fishing, and wage earning."

Household gardens tend to be located close to dwellings for security, convenience, and special care. They occupy land marginal to field production and marginal labor to major household economic activities. Featuring ecologically adapted and complementary species, household gardens are marked by low capital input and simple technology."

Criteria for the delineation of the boundaries of a compound farm or home garden do not exist yet. It is difficult to differentiate the home garden or compound farm from the associated fields.

Soemarwoto (1987) describes Indonesian home gardens as "an integrated agro-ecosystem" or "an integrated system of man-plant-animal", a system with a high level of cycling and recycling of matter fueled by solar energy.

Michon (1983) also considered that the Indonesian village-forest gardens, had reached "a highly elaborate stage in the limitation of natural forest ecosystem" with "a noticeable degree of harmonization with the natural environment".

Several features of the gardens show the imitation of the natural forest:

- diversity of cultivated plant species,
- multi-storied vegetation structure,
- cycling and recycling of matter, resulting in maintenance of soil fertility.

These features contribute in several ways to the stability and sustainability of the agro-ecosystem of compound farming.

Compound farms are not static but change with new opportunities and socioeconomic conditions. With increasing population pressure, more land receive intensive cultivation. Population pressure appears to have a profound effect on the stability of compound farms. Compound farms in more densely populated areas of southeastern Nigeria are less structured and contain more food crops than woody perennials compared with compound farms of southeast Asia.

Although compound farming is commonly practised in the humid zone of Africa, little detailed information is available about these complex systems, particularly on the factors that contribute to their yield and environmental stability.

6 Alley cropping and farming systems

Recent research clearly indicates the importance of soil organic matter and other biotic factors in maintaining the productivity of fragile low-activity clay soils, which cover large areas of the humid and sub-humid zones of sub-Saharan Africa.

To deal with the unique problems of managing these soils, scientists at the International Institute of Tropical Agriculture (IITA) in the 1970s began to use woody species in the crop production system. This led to the development of the alley cropping system.

In alley cropping, food crops, preferably legumes spaced 4-6 cm apart, are grown in alleys formed by hedgerows of trees and shrubs. The hedgerows are cut back at planting and periodically pruned during cropping to prevent shading and to reduce competition with the associated food crops. Root pruning is recommended during early stages of hedgerow establishment. The hedgerows are allowed to grow freely to cover the land when there are no crops.

The alley cropping system is an improved bush fallow system. It still retains the basic features of the traditional fallow system, integrating "the art and wisdom of traditional farmers" with "the efficiency of current science".

One major advantage of alley cropping is that cropping and fallow phases can take place concurrently on the same land. This allows the farmer to crop the land for an extended period without a fallow period. Although alley cropping was designed for small-scale farmers, it is adaptable to mechanized farming with appropriate machineries.

The International Livestock Research Institute (ILRI), has extended the concept of alley cropping to include livestock by using a portion of the hedgerow foliage for animal feed.

On non-acid soils, hedgerows of fast growing trees and shrubs, particularly leguminous species such as *Leucaena leucocephala* and *Gliricidia sepium*, do well and can provide green manure and mulch to crops grown between the hedgerows. This green manure/mulch contributes significantly to:

- nutrient recycling,
- nitrogen supply,
- soil conservation,
- weed suppression,
- maintenance of soil productivity.

In addition, trees and shrubs may provide fuel, staking materials and livestock feed.

L. leucocephala and *G. sepium* used as manure/mulch benefit soil fertility in three ways:

- contribution of nitrogen to soil,
- improvement of physical conditions of soil,
- improvement of soil moisture retention.

In a long-term trial conducted on non-acid soil in southern Nigeria, high maize yield was obtained with or without nitrogen application when mulched with *L. leucocephala* prunings.

Some progress has also been made in adapting the technology to acid and unfertile soils. The main problem is selecting suitable woody species that will grow well in acid soils with poor nutrient supply.

7 .Strips of perennial vegetation

The establishment of strips of perennial vegetation between bands of crops is appropriate throughout West Africa, from the humid coastal areas well into the drier parts of the Sahel. Whether in form of 15 m tall windbreaks every 150 m, or 0.25 m tall hedgerows every 4 m, strips of perennial vegetation are perhaps most unobtrusive among the various agroforestry prototypes proposed for introduction in the region.

Ultimate objectives vary widely (for example, maintenance of soil fertility, protection from erosive winds), as do end uses of products of the perennial vegetation (for example, prunings for mulch, pollarded poles). The interactive effects between crops and trees need consideration when designing such systems for a particular agroclimatic environment.

Although several studies in the African semi-arid tropics have reported increased crop yields between windbreaks, the most famous in the Sahel is the CARE study of the Majjia Valley of central Niger. CARE began planting neem windbreaks (*Azadirachta indica*) in 1974. Now, about 400 km of windbreak protect 3000 ha of millet and sorghum cropland.

Bognetteau-Verlinden (1980) conducted the first studies on the windbreak five years after planting, when the trees were 7 m tall. More recent studies have been carried out by the Texas A & M Tropsoils Project on 10-year-old trees about 10 m in height. In both studies, yields were 23 % greater (on a gross area basis) between the windbreaks than they were outside the windbreaks.

Tree windbreaks will no doubt prove to be an effective technology suitable for wide extension in the Sahel. However, caution should be taken in extending results of studies like CARE's to other sites.

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9 Suggestions for trainers

If you use this Research Guide in training ...

Generally:

- Distribute handouts (including this Research Guide) to trainees one or several days before your presentation, or distribute them at the end of the presentation.
- Do not distribute handouts at the beginning of a presentation, otherwise trainees will read instead of listen to you.
- Ask trainees not to take notes, but to pay full attention to the training activity. Assure them that your handouts (and this Research Guide) contain all relevant information.
- Keep your training activities practical. Reduce theory to the minimum that is necessary to understand the practical exercises.
- Use the questions on page 4 (or a selection of questions) for examinations (quizzes, periodical tests, and so on). Allow consultation of handouts and books during examinations.
- Promote interaction of trainees. Allow questions, but do not deviate from the subject.
- Respect the time allotted.

Specifically:

- Discuss with trainees about knowledge and experiences with agroforestry systems (10 minutes).
- Present and discuss the content of this Research Guide, considering the study materials listed on page 3 (45 minutes).
- Discuss examples of agroforestry systems with the help of slides and overhead transparencies produced from the illustrations of this Research Guide.

You may photocopy the illustrations of the Research Guide on transparencies for projection with an overhead projector.

- Conduct the practicals suggested on page 3 in groups (3-4 trainees per group; 2 hours). Make sure that each trainee has the opportunity to practice. Have resource persons available for each group and practical.
- Visit examples of agroforestry systems in your area ($\frac{1}{2}$ day). Ask participants to talk (in small groups) with farmers about farmers' experiences (Rhoades 1996). Summarize their experiences in a discussion at the end of the visit.



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