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Alley Farming in the Humid and Subhumid Tropics

(State of the art, research, training and collaboration)

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and

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ABSTRACT

Alley farming is an agroforestry approach for managing farming systems using particularly woody leguminous species. This management system allows continuous low input and sustainable crop production on fragile upland soils in the humid and subhumid tropics. Tree foliage provides high quality supplementary food for ruminant livestock.

This working paper summarizes the state of the art of alley farming and alley cropping for the humid and subhumid tropics. It identifies the potentials, management problems and research needs.

In addition the working paper also contains a summary of the proceedings and recommendations made by the participants in the Alley Farming Workshop that was jointly organized by IITA AND ILCA and held at IITA, Ibadan Nigeria, from March 10-14, 1986. The workshop was sponsored by IDRC and USAID and was attended by over one hundred persons from 19 countries.

1. INTRODUCTION

One of the challenges facing agricultural scientists working on upland food-crop production in many parts of the humid and subhumid tropics is the urgent need to find viable sustainable and environmentally sound alternatives to the centuries-old shifting cultivation and bush-fallow slash-and-burn cultivation system. The traditionally extensive food-crop production system, which is known to be stable and biologically efficient, operates effectively only when sufficient land is available to allow a long fallow period to restore soil productivity exhausted during the short cropping cycle. However, over the years, the system has undergone rapid changes due to various socioeconomic factors such as rapid population growth. In tropical Africa the population is increasing at a rate of over 3.0 percent annually (McNamara, 1984). Although in general there is still adequate land for upland farming in tropical Africa, there is not sufficient land available to maintain the needed long fallow period. This has put severe pressure on the land productivity under traditional farming systems and has led to increased deforestation. It is estimated that the closed forest area in the coastal zone of West Africa has disappeared at a rate of 5.1% (7.3×10^3 ha) annually since 1980 mainly to allow for agricultural production. At this rate, these forests have a "half life" of just 13 years (Brown and Wolf, 1985). As productive land becomes scarce, small holders are also compelled to exploit more fragile and marginal lands that cannot support large populations practicing subsistence agriculture.

The loss of forest and the rising population pressure has forced traditional farmers to shorten fallow periods and set in motion a spiral of degradation of the productive capacity of the land with the resultant decrease in crop yield as already observed throughout the tropics and particularly in tropical Africa. Overgrazing and indiscriminate fuelwood gathering further intensify the problem of land degradation. In addition, fuelwood and charcoal account for more than 90 percent of wood consumption in Africa. According to a recent report from the World Resources Institute, this type of situation, which prevails in many developing countries, can only be changed if rural populations are given alternatives to this ecologically destructive way of living.

Modern technology adopted from the temperate zone for increasing food-crop production under continuous cultivation has not always been very encouraging on the fragile upland soils. The rapid decline in the productivity of tropical soils under continuous cultivation even with supplementary fertilizers has been documented. The failure of various mechanized arable farming projects highlights the need for a different approach for continuous arable farming in the low-activity clay (LAC) soil (Kang and Juo, 1983). Lal (1974) stressed the importance of mulching and minimum tillage for maintaining the physical productivity of the soils. It appears, however, that a more important factor in maintaining the productivity of these soils is soil organic matter and soil biotic factors, which can be manipulated through a planned fallow system

that can provide adequate insitu mulch and green manure.

Since the bush-fallow system is widespread and is important to the livelihood of so many people, it will be virtually impossible to dispense with it completely. The bush fallow, in addition to its main role for restoring soil fertility and suppressing noxious weeds, also plays important functions in providing staking material, firewood, browse and other needs of the traditional farmer. There is therefore a need to develop technologies that can improve, reduce or eliminate the fallow period while retaining its merits. This approach has led to the development of the alley cropping technique (Kang et al., 1981; Wilson and Kang, 1981).

II. ALLEY CROPPING AND FARMING CONCEPT

For present-day farming the bush fallow which has a low cultivation factor despite its merits has two main weaknesses:

(1) The use of land resources is extravagant.

Despite the divergent views held in different parts of the tropics, a recent study by FAO (1980) showed the need for long rest periods to maintain soil productivity of the fragile tropical soils. Results of the survey compiled by FAO (1980) showed that the maximum acceptable cultivation period is 1-2 years in every 20 years in Latin America, 1 year in every 4 years in Asia and Africa for Ultisols and Oxisols, and one year in every 3 years in Asia and Africa for Alfisols. The need for a rest period can be reduced by the addition of inputs.

(2) The fallow land is unproductive for too long a period. The alley cropping concept, which emerged from IITA's work on using woody legumes for soil improvement during the early 1970s, was designed to improve the bush fallow to fit present-day circumstances to allow higher intensity of land use while still maintaining the basic merits of bush fallow (Kang et al., 1981). In alley cropping, arable crops are grown between hedgerows of planted woody shrubs and tree species, preferably leguminous species, which are periodically pruned to prevent shading of the companion crop(s). The shrubs and trees grown in the hedgerows still retain their functions as observed in the bush fallow for nutrient recycling, weed suppression and erosion control on sloping land (Figure 1). Prunings from the trees or shrubs are a source of mulch and manure. Leguminous woody species also provide free nitrogen to the production system. The alley cropping technique can therefore also be regarded as an improved managed bush-fallow system (Table 1) that has the additional advantage of combining the cropping and fallow phases to increase the land-use intensity.

To test the viability of the alley cropping concept, long-term field investigations on alley cropping food crops with Leucaena leucocephala were initiated on a degraded Entisol at the IITA main campus in 1976. Results obtained from this trial were

Table 1. Differences in management of traditional bush fallow and alley cropping systems

Traditional System	Alley Cropping System
° Retain mixed native woody species	° Planting selected preferably woody leguminous species.
° Irregular planting pattern	° Grown in hedgerows
° Before cropping, trees and shrubs are cut back and burnt to release nutrients.	° Trees and shrubs are periodically pruned, pruning used as mulch and green manure.
° Fire use for controlling growth	° Hedgerows are periodically pruned.
° Allow short-term cropping	° Allow continuous cropping

promising and a number of alley cropping trials were later carried out using other woody species and crops at the IITA main campus in Ibadan and the Ikenne and Onne substations. On-farm adaptive trials were also carried out at a number of locations in Nigeria.

Incorporation of small-ruminant production by ILCA into the alley cropping system, utilizing the supplementary browse produced from the hedgerows, has led to the development of the alley farming concept (Sumberg and Okali, 1983).

Working independently the agricultural extension department in Sikka district on the island of Flores in eastern Indonesia promoted during the mid-seventies the use of giant Leucaena for erosion control and for rehabilitation of degraded and very steep

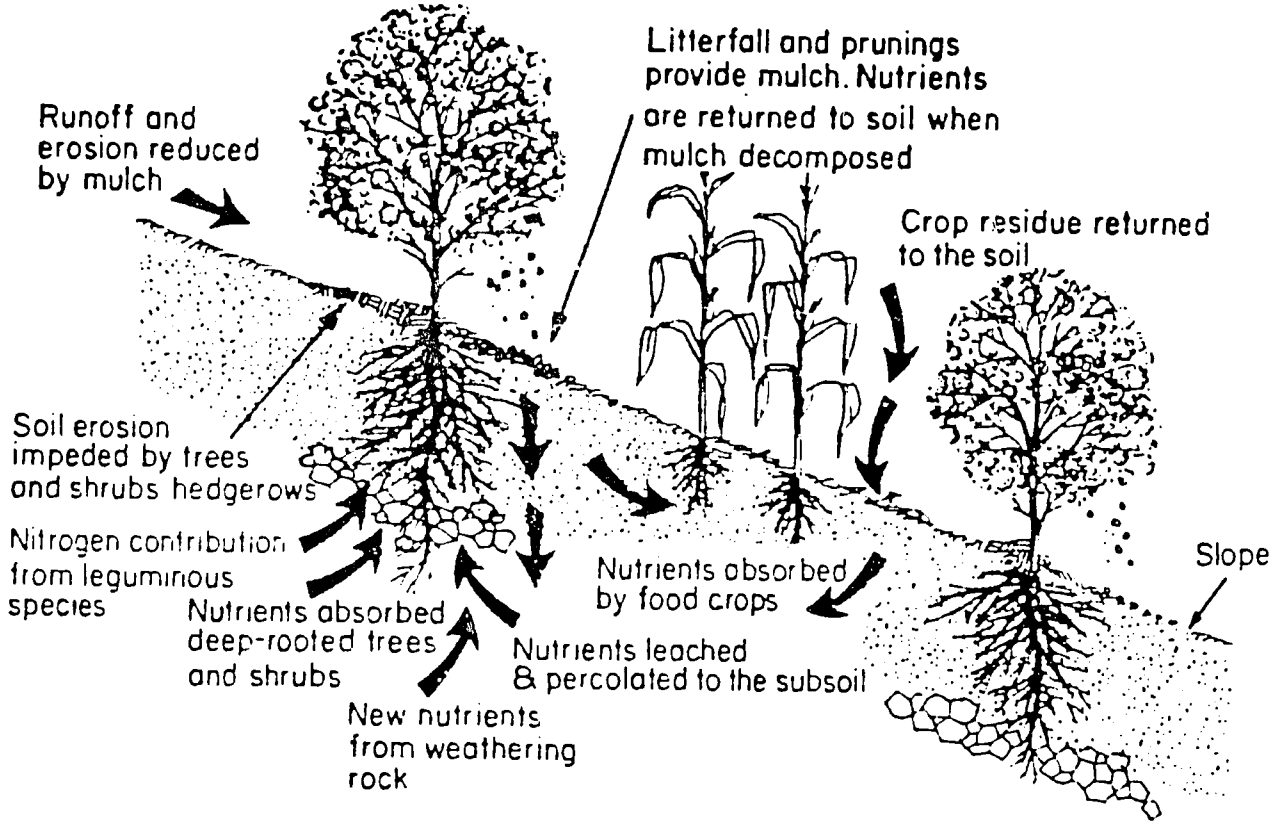

Figure 1. Nutrient cycling and erosion control in alley farming system.

land under the "lamtorosasi" program (Metzner, 1982; Piggin and Parera, 1985). This extension and development work using an alley cropping approach has been very successful. Similar work was also started on critical lands in the Philippines in the late seventies (Brewbaker, J. L. personal communication).

Currently the alley cropping technique is being evaluated and practiced in a wide range of tropical environments under different names; the International Council for Research in Agroforestry (ICRAF) in Nairobi Kenya, calls it "hedgerow intercropping" (Torres, 1983), while in Sri Lanka the term "avenue cropping" is used (Wijewardene and Waidyanatha, 1984).

III. HEDGEROW ESTABLISHMENT

For the success of alley farming, establishment of proper hedgerows is essential. *Leucaena*, *Gliricidia* and *Cassia siamea* hedgerows can be established cheaply by direct seeding. For other woody species such as *Acioa barterii* use of seedlings is preferable. *Leucaena* and *Cassia* seeds require acid or hot-water scarification, while *Gliricidia* seeds need no treatment. Direct seeding of *Leucaena* can be done in the same row with a crop such as maize. *Gliricidia* seedlings require more light for good establishment and can be direct-seeded in between rows of crops. Inoculation of the seeds with the appropriate inoculum will also guarantee fast establishment. The best planting depth for *Gliricidia* seed is about 1 cm and that of *Leucaena* seed about 1½ cm. Although *Gliricidia* can be stablished from stakes, stake establishment has two disadvantages,

One disadvantage is that shallow-rooting trees from cuttings suffer more from water stress during the dry season and are also more easily pushed over by grazing animals than are the deeper rooting trees established from seeds. A second is that a large number of stakes are needed for tree establishment.

The best alley width varies with the type of farming operation and with the farmer's requirements. For manual operation in the humid and subhumid zones, an alley width of 4 m is satisfactory. Under perhumid conditions where low radiation during the cropping period is a problem, a wider alley width of 6 m is preferable. For mechanized agriculture, wider alleys are preferable to reduce the amount of land occupied by the hedgerows and also to avoid damage to the hedgerows during land preparation. Further investigation is required to determine the best alley width for mechanized farming.

IV. HEDGEROW MANAGEMENT AND NUTRIENT YIELD IN ALLEY CROPPING SYSTEM

The importance of forest and savanna fallow in building up a suitable nutrient status through the development of a closed nutrient cycle is well known. This restorative role of the fallow is linked to the ability of deep-rooting trees and shrubs to recycle plant nutrients and build up soil organic matter. Jaiyebo and Moore (1964) have demonstrated that a forest fallow is more effective than legume or grass cover in nutrient recycling and soil organic matter improvement. Traditional African farmers are also known to retain certain woody species which are effective in restoring soil fertility during the

fallow period. These include species such as Alchornea cordifolia, Acioa baterii, Anthonata macrophylla, Harungana madagascariensis, Dialum guinensis, Cnestis ferruginia and Nuclea latifolia for the acid soils in the humid region (Obi and Tuley, 1973; Okigbo, 1976) and Gliricidia sepium for the nonacid soils in the humid and subhumid regions.

Inclusion of woody leguminous species such as Leucaena leucocephala and Gliricidia sepium grown in hedgerows in alley farming systems produced large quantities of nitrogen. A higher nitrogen yield was obtained with a narrow alley width. With an alley width of 4 m and with five annual prunings, Leucaena and Gliricidia grown on a degraded Alfisol produced over 210 kg N/ha and 110 kg N/ha per year, respectively. A higher N yield was obtained with higher pruning height and lower pruning frequency (Duguma, 1985), but both pruning height and pruning frequency affect crop yield. By reducing the pollarding height of the hedgerows, the frequency of prunings can be reduced. For example with a pollarding height of 25 cm, two prunings (one before planting and another one at 6 WAP) will be sufficient for a maize crop, while with a 75-cm pollarding height three prunings will be required.

The prunings of the hedgerows can be done manually with a cutlass or mechanically with a backpack rotary brush cutter or a tractor-driven rotary slasher. Investigation by the agricultural engineering section of IITA showed large labour savings with mechanical operation. Hedgerows should be sufficiently established before pruning the trees and shrubs. The main stems should be allowed to reach a certain diameter before pruning (e.g., a 2 to 3 cm diameter for Leucaena) because pruning too early will reduce coppicing at latter stages of growth.

Hedgerow species that produced large quantities of biomass also recycled other plant nutrients to a greater extent than did hedgerow species that produced smaller quantities of biomass (Table 2). Studies on a degraded Alfisol showed a higher nutrient yield with Leucaena and Gliricidia than with Acioa or Alchornea.

Large differences in nutrient content are also observed in the woody material of the various species. Leucaena and Gliricidia contain high amounts of nutrients. One ton dry weight of Leucaena wood will remove about 13.8 kg N, 1.4 kg P, 17.8 kg K, 9.1 kg Ca and 2.7 kg Mg. The high nutrient yields obtained with the prunings can greatly assist in nutrient recycling in the alley farming systems. However, the soil can also become impoverished under continous cut-and-carry systems if no nutrients are returned to the production system.

Table 2. Nutrient yield of hedgerow (4 m interrow spacing) prunings (not including woody material) of four fallow species grown in alley farming on a degraded Alfisol in southern Nigeria (B. T. Kang, unpublished data*)

Species	Biomass yield	Nutrient yield				
		N	P	K	Ca	Mg
	tons/ha/year	(kg/ha/year)				
Acioa barterii	3.0	40.5	3.6	20.4	14.7	5.4
Alchornea cordifolia	4.0	84.8	6.4	48.0	41.6	8.0
Gliricidia sepium	5.5	169.1	11.0	148.8	104.3	17.6
Leucaena leucocephala	7.4	246.5	19.9	184.0	98.2	16.2

*Fifth year after establishment; Total of five prunings

V. CROP PRODUCTION IN ALLEY FARMING SYSTEM

a. Weed Control

The control or suppression of noxious weeds, a major function of the bush fallow, is also a major attribute of alley cropping. *Gliricidia*, *Alchornea*, *Leucaena* and particularly *Acioa* and *Cassia* as fallow species are effective in suppressing weeds. Prunings of the hedgerow species, particularly those that decompose slowly such as *Acioa* and *Alchornea*, are also more effective than *Leucaena* or *Gliricidia* prunings for suppressing weeds. Trials are currently carried out in southwestern Nigeria using *Leucaena* and *Gliricidia* hedgerows for controlling *Imperata cylindrica*, a difficult-to-control weed commonly observed on degraded land.

b. Crop Performance

The performance of maize, cassava and cowpea in alley farming systems with *Leucaena* and *Gliricidia* has been widely studied on soils with a high base status (Kang *et al.*, 1984; Atta-Krah *et al.*, 1985). Higher maize and cassava yields were obtained with alley farming than in the control plots. From results of investigations conducted on an Entisol, it is estimated that *Leucaena leucocephala* prunings in alley cropping can contribute about 40 kg N/ha to the companion maize crop (Kang and Duguma, 1985). Ngambeki (1985) also reported substantial savings in nitrogen fertilizer use in alley cropping maize with *Leucaena.* Studies with cowpea, however, showed that alley cropping with *Leucaena* has either no effect or a depressing effect on cowpea grain yields. In investigations conducted on an Alfisol at Ikenne in southeastern

Nigeria, it was observed that upland rice alley cropped with Leucaena leucocephala did not respond to nitrogen application, while in the control plot with no alley cropping the crop responded to application of 30 kg N/ha. Maize and cowpea also performed well when alley cropped with alternate hedgerows of Leucaena and Acioa.

Early results of a trial carried out on an acid Ultisol at Onne showed better performance of cassava alley cropped with Acioa barterii and Cassia Siamea than in the control plot (Table 3). The per-plant tuber yield when alley cropped with Acioa and Cassia was higher than in the control treatment. Cassava performed poorly when alley cropped with Gmelina arborea this may be due to root competition or to shading.

Further investigaions need to be carried out with intercrop systems and also with other crops.

A very important aspect of alley cropping is its effect on the sustainability of crop yield (Kang and Duguma, 1985) and the role it can play for improving degraded soil. In a long-term trial on a degraded Entisol higher maize yields were observed on the plots alley cropped with Leucaena than in the control plots with and without nitrogen application (Kang and Duguma, 1985). Similar results were also observed in long-term alley cropping trials carried out on degraded Alfisol (Figure 2). Maize yields were higher for the alley cropped treatments than for the controls with or without fertilizer. Alley cropping with Leucaena gave the best yield. The results of these trials also showed that besides nitrogen, improvement of soil conditions with alley

cropping appears to be affecting maize yield. Improvements in soil condition under alley cropping may be related to higher biological activity. With the onset of the rain it is also observed that there is earlier and greater earthworm activity

Table 3. Effect of alley cropping with various woody species on an Ultisol at Onne (Kang, B. T.; A.C.B.M. Van der Kruijs and P. Austin (unpublished data)

Woody species/treatments	Fresh cassava yield	
	Stem	Tuber
	(tons/ha)	
**Control		
No fertilizer	7.3	14.2
+ fertilizer ***	10.4	16.0
Acioa barterii		
Prunings only	11.4	15.0
Fertilizer only	15.3	20.1
Pruning + fertilizer ***	15.0	16.0
Gmelina arborea		
Prunings only	4.1	5.4
Fertilizer only ***	2.3	3.5
Prunings + fertilizer***	5.2	6.9
Cassia siamea		
Prunings only	7.0	13.2
Fertilizer only***	6.7	10.7
Prunings + fertilizer***	9.2	17.2

*Harvested 9 months after planting.

**Cassava stand 10,000 plants/ha; other treatments 6,667 plants/ha.

***Fertilizer rate 30-13-25 kg/ha of N-P-K.

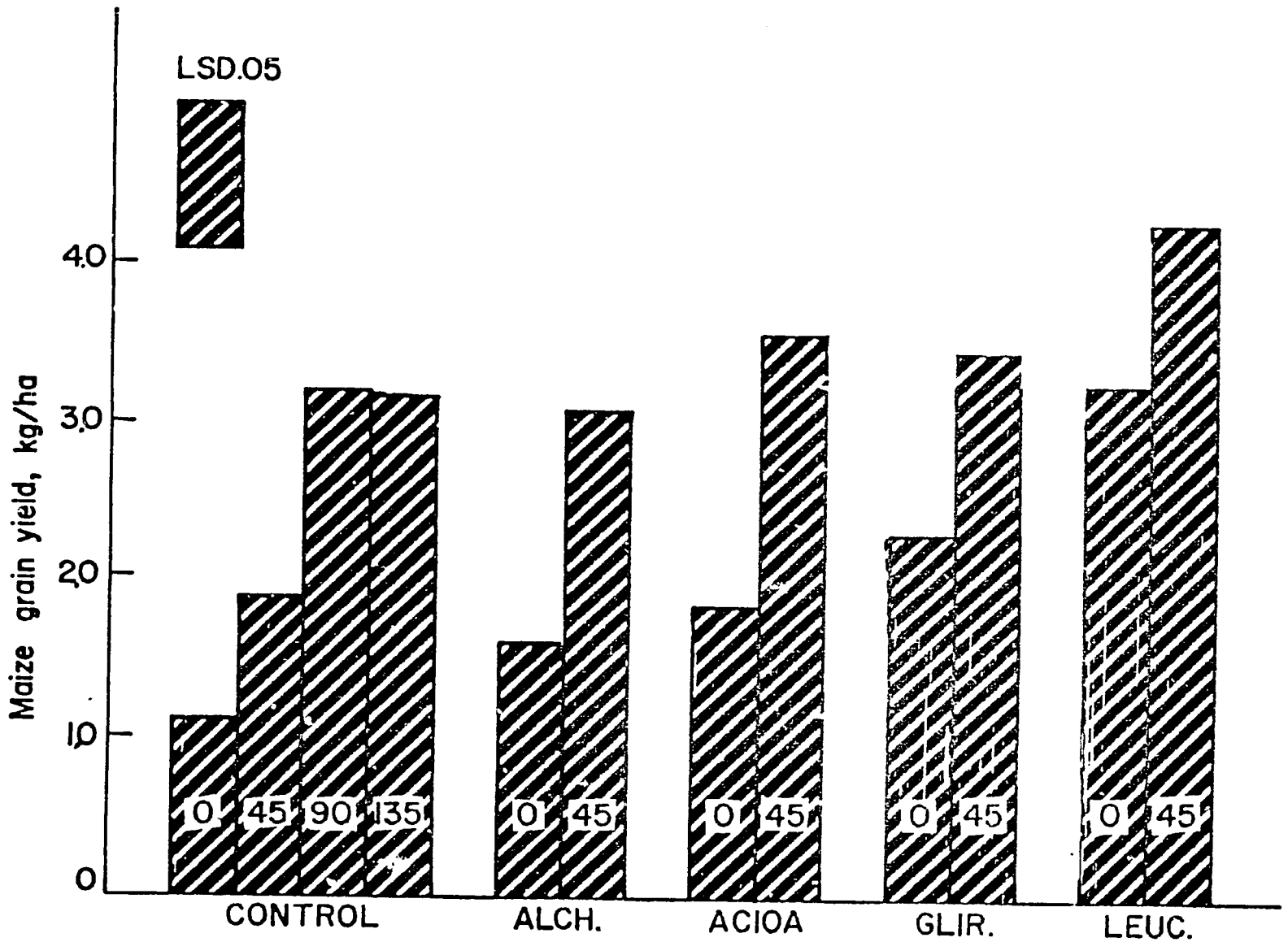

Figure 2. Grain yield of maize on eroded Alfisol (Oxic Paleustalf) at Ibadan, southern Nigeria as affected by alley cropping with woody species (Acioa barterii, Alchornea cordifolia, Gliricidia sepium and Leucaena leucocephala) and nitrogen rates (kg N/ha).

in the alley cropping plots. Observations by Yamoah and Mulongoy (1984) also showed higher microbial activity in the alley cropping plots as measured by the increased biomass carbon. The interactions of biological soil improvement and crop performance in alley cropping is a research area that deserves more attention.

C. Effect on Soil Properties

Results of long-term studies showed significant improvement in soil properties with alley cropping. Periodic addition of hedgerow prunings maintains higher soil organic matter and exchangeable potassium, calcium and magnesium levels at the surface and in the subsoil compared to treatments receiving no prunings. Addition of *Leucaena* prunings, unlike fertilizer nitrogen, has no acidifying effect on the soil.

Addition of prunings as mulch substantially increased the moisture retention of the topsoil. Measurement of soil moisture depletion in a maize-*Leucaena* alley cropping trial on an Entisol (Kang et al., 1985), showed distinct maximum soil moisture-depletion zones occurring at 0-30 cm and 60-90 cm in the soil profile. Maize roots do not grow deeper than 40 cm; it is assumed that the second moisture-depletion maximum is attributed to moisture uptake by the *Leucaena* hedgerows. The moisture loss from the topsoil layers was mainly attributed to uptake by the maize crop and to evaporation. This observation shows the compatibility of *Leucaena* for alley cropping with food crops such as maize. Under unfavourable soil conditions, such as those observed in acid Ultisols or on compacted Plinthustalf,

Leucaena may exhibit shallow surface rooting that will compete with the crops.

In addition to improvement of soil chemical, physical and biological conditions with alley cropping, the hedgerows also control runoff and soil erosion. Metzner (1982) and O'sullivan (1985) reported significant results in using Leucaena for soil conservation. Leucaena hedgerows improved and maintained the productivity of degraded and steep lands in the Island of Flores in Indonesia. Observations with mechanized alley farming on degraded and steep land at IITA, following bulldozer root rake clearing and conventional tillage crop production, showed stabilization and improvement of the land with Leucaena alley cropping as compared to an adjacent plot that was shearblade-cleared and cropped under no-tillage.

d. Mechanized alley cropping system

The alley cropping system was originally developed for the traditional farmers. However, in the course of investigation it was observed that alley cropping can also be used as a scale-neutral technology. Observations were made on two fields of over two hectares each. Plots were planted with Leucaena by direct seeding together with a maize crop in 1983. The hedgerow spacing was 4.5 m to fit the machinery available at IITA. The plots are sequentially cropped with maize and cowpea. Prunings of the hedgerows in a mechanized system has to be done frequently to prevent reseeding and for the stem not to become too thick to interfere with the mechanical pruning. A rotary slasher is used for pruning the hedgerows at ground level before

growing maize or cowpea. The hedgerows are slashed again before harvesting maize or cowpea, using a tractor with a 1.5-m wheel track and narrow tyres to prevent interference with mechanical harvesting.

Results of the three-year observations have shown that mechanized alley farming is feasible. However, with the 4.5-m hedgerow spacing used in the study, only two-thirds of the land is effective for cropping. A wider spacing between the hedgerows would be preferable to reduce the loss of land for the hedgerows Soil conditions appear to be improved under alley cropping which will allow continuous cropping. The yield reduction will be more than compensated for with sustained yield in this system. Cost of pruning for maintaining the hedgerows can be significantly reduced with mechanical operation as indicated earlier (Navasero, 1984). The time required to prune one hectare of Leucaena hedgerows spaced 4 m apart was 37.5 hrs/ha with manual pruning using thick blade cutlasses, 7.4 hrs/ha using the back-pack brush cutter, and less than 1.0 hr/ha using the tractor-driven rotary slasher.

Though the results obtained thus far have shown that mechanized alley farming is feasible, further research is still needed to determine the best spacing between the hedgerows and to develop tools that can cut and spread the prunings more evenly in the alleys. At present the rotary slasher leaves too much mulch in the vicinity of the Leucaena hedgerows.

VI. ALLEY FARMING FOR SMALL RUMINANT PRODUCTION

The concept of alley cropping was extended by ILCA to include livestock by using a portion of the tree foliage for animal feed in a cut-and-carry system . The primary constraint

to livestock performance is high mortality during the first year of life. Peste des Petits Ruminants (PPR) was identified as a major problem, and a solution using Tissue Culture Rinderpest Vaccine (TCRV) was implemented (Opasina, 1984). Availability of an adequate quantity of high-quality feed for confined and tethered animals in the densely populated areas of the humid zone of southeastern Nigeria and for dry-season feeding in southwestern Nigeria are also major limitations to increased small-ruminant production. When the mortality rate decreases, increasing animal numbers put more pressure on food availability.

a. Forage production

Pasture establishment, with and without herbaceous legumes, was first considered but soon rejected because of land and management requirements, and because of disease problems of both legumes (anthracnose) and animals (worms). Attention then focused on tree legumes which IITA had already shown could improve soil fertility and crop production and could also provide foliage for animal feed. The flexibility of alley farming allows the farmer the opportunity to alleviate the nutritional stress suffered by livestock under traditional systems during the dry season. In southwestern Nigeria sufficient land would be available for the farmer to establish large enough alley farms to provide supplementary feed throughout the year. In southeastern Nigeria this would not be the case because farm size is smaller, and so a more intensive use of the trees requiring less land was devised. This system, called an intensive feed garden (IFG), envisaged a small plot of 10 x 20 m of closely

planted trees intersown with grass and located near the house to provide readily available supplementary feed. The most promising leguminous trees from IITA studies directed towards soil fertility and crop production were Leucaena leucocephala and Gliricidia sepium. A combination of these trees planted in alley farms and IFGs could allow mixed foliage to be offered to livestock. This would minimize the possibility of toxicity from high levels of intake of Leucaena that might occur if farmers had only the one tree species available. Gliricidia is less productive than Leucaena, but no problems of toxicity have been observed with Gliricidia fed to ruminants. These two tree species could complement each other and be highly compatible in fodder-production systems. Alternate rows of the two species could be pruned at a 60-cm height 5-6 times each year when the growths reach about 1.5 m in length. Tree foliage for animal feed could be used in a cut-and-carry system. Farmers would have the option of using varying proportions of the foliage for mulch or feed. It is expected that mulching would be most important during the wet season and that an increased share of the foliage would go for animal feed during the dry season.

On-station trials were carried out to compare 25 leguminous browse species including Leucaena and Gliricidia. The desired qualities were ease of establishment, strength of growth and regrowth, persistence, palatability and quality as animal feed. Of the species tested Leucaena and Gliricidia were most productive while Leucaena was more palatable than Gliricidia. With a crude protein content of above 20% and with green forage

production throughout the year, both species were sufficiently attractive to warrant further investigation.

Few studies had been made of Gliricidia. In 1983 ILCA collected 49 accessions of Gliricidia from Central America in collaboration with the Centro Agronomic Tropica de Investigacion Ensenanze (CATIE). From these, four high-yielding accessions that were more productive than the local Gliricidia found in the Ibadan area were selected (umberg, 1985).

b. Small-Ruminant Produc[illegible]

In southern Nigeria, livestock is a minor enterprise contributing around 5% of total farm income. Small ruminants predominate in the area, averaging 2-4 animals per household. In southwestern Nigeria where land is not a constraint, animals roam freely around the household area feeding on natural vegetation, household wastes and food-processing by-products (Carew, 1981). As land is generally not a constraint to farming at present, fields are separated from the household by an uncultivated ring of land through which animals do not pass. In southeastern Nigeria on the other hand, where human population density is higher, land availability is limited, farm size is generally smaller and animals are confined or tethered around the household to avoid damage to food crops growing in compound farms (Mack et al., 1984). The farmer is responsible for providing animal feed, usually browse from the bush, crop residues, household wastes and food-processing by-products. The most commong by-product used for animal feed is cassava peel. The productivity of confined and tethered goats in the southeastern

Nigeria is lower than that of the free-roaming goats in the southwestern part, reflecting differences in the two farming systems (Adeoye, 1985). In these zones the positive additional returns to crop production through alley farming will enhance the acceptability of the system. In the traditional farming systems continuous cropping for a number of years results in a decline in crop yield as the nutrient content of the soil falls. Investigation on a sandy Entisol showed that tree rows 4 m apart and a tree spacing of 25 cm gives a dry matter yield of 6 tons/ha/year and is equivalent to 174 kg N/ha/year. Research results at IITA showed that 1 kg of mulch-N applied to the surface will produce an additional 5 kg of maize, and if incorporated into the soil it will give 10 kg of maize. ILCA has assumed that the primary use for tree foliage will be to maintain crop yields and that additional material can either be used to feed animals or to raise crop yields above the base level. A model based on experimental and field data to quantify the benefits of alley farming has been developed by Sumberg _et al_. (1985). If base maize yield is 2 tonnes/ha, falling by 20% each year, we would need sufficient mulch-N from the trees to produce an additional 400 kg of maize to maintain the base level of production (i.e., 80 kg mulch-N at 5 kg maize/kg mulch-N). Thus 2.8 tonnes DM of tree foliage at 2.9% N would be needed to maintain crop yields at 2 tons/ha. On-station we can expect tree foliage production of 6 tons DM/ha/year. The surplus foliage would therefore be 3.2 tons/ha, available either for mulch or feed.

Tree management will differ if the purpose is feed rather than mulch. For mulch, trees can all be cut at one time, while for feed pruning will be staggered over a period. Assuming a daily feed intake of 4% of body weight, a 15-kg goat needs 600 g DM/day. If supplementary browse from the tree provides 50% of daily intake, 300 g browse DM will be required. The surplus foliage from one hectare on-station in the example given above could supplement 29 goats for one year.

Under small-farm conditions a foliage yield of 3.5 tonnes/ha can be expected from the trees. Base maize yield is 1.5 tonnes/ha which can be expected to decline annually by 20% as soil fertility falls. From the model above 60 kg mulch-N/ha (2.1 tonnes tree foliage/ha is needed to maintain crop yields. The farmer has an excess of around 1.4 tonnes/ha to use for mulch to increase crop yield or to feed to animals. Since the average size of an alley farm at present is around 0.2 ha, the farmer will have sufficient feed to provide 50% of the daily requirements for 2.6 animals if all the excess tree foliage is used for feed. There is clearly a conflict between crop and animal demands for tree foliage, and the decision taken will depend upon the priorities and interests of the farmer.

While producing tree foliage and ascertaining the best management routines on-station, ILCA has also studied the effects of using mixed Leucaena/Gliricidia browse in a cut-and-carry system on animal production. A daily supplement of 800 g browse DM/head offered to pregnant and lactating ewes increased the productivity index (kilograms of offspring weaned/ewe/year) by

55% over those receiving only the basal diet of Panicum maximum (Reynolds and Adeoye, 1986). While it is clear that mixed Leucaena/Gliricidia browse increases livestock performance, it should be pointed out that the basal Panicum diet was of much lower quality than that obtained by free-roaming village animals. The productivity index of village sheep has been recorded at 10.3 kg offspring weaned/ewe/year (Mack, 1983), which was equivalent to that from animals on-station being offered about 400 g browse DM/head/day and consuming 270 g browse DM/head/day. The consumption of a further 180 g browse DM/head/day raised the productivity index by 20%, and there was no indication that the effects were tailing off. Sheep showed signs of mimosine toxicity (loss of facial hair) when offered the highest levels of browse during this trial. However, group feeding was practiced and individual dominant animals are suspected to have taken more than their share of Leucaena, which is more palatable than Gliricidia. During a further browse supplementation trial with individual feeding, no signs of toxicity were encountered, even though the quantities offered per head were the same as in the earlier trial. The effects of rumen microbes able to detoxify mimosine will be studied in West African Dwarf sheep and goats during 1986.

c. Alley Grazing

The inclusion of a 2-year fallow period in Leucaena alley farming has also been studied, with the idea of grazing animals on natural regrowth between the trees during the fallow years. Goats were found to debark the trees and so the study was

concentrated on sheep. However, bark damage has also been observed with sheep, and the management of animals has posed some problems. During the early rains regrowth is vigorous and animals are not keen to enter the long grass/weed mixture, preferring to remain around the trampled outside areas. Hand slashing was performed on the regrowth. Later in the year tree growth shaded out many of the plants and as there was little remaining on the ground for animal feed, Leucaena intake became a more important component of the diet and signs of mimosine toxicity became apparent. At present we are unable to recommend grazing sheep in alley farms during the fallow period. However, the effect on crop yield when the grazed fallow plots were returned to maize production was significant, with yields being 75% higher than those from conventional continuously cropped alley farms. It was not possible from the trial to differentiate between benefits accruing from the presence of animals and those from a fallow period itself. The effects of different lengths of cropping and fallow periods in alley farming deserve further study.

d. Intensive Feed Garden

Preliminary observations have been made on combinations of trees and grasses designed to intensify animal feed production from a small area (10 x 20 m) for use in the higher population density areas of southeastern Nigeria. During the establishment year high foliage yield was obtained (9.85 tonnes/ha) with tree rows 4 m apart interplanted with 4 rows of grass in each

alley. Crude protein yield (483 kg/ha) was higher with closer tree rows of 2.5 m apart and 2 rows of grass. In the second year trees will be more productive, but even in the first-year intensive feed garden production from a 0.02-ha plot would be sufficient to supply 25% of the daily intake of 3.6 small ruminants.

VII. ON-FARM RESEARCH AND SOCIOECONOMICS

a. On-farm research

The target groups for on-farm research are the smallholder farmers. The IITA's on-farm research started in 1980 with the establishment of *Leucaena* alley cropping plots for soil fertility improvement and for yam staking on farmers' plots in east-central Nigeria. In these trials *Leucaena* hedgerows were planted using a 2-m alley width. Results of these trials showed that farmers are accepting the alley cropping concept, but they rejected the hedgerow spacing of 2 m as being too narrow (Ngambeki and Wilson, 1984). The alley width was increased to a minimum of 4 m in subsequent trials.

At present IITA's on-farm research on alley cropping focuses on soil fertility maintenance, weed control and yam staking. Alley cropping is only one of the many technologies subjected to on-farm testing by the OFR team. On-farm trials with alley cropping are based on the technological constraints identified in selected pilot research areas. These constraints are low inherent fertility of soils and predominance of difficult-to-control perennial weeds such as *Imperata cylindrica*. The trials are established using appropriate experimental designs in order to quantify data for analysis. The analysis is used

for evaluating the technical and economic feasibility of alley cropping under real farm environment. Twenty well-established on-farm plots are currently being maintained. The number will be greater in 1986.

ILCA has been involved with on-farm testing of alley farming since 1981. The purpose of on-farm trials is to obtain information about the performance of a technology under farm conditions. Two kinds of such information may be distinguished. The first, Type 1, consists of quantification of technical, biological and economic implications of an intervention. Such data are obtained from trials with standardized designs, the execution of which requires a high level of researcher involvement. The second, Type 2, is concerned with the farmer's own evaluation of the technology in terms of its relevance, workability and acceptability. Obtaining this kind of information requires that the farmers control, manage and utilize the technology themselves.

Two properties of alley farming have critical implications for the conduct of on-farm research. The first of these is the fact that alley farming is a system that involves and links a number of farm enterprises. In this it differs from technologies such as improved varieties or fertilizer which involve only a single component. The second is that the planting and management of the trees implies changes in farmer behaviour. In the case of the on-farm testing of single-component technologies, both Type 1 and Type 2 information may generally be collected from the same trial. However, the flexible and innovative nature of alley farming means that different kinds of trials are

required to collect the necessary information.

An important feature of on-farm research strategy is its ability to increase the relevance of on-station work through the identification of realistic and researchable problems during the phase of farmer-managed trials. Feedback from these trials helps to define the objectives, designs and methods of on-farm work, in the light of farmer circumstances, needs and priorities.

The testing of the alley farming technology under farm conditions through 'developmental' on-farm research has taught us a good deal about the establishment and management problems of the browse trees under a wide range of environments and their sustainability to farmers with varying levels of resources and production objectives.

ILCA's approach, shown in Fig. 3 gives the linkage between on-station and on farm research which will allow feedbacks and modification of interventions based on information directly gathered from the farmers, before attempts are being made to quantify the on farm benefits.

The spontaneous spread of a technology is the most crucial test of its acceptability to farmers. ILCA's figures indicating the rate and success of adoption on Owu-Ile and Iwo-Ate are presented in Table 4. At the inception of the project in March 1984, 66 farmers obtained browse seeds from ILCA for planting alley farms. Twelve other farmers requested seeds at a later date. Of these 78 farmers, 68 planted alley farms. Eight more alley farms discovered later had been planted by farmers having obtained seeds from their neighbours without the knowledge of ILCA.

Table 4. Adoption and establishment of alley farms in two pilot project villages

	Owu-Ile	Iwo-Ate	Total
A. Numer of farmers			
1. Who received seeds from ILCA (March 1984) for planting alley farms	38	28	66
2. Later requesting seeds from ILCA and planting alley farms in 1984	8	4	12
3. Obtaining browse seeds from neighbours and planting alley farms in 1984	3	5	8
Total number of farmers that obtained browse seeds to plant alley farms in 1984	49	37	86
Number of 1984-established alley farms viable			
- as of July 1985	38	30	68
- as of Jan. 1986	31	29	60
B. Drop-outs (after having planted)			
- as of July 1985	4	4	8
- as of Jan. 1986	11	5	16
Number of farmers obtaining seed but not planting	7	3	10
C. Number of farmers planting alley farms in 1985	14	26	40
D. Total number of farms being monitored (March 1986)	45	55	100

Sixty-eight farms were considered viable as of July 1985. During 1985 40 more farmers planted alley farms. Among these were two of the farmers who had in the previous year made unsuccessful attempts to establish trees on exhausted soils. In 1984 only 17% of the participants were women, but in 1985 women farmers made up 50% of the participants after ILCA had posted a female research associate to the village specifically to investigate the question of women's participation in alley farms. Farmers from neighbouring communities have approached ILCA for seed to plant alley farms in 1986.

The focus of ILCA's on farm work has so far been in the developmental phase (Fig. 3), but in 1986 it is planned to collect quantitative data, imposing specific treatments on already established alley farms.

b. Socio-economics

Alley farming is a long term investment in soil fertility. The discount rate of future earnings and the planning horizon are critical in farmers' investment decisions. They are influenced by economic policy. Institutional factors like tax laws and the land tenure system determine which share of the benefits the farmer can capture.

Benefits to alley farming come from increased crop and animal production, the products from the trees in the alleys and erosion control. In general, the value of these benefits and the incentive to adopt the technology increase as the pressure on land rises. A number of benefits or parts of them such as; for erosion control, conservation of forest, savings in

foreign currency from reduced fertilizer import, and lower prices due to higher production, will benefit the society as a whole rather than the individual farmer. Such benefits should be quantified and included in the evaluation.

All economic studies concluded that alley farming is profitable (Ngambeki, 1985; Sumberg et al., 1985). An economic analysis of alley farming has shown that with the control of Peste des Petis Ruminants (PPR) partial feeding of tree foliage from the hedgerows to livestock is profitable if net output from goats is increased by 23%, as compared to only sole maize production (Sumberg et al., 1985). These results are mostly based on experimental station work. On farm research

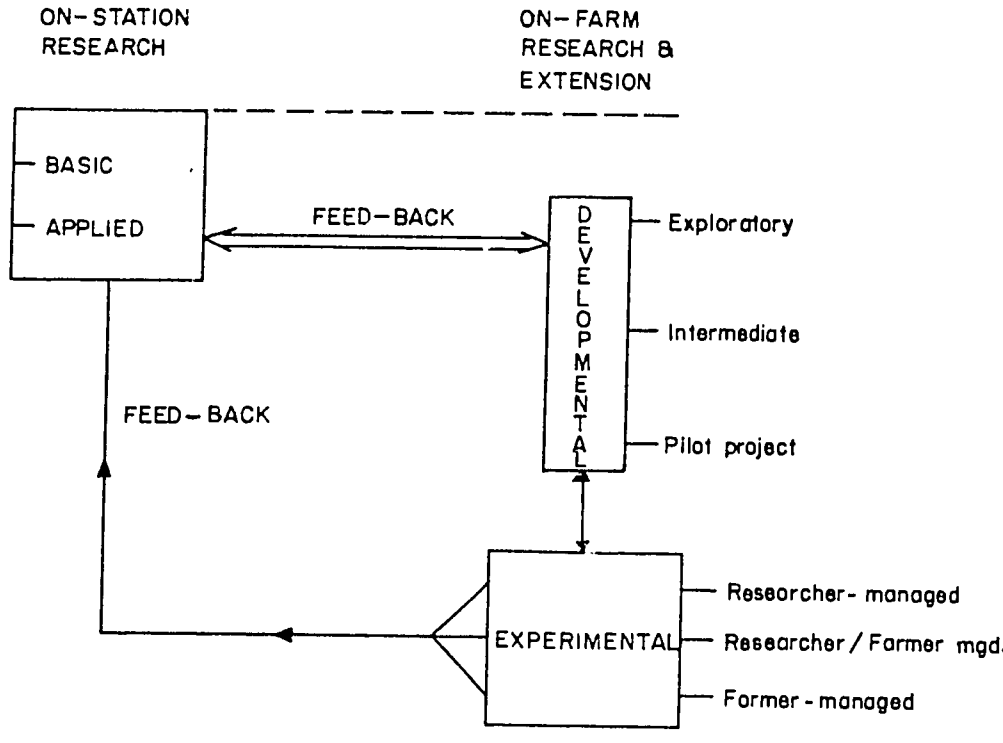

Fig. 3. Scheme Linking On-station and On-farm Alley-farming Research

needs to be extended. The long-term nature of the investment makes more researcher involvement in on-farm trials desirable to demonstrate the whole range and size of benefits to farmers.

Land tenure has emerged as a potentially critical constraint to the adoption of alley farming. There is considerable variation on the land tenure system between areas. Within any one system different categories of land exist, for which different tenure rules and patterns of land use apply. In southeastern Nigeria in particular, communal control over allocation and use of land may undermine the right to plant trees and the incentive to invest in improving soil fertility. In southwestern Nigeria land tenure systems have been modified and developed with changing agricultural techniques and pressure on land, but in general tenants with rights to cultivate food crops may be disallowed from planting trees (Francis, 1986).

VIII. RECOMMENDATIONS OF THE ALLEY FARMING WORKSHOP

The following recommendations were unanimously agreed upon, by participants of the workshop:

a. Research Needs

The overall objective of alley farming is to improve and stabilize the productivity and well-being of the farmers. In achieving this objective, further improvement is needed concerning the socioeconomic, agricultural and biological environments within which the techniques of alley farming are to be developed. Although much information already exists, nevertheless many problems remain unanswered and will require experimental and observational investigation. The following are suggested

areas for research:

(i) Systems description - The adoption of alley farming within different agricultural systems will require knowledge of the following factors: present farming systems, agro-ecological zones, pedological factors, socioeconomic structures and physical and biological factors and acceptability.

(ii) On-station research - It is often easier and more economical to obtain information on basic biological relationships under controlled conditions available on research stations than on farmers' fields. Inclusion of research topics in this list does not preclude these topics from being studied on independent farms. The following studies are required:

- Site adaptability and identification of trees for different physical environments including acid soils, tropical highlands and semiarid and arid areas.
- Because intercropping predominates in most of the systems to which alley farming is targetted, more intercropping combinations should be studied.
- Testing of germplasm for specific feeding qualities and chemical properties.
- Optimisation of the use of materials for trees in crop and livestock systems.
- Evaluation of a wider range of food crops.
- Investigations on basic soil, plant and water relationships in alley farming.
- Investigations on nutrient recycling and maximisation of N

contribution from prunings and better assessment of biological improvement of soil under alley farming.

- Regional coordination and standardization of research methodology will be encouraged.

(iii) On-Farm Research

On-farm research should involve the testing, evaluation and development of alley farming. This should be an inter-disciplinary study undertaken by the national collaborators. Feedback from on-farm research will form a major component for planning on-station research.

b. Organization and Coordination for Collaboration

- That an international alley farming network be established.
- That the scope of the network be established.
- That the scope of the network be primarily the humid and subhumid zones but that the arid and semiarid zones should not be included.
- That the executive responsibilities of the network should be discharged by a central coordinating unit to be based at the IITA/ILCA campus in Ibadan.
- That there should be an international steering committee which will have an advisory role chosen to represent the interests of participating countries and to reflect the multidisciplinary needs of alley farming.
- That together IITA and ILCA should pursue funding for an initial period of 5 years.
- One of the objectives of the network shall be the maintenance of communication among members.

c. Training Needs

- The two main emphases are to train research workers and to train the trainers.
- The organization of the "train the trainer" courses should be undertaken jointly by ILCA and IITA with support from ICRAF, NFTA and other national and international institutions with relevant experience.
- The network will attempt to get funding for training activities. Participants will be encouraged to seek their own funds but help will be given in identifying sources of finance.
- The network and centres should provide limited follow-up support by providing instructional materials and arranging exchanges and visits of staff to reinforce the efforts of participants on their return to their countries. Within the framework of the network, attempts will be made to support individual participants especially by organising cooperation among programmes in adjacent countries.

Participants in the workshop then nominated a steering committee of eight African delegates for the 10-member ad hoc steering committee for the establishment of the alley farming network.

IX SUMMARY OF ALLEY FARMING WORKSHOP PROCEEDINGS

The Alley Farming workshop held at Ibadan, Nigeria, from 10-14 March, 1986, was attended by 101 participants from 19 countries. The theme of the workshop was the development of

more productive and sustainable farming methods with low inputs in the humid and subhumid tropics using alley farming. The objectives were to review the state of the art of alley farming research and application, to review woody species in farming systems in the tropics, and to review training and research needs and to establish channels for collaborative research. The workshop was divided into nine sessions, with a pre-opening field tour of IITA and ILCA on-station trials.

Session 1 contained opening and welcome addresses and general papers on the role of woody species in compound farming and in tropical agriculture. A model showing the effect of alley farming on long-term productivity was presented, but it was found that some of the basic assumptions of the model required validating in practice.

Session 2 concentrated on alley farming particularly using leguminous tree Leucaena leucocephala. The role of tree species in the improvement of soil fertility and crop production, in animal production, and in controlling soil erosion has clearly been established. African and Asian experience was cited in the papers to show that the technology had been accepted by small farmers and was relevant to low-input agricultural situations in the humid and subhumid tropics.

Session 3 presented alley farming in the Indian semiarid tropics where responses in crop productivity to mulch application reflected the importance of timing of nitrogen fertilisation under low-rainfall conditions. The effects of competition for water were also presented. In the semiarid tropics, alley farming can play an important role as source of fodder.

Session 4 concentrated upon leguminous fodder trees. Only four leguminous tree species have been subject to indepth scientific investigation, of which Leucaena was the most prominent. Foliage from leguminous trees improves the digestibility of low-protein roughage and raises animal productivity both for small ruminants under cut-and-carry systems and for cattle in extensive pasture.

Alley farming experiments from West, East and Central Africa were presented by 6 participants during Session 5.

In session 6 the contrasting requirements for quantification of alley farming benefits on-farm as opposed to the determination of its acceptability and suitability to the small-farmer community were discussed. A working outline to encompass both factors was given. The economic returns to the individual and to the community were covered as were the possible constraints to the adoption of alley farming imposed by various land tenure systems in southern Nigeria. This session continued with a field trip to IITA researcher-managed on-farm trials and to ILCA farmer-managed sites.

The role of USAID in cooperative research and the requirements for successful collaboration between and within countries was presented at the opening of Session 7. Participants then divided into working groups to discuss research needs. Crop-livestock interaction, socioeconomics and on-farm research and food-crop production were considered as separate groups. Recommendations were presented to a Plenary session, and a synthesis of the three reports was prepared with the major headings of systems

description, on-station research and on-farm research. Delegates redivided into two groups to consider training needs and methods of collaboration. Recommendations presented in Session 8 to a Plenary sesion called for training for research workers and a 'train the trainer' course for extension organisers. Collaboration should be through an alley farming network coordinated jointly by IITA and ILCA based at Ibadan, assisted by the steering committee chosen by participating national scientists. IITA and ILCA were given a mandate to seek funding for the network. In a closed session the African delegates elected eight representatives, to serve on an adhoc steering committee.

The recommendations were unanimously accepted by the participants in Session 9, and the meeting was declared closed.

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