Chapter 8

# Improved Cropping Practices

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# Chapter 8
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## INTERCROPPING[1]

### Summary

Intercropping, the growing of two or more crop species or varieties simultaneously in the same field, is the predominant form of agriculture throughout Africa. In West Africa, for example, 80 percent of the agricultural land is intercropped (12,47).

Intercropping is such a widespread practice among resource-poor farmers because of its numerous benefits. Intercropping:

- reduces risk of crop failure and improves production stability;
- increases yields per unit of land by more efficiently using natural resources;
- increases returns to labor and spreads labor requirements, thereby reducing labor bottlenecks;
- improves control of diseases, pests, and weeds; and
- reduces soil erosion and water runoff (7,13,15,35).

Because intercropping is a widespread, indigenous practice, it is unlike many unfamiliar technologies that are difficult to transfer from the research station to the farmer. Introduced improvements that build on this traditional practice are more easily accepted by farmers. However, despite its importance and prevalence among African farmers, intercropping has received relatively little research attention (12). This is partly because research objectives are more easily identifiable for single crops, because of a historical focus on non-food cash crops (e.g., cotton) which may be less suitable to intercropping, and partly because research decisions largely have been made by Western-trained scientists whose temperate-region experience has favored monocropping. Problems associated with monocropping, particularly in tropical agriculture, and a growing appreciation of the merits of intercropping, is leading to a reevaluation of conventional emphasis on monocrop research (4,40).

This reevaluation has led to a recent increase in intercropping research (4,13). This shift, although still small, has been motivated by the realization that in low-resource agriculture crop diversity is valuable, stability of production important, and optimum use of scarce resources necessary. The potential for meeting these objectives often is greater with intercropping than monocropping, thus arguing for increased funding and a continued commitment.

Development assistance can best support intercropping by: 1) not pressuring farmers to abandon the practice (e.g., currently agricultural credit and inputs may be supplied only for monocropping); 2) ensuring that additional research on agricultural technologies, such as fertilizers, is appropriate for intercrop situations; and 3) directing increased basic research to the practice itself (e.g., conducting research on ways to minimize competition between component crops). Intercropping could be improved significantly if it received the share of scientific research attention that it warrants based on its importance in African agriculture.

The most immediate gains can be achieved through integrating existing technology into intercrop systems, including new varieties, fertilizer, pest and disease management, animal traction, and even partial mechanization. Further gains may also be provided through research and technology developed specifically for intercrop systems, but these probably will evolve over a longer period.

[1]The material on intercropping is based primarily on two OTA contractor reports prepared by David J. Andrews and Charles A. Francis (app A).

## Various Types of Intercropping

Intercropping, as discussed in this chapter, is the growing of two or more crop species or varieties simultaneously in the same field. (This can include agroforestry—the use of trees in intercrops, which is discussed in the following section). Various types of intercropping systems exist:

- Mixed intercropping: a variety of crops are planted with no distinct row arrangement.
- Row *intercropping:* crops are planted in rows, either adjacent rows of different crops, or mixed within the row.
- *Strip cropping:* several rows of a crop are grown together forming a strip. Strips, each having a different crop or variety, are wide enough to permit independent cultivation, but close enough to interact agronomically.
- *Relay intercropping:* growing two or more crops simultaneously during part of the life cycle of each. A second crop is planted after the first crop has reached its reproductive stage of growth but before it is ready for harvest. If crops are planted successively in the same year, but with no significant overlap in time, the system is called sequential cropping (7).

Food and export crops are grown as intercrops throughout all agroecological zones of Africa (table 8-1). National statistics rarely identify the production system, but studies clearly indicate that intercropping accounts for the majority of Africa's agricultural production (table 8-2).

In arid areas, two or three species commonly are mixed, but in wetter zones the systems become increasingly more diverse (47). The diversity of crops produced in the humid lowlands is illustrated in Zaire, where farmers sometimes grow 80 varieties of 30 different species. In one study, this included 27 varieties of banana and plantain and 22 varieties of yams and other root crops (13). In another example, Nigerian farmers designed a system of mounds which allowed them to plant crops with differing soil moisture requirements and thus greatly diversify their production (figure 8-1).

**Table 8-1.—Examples of Common Intercrops in the Agroecological Zones in Sub-Saharan Africa**

| Zone | Crop mix |
|---|---|
| Arid and semiarid | millet/sorghum<br>millet or sorghum/cowpea |
| Subhumid uplands | maize or sorghum/beans or cowpea<br>rice/cassava |
| Humid lowlands | root crops/maize/food legumes/perennial crops |
| Tropical and subtropical highlands | maize or sorghum/beans or other food legumes<br>bananas/coffee |

SOURCES: David J. Andrews, "Intercropping in Low-Resource Agriculture in Africa," contractor report prepared for the Office of Technology Assessment (Springfield, VA: National Technical Information Service, December 1987);
B.N. Okigbo and D.J. Greenland, "Intercropping Systems in Tropical Africa," *Multiple Cropping,* R.I. Papendick, P.A. Sanchez, and G.B. Triplett (ads.), American Society of Agronomy Publi. No 27 (Madison, WI: American Society of Agronomy, 1976), pp. 63-101;
D.R. Harris, "Traditional Systems of Plant Food Production and the Origins of Agriculture in West Africa," *Origins of African Plant Domestication,* J.R. Harlan, J.M.J. De Wet, and A.B.L. Stemler (eds.) (Mouton, The Hague, 1976);
Charles Francis (cd.), *Multiple Cropping Systems (New* York, NY: Macmillan Publishing Co., 1966);
K.G. Steiner, *Intercropping* in *Tropical Smallholder Agriculture with Special Reference to West Africa,* Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ), Bonn, West Germany, 1982.

## Benefits of Intercropping

### Reduces Risk and Improves Production Stability

A principal reason why farmers have adopted intercropping is that it reduces risk, i.e., it increases the reliability or stability of production (1,16,30,36,41). Millet, for example, is less susceptible to drought than sorghum, with which it is often intercropped. The two crops also differ in their susceptibility to diseases, pests, and weeds. Thus, growing both increases the likelihood that there will be some harvest regardless of the damage of that season's pests or weather. If one crop dies, the remaining crop can help compensate for the loss by using some of the water and other resources that become available. Moreover, since different species usually are not planted at the same time, the farmer can compensate for the failure of the first crop by increasing the density of subsequent crops.

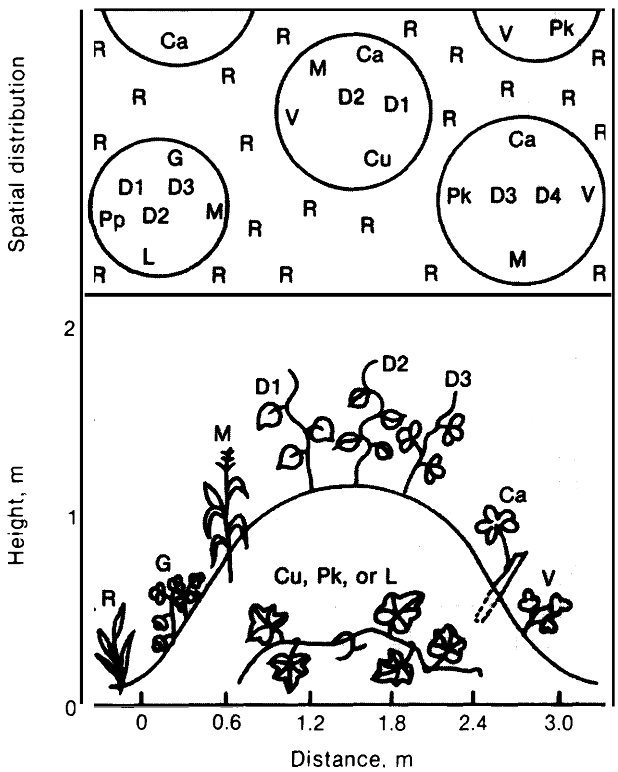
**Table 8-2.—intercropping of Cereals in Africa (percent intercropped)**

| Cereal | Ghana | Ivory Coast | Nigeria | Sierra Leone | Uganda |
|---|---|---|---|---|---|
| Maize . . . . . . . . . . . . . . . . . . . . . . . . . . . . | 84 | 80 | 76 | NA | 84 |
| Millet . . . . . . . . . . . . . . . . . . . . . . . . . . . . | 87 | 81 | 90 | NA | NA |
| Rice . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | 29 | 75 | 58 | 91 | NA |
| Sorghum . . . . . . . . . . . . . . . . . . . . . . . . . | 95 | 72 | 80 | NA | 46 |

NA=not available

SOURCES: David J. Andrews, "Intercropping in Low-Resource Agriculture in Africa:' contractor report prepared for the Office of Technology Assessment (Springfield, VA: National Technical Information Service, December 1967).
M. Rae, "Cereals in Multiple Cropping, " *Mu/tip/e Cropping Systems,* Charles Francis, (cd.) (New York, NY: Collier Macmillan, 1966).
D.S.C. Spencer, "Rice Production and Marketing in Sierre Leone," I.M. Ofori (cd,) Factors *of Agricultural Growth in* West *Africa,* Procedure of Internal Confer. ence, Accra, Ghana, 1973.

**Figure 8-1.—Growing Thirteen Crop Species on and Between Raised Mounds in Nigeria**




Ca—Cassava
G —Groundnut
L—Lagenaria
Pp—Pigeon pea
V—Voandzeia
Cu—Melon
M—Maize
Pk—Pumpkin
R—Rice
D1—Dioscorea rotundata
D2—D. alata
D3—D. bulbifera
D4—D. cayenensis

SOURCE B. Okigbo and C. Greenland, "Intercropping Systems in Tropical Agriculture," Multiple *Cropping,* R. Papendick, P. Sanchez, and G. Triplett (ads.), American Society of Agronomy Special Publication Number 27 (Madison, Wisconsin: American Society of Agronomy, 1976) pp. 63-101

## Increases Yields Per Unit of Land by More Efficiently Using Natural Resources

Intercropping also provides yield benefits over monocropping, usually measured as nutritional or economic gains, that can average 15 to 20 percent or in some cases more (51). One explanation for increased yields is that species and varieties differ to some extent in the resources that they need and how they obtain them (23). Differences among crops in their shoot and root geometry can allow mixtures of crops to exploit more of their environment than is possible in monocropping (48).

Competition between crops in the same field can have a negative impact on production but this problem is reduced when the selected plants differ in their life cycles and critical growth periods. For example, pearl millet and a traditional cowpea variety are often intercropped in the West African Sahel. Millet is planted with the first rains, and cowpeas planted only when the millet is well established. As a result, cowpeas offer little competition to the millet. The cowpeas are at first suppressed by the millet but this is of little consequence since cowpeas can only begin to flower after the rains end. By then, the millet is ready to harvest. The cowpeas continue to grow and flower after millet harvest so long as stored soil moisture is available. If rainfall is below average, cowpea pod yields will be low, but there will be hay for animals. In good rainfall years, the system has the flexibility to use the extra moisture efficiently with repeated harvests of cowpeas. Thus, the total growing season, whether short or long, is used more fully.

Intercrops containing legumes can help restore nitrogen to the soil. unless the legume is earlier maturing than the cereal, there is no immediate transfer of fixed nitrogen from the legume to the cereal, but there is the beneficial residual effect of the legume on the next year's cereal crop. Legumes grown alone would also be able to add nitrogen to the soil, but the higher risk of increased damage by pests and disease can prohibit resource-poor farmers from raising them as monocrops.

### Increases Returns to Labor and Spreads Labor Requirememts, Thereby Reducing Labor Bottlenecks

Another important advantage of intercropping is that it reduces labor bottlenecks and gives a higher return on the labor invested (35). Labor requirements are spread out because planting, weeding, and harvesting schedules are different for each crop.

Furthermore, intercropping can reduce weed problems (6,13,20). In Nigeria, for example, a native legume has been intercropped with maize to suppress weeds. Since farmers in this part of Africa devote nearly half of their time to weeding and the amount of land a family can cultivate is normally controlled by how much family members can weed, intercropping can be very advantageous (3,21,35).

### Improves Control of Diseases and Insects

Intercropped crops typically suffer less insect and disease loss than monocropped ones (5). Pest populations remain lower and they inflict less damage in intercropped systems (9, 43) (table 8-3). One reason for this is that the diverse crop environment provides shelter and necessary food sources for predators and parasites of the pest insects (42). In addition, pests and diseases damaging one crop may not be able to survive on other crops and intercropping decreases the number of plants on which they can live and makes those plants harder to find.

### Reduces Erosion and Runoff

Intercrops can reduce water runoff and soil erosion where they provide more continuous coverage of the soil than occurs in monocropping. Also, the deeper layers of vegetation can reduce the impact of heavy rains and allow more water to infiltrate the soil (28,45). In one study, intercropping maize in cassava on a 15 percent slope reduced runoff and soil erosion relative to cassava alone by 38 percent (2). Wind-induced soil erosion and damage also can be reduced with intercrops. For example, on sandy soils in western Sudan sesame is planted with sorghum or millet when the cereals are large enough to shield the sesame seedlings from abrasion by windborne sand.

## High Adoption Potential of Improvements

The long history and widespread acceptance of intercropping by resource-poor farmers makes it an excellent candidate for development assistance. Unlike many other technologies, the potential of intercropping can be realized without many of the typical constraints involved in transferring technology from the research station to the farmer. Perhaps the strongest argument for improving existing intercropping practices rather than trying to substitute monocrops is that all interventions—e.g., new varieties, fertilizer, pest and disease management, animal traction—have a good chance of success when they build on an already familiar base (17).

## Research Needs and Constraints for Intercropping

Despite increased attention to intercropping over the last 20 years, it remains inadequately researched. Currently, only an estimated 10 percent of AID's research and extension efforts in agriculture involve intercropping (12). The knowledge base, research investment, and extension efforts for intercropping are insufficient given its prevalence and importance to food production as compared to monocropping.

The low level of attention and funding derives from the negative attitudes concerning in-

**Table 8-3.—Possible Effects of Intercropping on Insect Pest Populations**

| Factor | Explanation | Example |
|---|---|---|
| ***Interference with host-seeking behavior:*** | | |
| Camouflage | A host plant may be protected from insect pests by the physical presence of other overlapping plants. | Bean seedlings camouflaged by standing rice stubble helps limit damage from beanflies. |
| Crop background | Certain pests prefer a crop background of a particular color and/or texture. | Aphids, flea beetle, and *Pieris* rapae are more attracted to crops, (e. g., cabbage) with a background of bare soil than to plants with a weedy background. |
| Masking or dilution of attractant stimuli | Presence of nonhost plants can mask or dilute the attractant stimuli of host plants leading to a breakdown of orientation, feeding, and reproduction processes. | Phyllotreta cruciferae (flea beetle) can be diverted from collards to intercropped wild mustard. |
| Repellent chemical stimuli | Aromatic odors of certain plants can disrupt host-finding behavior. | Grass borders repel leafhoppers in beans. |
| ***Interference with population development and survival:*** | | |
| Mechanical barriers | Companion crops can block the dispersal of pests across the intercrop. Restricted dispersal can also result from mixing resistant and susceptible cultivars of one crop. | |
| Lack of arrestant stimuli | The presence of different host and nonhost plants in a field may affect colonization by pests. If a pest descends on a nonhost it may leave the plot more quickly than if it descends on a host plant. | |
| Microclimatic influences | In an intercropping system favorable aspects of microclimate conditions are highly fractioned, therefore insects may experience difficulty in locating and remaining in suitable microhabitats. Shade derived from denser canopies may affect feeding of certain insects and/or increase relative humidity which may favor entomophagous fungi which feed on pests. | |
| Biotic influences | Crop mixtures may enhance natural enemy complexes leading to a greater abundance of natural enemies of pests in intercropping than in monocropping. | |

**SOURCE Compiled by M. Altieri and M Liebmann, "Insect, Weed, and Plant Disease Management in Multiple Cropping Systems,"** *Multiple Cropping Systems,* **Charles Francis (cd.) (New York, NY: Macmillan Publishing Co., 1986), p. 186. Data from: V. Hasse and J.A. Litsinger, "The Influence of Vegetational Diversity on Host Finding and Larval Survivorship of the Asian Corn Borer,** *Ostrinia* **furnacalis," IRRI Saturday Seminar, Entomology Department, International Rice Research Institute (IRRI), Los Banes Philippines, 1981**

tercropping and the difficulty in researching it. Negative attitudes include the belief that intercropping is a primitive technology and the notion that intercropping can only absorb technical changes specifically researched for it. Such attitudes are inconsistent with research results however. A number of areas exist where intercropping can benefit from research designed for monocrops. For example, the responses of cereals to low levels of fertilizers are similar whether they are monocropped or intercropped. Row intercrops can also make use of advances in monocropping in such realms as new plant varieties, fertilizer and pesticide applications, and animal traction.

Research on intercropping can encounter unique difficulties. In some cases this is simply a function of having been neglected. Intercropping is a relatively new research area and, therefore, a smaller knowledge base exists. In other cases it is more a function of understanding the complexity of intercropping and the multiple interactions of crop species. Addressing this complexity is difficult because the majority of plant interactions probably takes place below ground. The complexity is further increased as specific types of intercrops are often adjusted to meet social needs (e.g., labor constraints), therefore, efforts to understand intercropping as an agricultural system must also draw on social science research.

As long as the majority of farms remain small, production per unit of land and labor will remain important and will favor the retention and improvement of intercropping. Specific intercrop combinations (though not the practice of intercropping itself) are relatively site-specific. Thus, improvements must necessarily come from research at the farm level. Areas for site-specific research include: determining optimum plant densities, crop combinations, and relative planting dates, and the best means to provide plant nutrition through use of organic and inorganic fertilizer.

Notwithstanding the need to emphasize local research, the following general research areas are also important to the improvement of intercropping.

- *Testing improved varieties for intercropping:* Although the best approach would be to breed varieties specifically for an intercrop situation, this is a long-term solution (12). For now, improvements can be achieved by testing and selecting for the best combinations from the existing range of varieties (52).
- *Incorporating animal traction with intercropping:* This is important for cultivation, weeding, transportation, and manure production. It will lead to an emphasis on row cropping. Other problems associated with the incorporation of animals into farming systems also will have to be resolved (see ch. 11).
- *Basic research:* Apart from on-farm research designed to give results for quick use by extension services, a need exists to understand more clearly how intercropping works—what is the nature of competition between species over the season, and what are the long-term environmental effects. An important research need is to understand competition for soil moisture and plant nutrients and resultant soil changes. Support could be given to institutions capable of using advanced research technologies such as neutron probes and isotope-labeled fertilizers needed to study below-ground interactions (7).

## AGROFORESTRY[2]

### Summary

Agroforestry is the term used for agricultural systems in which trees or shrubs are deliberately grown with crops and/or livestock. Although the term agroforestry has been coined only recently, agroforestry techniques have been practiced for generations. Indeed, trees and shrubs are an integral part of most traditional low-resource agricultural systems, and cleared treeless fields, such as those common in the temperate zones, are the exception rather than the rule in Africa (31). Agroforestry includes a wide range of practices:

- ***Dispersed Field Tree Intercropping***: "Farm trees" are grown within and adjacent to crop fields. For example, in semi-arid areas a nitrogen-fixing tree, *Acacia albida*, can double yields of certain crops grown under its canopy and provide valuable browse for livestock. The tree reduces soil erosion and water loss from runoff and evapotranspiration (water loss from evaporation and crop transpiration) and allows more intensive use of the land (32).
- ***Alley Cropping***: A newly developed technique in the humid lowlands allows crops to be planted in the narrow "alleys" between rows of nitrogen-fixing trees or shrubs. Using prunings from these perennials as mulch allows yields of maize to stabilize at 2 tons/ha, three to four times more than maize grown without alley cropping (24). The prunings can also be used for fodder or fuelwood, depending on the farmer's needs.
- ***Windbreaks (or shelterbelts)***: Continuous, uniform rows of trees are planted in crop fields perpendicular to the prevailing winds to reduce wind-induced crop damage, evapotranspiration, and soil erosion. In Niger, windbreaks have increased crop yields by 15 to 23 percent, even accounting for land taken out of crop production to grow the trees (19).
- ***Live Fencing and Other Linear Plantings***: Trees or shrubs are used to form live fences

[2]The material on agroforestry is based primarily on Roy T. Hagen's contractor report (app. A).

and hedgerows to mark field or garden boundaries, to control livestock movement, and to produce fuelwood and building material when they are pruned (53). Also, trees and shrubs can be planted on contour lines on sloping fields as a soil and water conservation practice. Linear plantings commonly are sited along roads, trails, and waterways (18).

In addition to these benefits, which lead to higher and more stable crop yields because of improvements in soil and water use, trees in agroforestry systems supply several products to resource-poor farmers and herders. An important product for livestock production is fodder. The protein-rich prunings can improve animal nutrition, which is considered a major constraint to improving the health of African livestock (see ch. 11), Agroforestry can supply numerous other products that may be consumed directly by a household or sold to generate income (18,53).

Agroforestry's contribution to the food security of resource-poor farmers and herders can be improved substantially. Development assistance for efforts to integrate agriculture, forestry, and livestock will be essential if this is to occur. Agroforestry programs have shown enough success to justify expanding such efforts, Key factors contributing to the potential importance of agroforestry systems are: 1) they fit well into existing African farming systems, 2) they meet numerous needs of resource-poor farmers and herders, and 3) these techniques are less capital-intensive than many other technologies.

## The Role and Nature of Agroforestry

Agroforestry systems can help alleviate three of the most important constraints in African agriculture—low-fertility soils; insufficient, erratic water availability; and lack of animal fodder. Leaves from trees and shrubs, and to a lesser extent branches and roots, increase soil organic matter as they decompose. This organic matter improves soil structure, soil fertility, and soil water-holding capacity. The deep root systems of trees enable them to use nutrients in the deep soil layers. Some of these nutrients have leached down from the topsoil, a problem that is especially severe in degraded soils. The recycling mechanism of trees and shrubs brings these nutrients back to the soil surface where they again can become available to shallow-rooted annual crops (34,5 o),

Trees and shrubs used in windbreaks can increase water availability y by reducing wind and thereby reducing evapotranspiration. Also, their vegetative canopies reduce the impact of heavy rainfalls, cut run-off, and thus increase infiltration of water into the soil. Also, more water remains available for plant growth because the shade provided by trees lowers soil temperature, which in turn acts to slow decomposition of organic matter (32).

By improving soils and increasing water availability, agroforestry systems contribute to higher and more stable yields of crops and forage. Tree and shrub prunings also contribute to livestock nutrition. Since poor nutrition is considered a major constraint to improving animal health, the protein-rich browse possible from agroforestry is an important consideration in promoting its use.

Agroforestry systems provide many of the products resource-poor farmers and herders formerly obtained from forests: firewood and charcoal; posts, poles, and construction wood; fruits, nuts and edible leaves; fiber for mats, baskets, and ropes; and plant materials for medicines, dyes, and cosmetics (18,53). These goods may either be used by the household or sold. These benefits of agroforestry will continue to grow in importance as remaining forested areas of Africa continue to succumb to human population pressures.

### Dispersed Field-Tree Intercropping

Dispersed field-tree intercropping is the second most widely practiced general agroforestry technique in Africa, (Traditional shifting agriculture that relies on trees to restore soil fertility, is the most common,) Numerous vari-

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ations exist on the mixture of species and the patterns in which they are planted.

The practice is used extensively by resource-poor farmers in semiarid regions, particularly in West Africa, "farm trees" are grown within and adjacent to crop fields. When natural regeneration is relied on, the trees appear to have a random arrangement. When clearing the bush for a new field, certain species are preserved. These most commonly are food-producing trees (fruits, nuts, leaves, etc.) such as the shea tree *(Butyrospermum parkii)* or the locust bean (*Parkia biglobosa).* Such savanna species, however, commonly do not regenerate well under natural field conditions (18).

*Acacia albida* is a particularly beneficial tree used widely in the semiarid areas of the Sahel. The most unusual feature of this nitrogen-fixing tree is that it loses its leaves during the rainy season, making it possible to raise crops, such as sorghum and millet, directly under the canopy of the tree with little competition for light. Crop yields are much higher under the tree than outside the canopy (table 8-4).

*Acacia albida* also benefits livestock production. Its pods and leaves provide more fodder per unit weight than meadow hay, rice straw, or groundnut tops (11), and *Acacia* fodder is produced during the dry season when annual grasses have disappeared (32). In addition, livestock concentrate near the trees and their manure further enriches the soil (32).

Where the proper balance has existed between *Acacia albida,* crops, and livestock, the system has been able to support several times the average human population for Sahelian West Africa (39). For instance, millet was continuously cropped in Sudan for 15 to 20 years in association with *Acacia albida,* compared to only 3 to 5 years without the tree (32).

Natural regeneration of *Acacia* is erratic and has declined over the past 20 to 30 years because of extended drought and grazing pressures. Few *Acacia albida* still exist in areas recently cleared for farming, but their number is slowly increasing in existing farm fields because some farmers are protecting the seedlings. It may take about 10 years before the new trees have much effect on crop yields, but the benefits last the remaining 70 to 90 years of the trees' lifespan (25). Even on old fields where the tree is common, the tree cover is often far below that which would give optimum yields (18).

The list of useful trees, however, does not end with *Acacia albiba.* For example, one investigation of trees and shrubs in the Sahel identifies some 114 multipurpose species. The use of *Balanites aegyptica* in agrosilvopastoral systems (i.e., that combine crops, trees, and livestock), or *Acacia senegal* in bush fallow systems, provides two more examples of traditional production systems that integrate trees (38). However, a combination of factors is contributing to the decline of many species, including species that have historically provided food during recurrent and critical food-shortage periods, or products for local use and

**Table 8-4.—Grain Yields Under the Crown of *Acacia albida* Compared to Grain Yields Outside the Crown[a] (kilograms per hectare)**

| Grain | Yield without *Acacia albida* | Yield with *Acacia albida*[b] |
|---|---|---|
| Millet . . . . . . . . . . . | 810 | 1,110 |
| Millet . . . . . . . . . . . | 457 | 934 |
| Millet . . . . . . . . . . . | 820 | 1,250 |
| Sorghum . . . . . . . . | 457 | 934 |

aData is from Senegal and Burkina Faso.
bTwenty-five to forty mature trees per hectare.

SOURCE: Michael McGahuey, *Impact of Forestry Initiatives in the Sahel: Effect of Acacia albida on Millet Production in Chad* (Washington, DC: Chemonics International, January 1986).

Photo credit: Mike McGahuey

The millet growing under this *Acacia* tree in Chad is denser, taller, and greener than that in the foreground because *Acacia* increases soil fertility and water availability for the intercropped cereal.

trade (44). Indigenous information on use of these resources is also being lost.

### Alley Cropping

Alley cropping is a modern agroforestry technique developed from well-established traditional practices. Its precursor, the bush fallow system of shifting agriculture, is an indigenous form of agroforestry that has been practiced for centuries. Fields were cropped for several years followed by an extended woody fallow when deep-rooted trees and shrubs played a key role in restoring soil fertility. In the past, with low human population levels and land freely available, this represented an ecologically sound system of subsistence agriculture. Today, however, few areas remain where the population/land balance permits land to be left fallow for the necessary 15 to 30 years to restore fertility.

Scientists at the International Institute of Tropical Agriculture (IITA) incorporated the desirable features of bush fallow into a continuously productive farming system for the humid tropics. Rows of nitrogen-fixing trees or shrubs, such as Leucaena, *Gliricidia,* and *Calliandra,* are planted 2 to 4 meters apart, and the space between is planted in an annual crop like maize. The shrubs are pruned frequently, with the trimmings used as mulch, fodder, or fuelwood. Yields of maize stabilized at about 2 tons/ha after 6 years of continuous alley cropping; without alley cropping, the yield was no more than one-half ton/ha (24). An especially promising shrub for use on waterlogged soils is *Sesbania rostrata,* native to Africa. Rice yields were increased 55 percent with the addition of the Sesbania prunings, comparable to the addition of 120 kg nitrogen/ha (33).

Although experimental results such as these indicate the technical feasibility of alley cropping, farmer acceptance and adoption is in the early stages of evaluation. Alley cropping is more labor-intensive than traditional methods and requires a considerable change in farming practice. Farmer participation in farm trials organized by IITA and the International Livestock Center for Africa has been enthusiastic, however (19). Of particular interest is the evidence of farmer adaptation and experimentation with introduced agroforestry systems, suggesting the ability to tailor systems to variable circumstances and needs (37).

Alley cropping probably will find its greatest acceptance in areas where land scarcity is the most acute, that is, where shifting agriculture is no longer possible. It will require adaptive research for the seasonally humid and highland areas and major modifications before it can be used in the semiarid zone where water competition between trees and crops would be a constraint. Furthermore, none of the species used for alley cropping in the humid zone seem suitable for the non-irrigated semiarid zone, and likely alternatives are not readily apparent. This is especially true for hardy, fast-growing nitrogen-fixers (18).

### Windbreaks (or Shelterbelts)

Windbreaks are uniform rows of trees planted in fields perpendicular to the prevailing winds to reduce evapotranspiration, soil erosion, and wind-induced crop damage. Windbreaks are a virtually unknown practice in traditional low-resource agriculture in Africa, but are receiving some attention among the development agencies. The Majjia Valley Windbreak Project in Niger is one of the most successful projects in the Sahel. The project, begun in 1975 with the assistance of the private voluntary organization CARE, has established about 350 kilometers of windbreaks to protect some 3,000 hectares of rainfed millet and sorghum fields (10). Early evaluations of this project indicate that crop yields had increased 23 percent, while a more recent estimate is that they increased 15 percent. Both estimates take into account the 6 percent of farmland “lost” to trees. The most likely explanation for the differing estimates is that the trees are now larger, depressing crop yields by causing more shading and competing for nutrients (53).

The small average field size and the need to orient the windbreaks perpendicular to prevailing winds makes it impractical for an individual farmer to establish windbreaks. To be successful, a group of farmers, ideally an entire village as was done in the Majjia, must cooperate in the effort so that windbreaks can extend across adjoining fields. Another constraint in windbreak establishment is that they need protection from livestock. Livestock in semiarid regions usually are left to roam freely during the dry season. Windbreaks or other field plantings dispersed over large areas are difficult to protect from grazing. The villagers in the Majjia agreed not to allow grazing during the approximately 3 years required for the tree branches to grow out of the reach of livestock. This was enforced by guardians hired with project funds. Also, rights to the trees can be controversial; ownership of the windbreaks in the Majjia Valley and the distribution of wood products harvested from them are still unresolved 13 years after the project's start (18).

The Majjia Valley project started out in response to a request for assistance from local villages. It began on a small scale working closely with forest service agents and villagers. The project has developed enthusiastic support from villagers who have seen the benefits firsthand. Now 60 farmer-owned, private nurseries exist in the valley and these help respond to requests for assistance from surrounding villages (19). Periodic partial harvesting of the windbreaks could make the participating villages largely self-sufficient for their wood needs (18).

### Live Fencing and Other Linear Plantings

Another agroforestry approach is to use trees or shrubs to form live fences or hedgerows to mark field or garden boundaries and control livestock movement. These also can be pruned to produce fuelwood and building materials (53). Live fencing requires a large number of closely spaced plants and frequent pruning. The use of live fencing varies greatly between regions. In some places it is almost unknown, yet in the Fouta Djalon Highlands in Guinea there is a social caste who make their living establishing live fencing (18).

Live fencing, although labor-intensive to establish, provides a low-cost alternative to metal fencing (27). Fences in the semiarid regions formerly were made with readily available thorn bushes chopped down and arranged where needed. With desertification and increased demands on resources, thornbushes are increasingly in scarce supply. Thus, live fencing could be advantageous, especially around dry-season gardens which must be protected from free-ranging livestock. Unfamiliarity with live fencing techniques seems to be a significant constraint in many areas.

Other linear plantings do not necessarily have to be as densely planted or require as frequent pruning as live fencing. Encouraging the planting of multipurpose trees and shrubs along field margins often is easily achieved because many farmers want to define the limits of their property clearly. Field border plantings may be a first step toward more integrated (e.g., of crops, trees, and livestock) agroforestry techniques. A second step can be planting trees and shrubs on contour lines on sloping fields as a soil and water conservation practice, Linear plantings also commonly are established along roads, trails, and waterways (18).

## Potential for Adoption

Agroforestry offers strong potential because it tends to fit well into existing African farming systems and meets numerous needs of resource-poor farmers and herders. Agroforestry can contribute to improved management of soil and water resources, leading to increased, more stable yields. The multiple benefits—food, fodder, fuelwood, building materials, and income—possible from agroforestry systems also can reduce pressure on natural forest and grazing lands.

Agroforestry techniques are rarely capital-intensive compared to many other technologies, thus encouraging farmer and herder experimentation and adoption. If seedlings are provided by a service or project, the main inputs from the farmer or herder is labor. An important fringe benefit of agroforestry development is that by increasing soil organic matter it enhances effectiveness and reduces potential waste in commercial fertilizer applications. Most tropical soils are characterized by highly

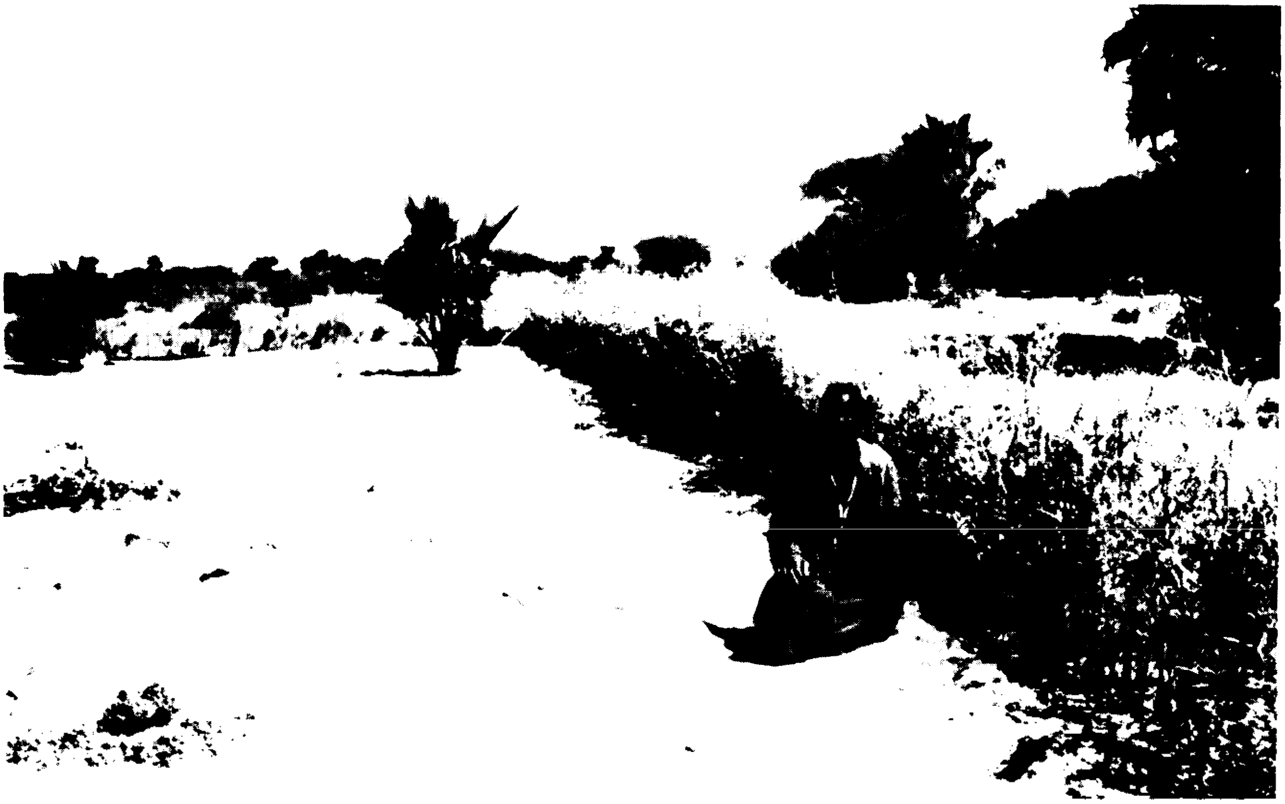

Photo credit: Mike McGahuey

Live fencing protects gardens and prevents the deforestation that arose from cutting thorn bushes for fences.

oxidized, low activity clays that are unable to bind nutrients in a form usable to the plants. The addition of organic matter to the soil improves its ability to retain fertilizers until crops can make use of them.

Newly developed, synthetic, water-absorbing polymers applied to form a water-absorbing layer at the root zone may prove to be instrumental in afforestation efforts, particularly in the arid/semi-arid zone. In experiments conducted in Sudan, the survival period of tree seedlings was increased fivefold when polymers, able to hold 400 times their weight in water, were used in the soil mixture. The present survival rate for tree seedlings in Sudan is no more than 50 percent and in Ethiopia the performance is even worse, with only 15 percent survival recorded among 500 million seedlings. At a cost of 14 to 22 cents per tree, the new technique could be a cost-effective way of improving afforestation efforts (8).

Despite its promise, development assistance agencies have become interested in agroforestry only recently. PVOs, and CARE in particular, have been innovators in agroforestry. CARE has 13 agroforestry projects in 11 African countries (26). Few projects are as much as 10 years old, but these have already made substantial progress toward developing stable, sustainable farming systems. It appears that development agencies have only scratched the surface of agroforestry's potential for improving the lot of the resource-poor agriculturalist in Africa.

## Problems and Approaches

### Integrating Agriculture, Forestry, and Livestock

One of the most serious obstacles to promoting agroforestry as a sustainable land-use system is institutional, The fact that agricultural education and administration typically are pursued along narrow disciplinary lines creates fundamental problems for agroforestry–by definition an integrated production system requiring interdisciplinary research. In simplest terms, the dilemma this creates can be characterized the following way:

> Agroforestry is institutionally considered a sub-division of forestry. Forestry institutions deal with forestry and forest land. The major potential of agroforestry lies in the integration of trees into agricultural and pastoral lands. The development of these lands is the mandate of agricultural institutions. Agricultural institutions are not mandated to deal with agroforesty [29).

Even forestry departments have until recently shown considerable reluctance in promoting agroforestry, Foresters now seem more willing to support agroforestry, realizing that farmers faced with insufficient crop yields will not devote land and energies to tree plantations solely for firewood production. Those few projects such as the Majjia Valley Windbreak Project that have involved tree planting on farmers' fields to increase crop yields have enjoyed much greater success than projects that have just emphasized maximizing wood volume/ha/year.

The agriculture, livestock, and forestry services of most African governments are as strongly separated among disciplines as, and in part because they reflect, their Western country counterparts (53). The need to improve integration of these agricultural activities is particular important in the case of African agriculture. Such institutional changes cannot occur overnight, but increased integration and cooperation among disciplines could be strongly encouraged, among agricultural as well as social sciences. For example, development assistance could ensure that participation by all relevant government services be negotiated in the project planning stage, even though this may make the project administratively more burdensome. Funding could be provided for multidisciplinary agroforestry workshops that include foresters, agronomists, livestock specialists, and social scientists.

The number of schools offering agroforesty courses in developed countries is increasing, but still is small. Probably no more than six universities in the United States offer instruction in agroforestry, usually a single, recently created, course (46). This shortage is paralleled in Africa. Development assistance agencies could support agroforestry courses as part of degree programs in tropical forestry. AID, for example, could provide funding to selected U.S. universities to develop or bolster agroforestry curricula. Support for regional agroforestry schools for the different agroecological zones could also be promoted.

### Obstacles of Land and Tree Tenure

Farmers rarely will plant trees, let alone protect and care for them, if they have no assurance that they will reap the benefits. This makes agroforestry difficult for those farmers who lack secure rights to their land. Few poor farmers actually hold title to the land they cultivate, as central governments generally claim most of the land. In practice, however, most of the farmland is passed down from one generation to another and remains under family control (18).

A large percentage of farmland in some areas is cultivated by families who borrow or lease farmland. The landowner in such cases may forbid tree planting by the tenant if local custom associates tree planting with land tenure rights. Lack of land and tree tenure is especially problematic for women, who could benefit greatly from having an improved, more accessible supply of fuelwood and fodder. Even where land tenure is well defined, land and tree rights may be separate.

Communal farmland has also been the target of a number of efforts to mobilize tree planting efforts, but the track record of these efforts is not good. What belongs to the group is no one individual's responsibility, and the care and protection needed by young trees is too often lacking on communal lands (18). The problem can be particularly acute in the case of communal grazing areas. Development assistance efforts will be more successful when they take local land- and tree-tenure practices into account in the design of agroforestry projects. The rights to use the trees need to be defined as part of the project design. African governments may need to reassess their land tenure and forestry legislation if agroforestry is to reach its potential.

### Encouraging Investment in Agroforestry

The payback period varies considerably for different agroforestry techniques. Alley cropping may start to improve yields during the first year or two. A live fence, if managed properly, may become effective in 1 or 2 years. Windbreaks may begin to produce results in 3 or 4 years. Some fruit trees used for intercropping may begin to bear fruit in 3 years. The shorter the period before benefits are realized, the more likely farmers are to invest scarce land, labor, and capital in agroforestry initiatives. Thresholds of investment are obviously highly variable and will depend on such factors as level of investments required, added risks that may be created, how and to whom benefits are derived, or previous experience with innovation. A better understanding of these economic trade-offs from the farmers' point of view is in itself an important research area that could also help "calibrate" research priorities in experiment stations to what is needed and adoptable by farmers.

Other agroforestry techniques may take much longer to produce a return on investment. For example, *Acacia albida* intercropping may yield few benefits for the first 10 years, although the long-term benefits may be very substantial, particularly in light of increasing demands being placed on the resource base. Few resource-poor farmers have the luxury to approach investment decisions using such a long-term perspective, however. Under such circumstances, supporting agencies may need to underwrite costs until farmers and herders begin to realize benefits. Expanding markets for agroforestry goods also may provide incentives and support the sustainability of such efforts. In other cases, however, continued support may depend on more permanent forms of government incentives or restrictions, the costs and benefits of which should be viewed within the context of long-term national interests in sustaining the natural resource base.

### Support for Docentralizod, Locally Managed Nurseries

Most seedlings for agroforestry plantings are produced in central nurseries, usually in cooperation with national forest services. Without development assistance, forest services of many African countries are incapable of producing and distributing the quantity of seedlings necessary for large-scale plantings. More importantly, many are not capable of helping large numbers of widely scattered farmers, each needing small-scale plantings. Even if farmers accept a particular agroforestry technique, it will do little good if they have no source for the required seedlings. Improving local capacity to produce seedlings would give farmers better control over access to desired tree species, and would greatly reduce the significant logistical and transportation problems involved with centralized nurseries. A few projects have begun to encourage and support the creation of local village, school, and private nurseries. The CARE Koro Village Agroforestry Project in Mali, the AID Community Forestry Project in Guinea, and the Somalia Community Forestry Project are examples (box 8-l).

#### Box 8-1.—Community Agroforestry in Somalia

For the first time, women have become an important force in a major agroforestry project in northwest Somalia—an area hit hard by desertification and a fuelwood crisis. At least 7,000 people, including members of the Somali Women's Democratic Organization (SWDO), the National Range Agency (NRA), and local residents and refugees have learned a variety of skills that can be used in future development work. In addition to planting some 300,000 trees, skills have been learned for establishing and managing local nurseries, collecting and analyzing data, and coordinating large community-based reforestation and conservation activities. Some 60,000 persons have benefited in 2 years.

Associated enterprises include producing and marketing fuelwood and growing vegetables between rows of newly planted trees. The trees fix nitrogen in the soil; protect the vegetables from wind and soil erosion; and produce green manure, mulch, and firewood, The firewood provides fuel, and the vegetables improve diets, and both will be marketed by the women. Feasibility studies are also looking at beekeeping/honey production as another income-generating enterprise because the trees' flowers attract large numbers of bees.

The communities involved want to expand their forestry and agriculture activities. Plans for water reservoirs and irrigation systems are underway. The Overseas Education Fund (OEF) has provided extensive training to SWDO members and NRA extension agents in program design, implementation and management, technical agroforestry, and small business management and marketing to enable them to carry out programs in other parts of the country. Training materials have been published for use in similar efforts in the region.

A factor in the success of this project is the government of Somalia's recognition of the importance of conservation issues, This region of Somalia has suffered for many years from severe drought and desertification caused in part by mismanagement of natural resources. Because of the scarcity of trees, supplies of the region's most important source of fuel—firewood—were very low and were further depleted by an influx of refugees from Ethiopia. In response to this crisis, the government developed a 5-Year Plan (1982-86) which gives anti-desertification and forestry top priority. OEF, in turn, launched this 2-year pilot agroforestry project with funding from AID.

The refugees are mostly women and children who came from Ethiopia. While only 43 percent of the over 500 Ethiopian refugees and Somalis hired from the local communities are women, this is considerably more than the usual number of women engaged in paid manual labor in rural Somalia. This is probably the first time that the men in the project have had so many female co-workers, or that so many had access to training in technical and management skills.

SOURCES: Overseas Education Fund International, Washington, DC, Press Release, Dec 11, 1986; OEF International *Annual Report,* 1986; OEF Internatlonal *Final Report: Community Forestry for Refugee Related Areas,* 1987

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