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## **The Role of Alley Farming in African Livestock Production**

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*The incorporation of livestock into alley farming systems, in which food or forage crops are grown between hedges of multipurpose trees that are regularly pruned for mulch and/or forage, has been studied for over 10 years in Africa. Prunings from leguminous trees such as Leucaena and Gliricidia can be used for mulch, increasing crop yields, but the trees may also be pruned for fodder, especially during fallow periods. The major benefit from supplementing the diet of free-roaming small ruminants in West Africa with the foliage of leguminous trees is increased survival, and the forage is best directed at late pregnant and lactating females. In East Africa crossbred dairy cows show a significant response in milk production to supplementation with Leucaena. Economic analyses of livestock production show that continuous alley farming is more profitable than alley farming with fallow, or conventional no-tree farming, even when the cost of clearing trees at the end of their useful life is included.*

Smallholder farmers in Africa are involved in a risky and uncertain occupation. When rainfall is poor or the national economy falters, essential inputs are not forthcoming. It is not surprising that farmers use strategies to minimize risk such as mixed cropping, keeping livestock as well as growing crops, and seeking off-farm income. For many small farmers, livestock are an essential plank in that strategy, acting as a cash reserve to be sold when a pressing need arises.

Low soil fertility and soil erosion are an increasing problem over much of Africa, as human population pressure on the land shortens fallow periods and forces farmers to cultivate less productive and more marginal areas. Generally in humid and sub-humid zones, animals are confined, tethered or closely herded during the crop growing season, but graze and browse more freely once the food crop has been harvested. Unimproved natural pasture comprises the main feed source, backed up with crop residues after the harvest, but demand for farm land is removing the most productive grazing areas for arable production. Over 60% of farmers own small stock (sheep or goats), but less than

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20% of farmers with mixed crop-livestock production systems own cattle. Sheep and goats generally contribute less than 5% to farm income in smallholder mixed farming systems in the humid and subhumid zone, but specialized subsystems, such as dairy production, can provide up to half the farm income. Many attempts have been made to introduce improved grass or grass/herbaceous legume pastures for grazing on smallholder farms, but this has not yet proved sustainable anywhere. Supplementary feeding with concentrates is an alternative method to improve livestock nutrition, but availability and cost have limited adoption on all but dairy farms. Small stock are generally left to fend for themselves, and farmers are reluctant to spend cash on purchasing inputs for them. Farmers will spend money on veterinary inputs, especially for cattle, but even after treatment, animals need a good diet to remain healthy and productive.

Traditional approaches to improve animal nutrition have had little impact, so alternative solutions are needed that take into account the concerns and objectives of smallholder farmers with crop and livestock interests – primarily concerns about crop yields, with livestock problems taking a subsidiary position. Any new technology must be resilient to unexpected forms of management and allow flexibility in the allocation of its benefits, so that farmers can modify the system to meet changes in their own environment and circumstances.

Alley farming is a technology with an in-built flexibility, designed to alleviate the problems of soil fertility maintenance, declining crop yields and/or animal feed shortages, while providing wood for fuel or construction. The technology involves leguminous trees grown in hedgerows, interplanted with food or forage crops between the rows (most commonly in alleys 4 m wide). When pruned, the trees provide foliage that can be used as mulch or fodder, and wood for fuel or timber depending on the age of the tree. It can also prevent soil erosion on sloping land. Agronomic studies have included tree-forage mixtures as well as tree-food crop mixtures. The effects on soil fertility and crop production of varying the mulch/fodder ratio has also been studied, together with the incorporation of fallow periods into the system. Tree legumes are more hardy than herbaceous legumes, a definite advantage under farmer management.

Forage is usually taken from the farm to the animals (a cut-and-carry feeding system) rather than vice versa, to prevent crop damage from roaming animals. (It is worth noting that at the end of one smallholder dairy project in the Caribbean, after the advisory staff were withdrawn, the farmers started to graze the tree-grass forage plots instead of using them for cut-and-carry feed. This may indicate that farmers place a higher value on saving labour than on maximizing forage production). Initial studies on-station with livestock investigated the effect of forage from *Leucaena leucocephala* and *Gliricidia sepium* on animal growth, reproduction, milk production and health.

On-station studies can demonstrate the biological potential of an intervention and allow an ex ante economic assessment of its potential, but the impact can only be determined when farmers adopt and modify the system to meet their own requirements.

Biological and socioeconomic studies on farms allow a full evaluation of the intervention, so that recommendation domains and guidelines for implementation can be drawn up by researchers, extension staff and farmers. On-farm work with alley farming initially showed how farmers modified recommendation from researchers during the establishment phase of alley farming. Subsequent work has monitored and evaluated biological, social and economic aspects of the crop and livestock subsystems under the control of farmers. Alley farming studies with livestock in Africa started in the humid zone where smallstock are marginal to the farming system, although they have an important role in the household economy. Once the potential of forage produced on alley farms had been demonstrated, the scope of the investigation was expanded to encompass smallholder dairy farming, where significant improvements in farm income could be expected.

### On-station research

On-station trials were designed to determine the biological potential of the technology under controlled conditions. A wide range of food crops have received attention including maize, rice, beans, cowpea, cassava, yam and cotton. More information on the impact of alley farming on crop production is given by Kang et al. (1990).

#### *Tree-food crop interactions*

The primary objective of most small-holder crop/livestock farmers is food production for human consumption. Other activities, introduced with new technology, should not detract from food crop yields. Hedgerow trees are pruned every 6-8 weeks to provide mulch, and to prevent companion food crops being adversely affected by shade. The mulch can be spread on the ground or incorporated in the soil. Crop production increases as a result of the nitrogen provided by the foliage, changes in microclimate produced by mulching and by the tree rows, the effects on the soil microflora and fauna and the increased soil moisture content. Maize, the most important single food crop in Africa, is particularly responsive to legume mulch. In alley farming trials in southwest Nigeria, a linear response was obtained in maize grain yield to the level of *Leucaena* or *Gliricidia* mulch applied (Table 1).

Table 1 Effect of proportion of total prunings from *Leucaena* and *Gliricidia* hedgerows applied as mulch with and without fertilizer on maize grain yield (tones per ha), on-station (mean of 1985, 1986 and 1987 values).

N (kg/ha)	Prunings applied (%)		
	0	50	100
<i>Leucaena</i>			
0	2.6	3.9	4.5
40	4.0	5.3	5.4
80	4.4	5.2	6.2
<i>Gliricidia</i>			
0	1.7	2.6	3.3
40	3.8	4.2	5.1
80	4.5	4.9	5.6

Grain yield increased by over 40% when all the tree prunings were returned as mulch to the soil. A similar response was observed in Kenya when varying proportions of *Leucaena* prunings were used as mulch on maize (Mureithi, 1992).

An alternative approach is to use tree foliage for mulch when the food crop is physiologically most capable of deriving benefits from extra nutrients, and at other times to use the prunings for animal feed. In the humid zone tree growth is rapid and three prunings are possible in the time between planting and harvesting a maize crop. The first pruning is applied as mulch when the food crop is planted, the second at the time of tasselling (6-8 weeks later), and the third as the crop approaches senescence (another 6-8 weeks). ILCA (1989), in a comparison of the use of the first, the first and second, or all three prunings as mulch, showed that incremental crop response decreased from the first to the second to the third application (Table 2). Thus, the opportunity cost of fodder from the second and third pruning is lower than that from the first pruning. It can be concluded that the first pruning should go for mulch, the second could be used in either way, but the third should be fed to livestock, provided the incremental returns from livestock outweigh the cost of crop yields foregone.

Table 2 Effect of mulching with *Leucaena* foliage from different prunings on maize grain yield (tones per ha), Nigerian humid zone, 1988.

Prunings applied as mulch	Maize grain yield <sup>1</sup>	
	Unfertilized	Fertilized <sup>2</sup>
None	3.10	4.86
First (preplanting)	4.35	4.94
First and second	4.68	5.32
First, second and third	4.84	5.31

<sup>1</sup> Total grain yield for first and second cropping seasons.

<sup>2</sup> 45 kg of 15:15:15 compound per hectare, 15 kg at planting and 30 kg 6 weeks later.

However, this does not take into account any long-term effects on soil fertility. A long-term trial undertaken by ILCA during 1983-89, in which all tree foliage was returned as mulch, showed that soil nitrogen levels were maintained or improved under the alley system, but that even with a limited application of inorganic nitrogen fertilizer, soil organic matter and potassium levels still declined on alley plots, although the rate of decline was slower than on no-tree plots. Soil phosphorus levels declined as fast in the alley plots as in no-tree plots. Not surprisingly, alley farms benefit from fallow periods (ILCA, 1990) but the fallowing does not need to be as frequent as in traditional systems.

Soil organic matter levels are higher on mulched plots, and this enhances the response to inorganic nitrogen fertilizer. Manure is a source of nutrients that is readily available in some areas. Slurry, a mixture of cattle manure and water, applied at a rate of 13 tonnes DM/ha/year to a *Leucaena* maize intercrop, increased crop yield by 45%, from 2.8 to 4.6 tonnes grain DM/year with a similar increase in stover yield (Mureithi et al., 1994). As with inorganic fertilizers, manure has more effect on plots receiving mulch from

leguminous trees. Livestock can benefit indirectly when tree foliage is used for mulch because the quantity and quality of crop residues, as measured by nitrogen content, is higher in mulched alley farms than on plots where no leguminous mulch is available (Atta-Krah and Reynolds, 1989).

In the absence of external inputs, alley farming reduces but does not eliminate the need for fallow. During fallow periods tree foliage can be removed for animal feed. Forage yields from *Leucaena* on fallow plots at Ibadan, starting with a uniform pruning in January and comparing different pruning regimes, are shown in Figure 1. Pruning after 9 months growth, coinciding with the end of the rains, combined with a second pruning 3 months later in the middle of the dry season, gave the highest edible biomass yield (ILCA, 1989). While this demonstrates the management needed to maximize tree foliage offtake, information is lacking on the long-term effects on soil fertility and crop production.

#### *Tree-grass interactions*

Studies in West Africa have focused on *Panicum maximum* in combination with either *Leucaena* or *Gliricidia*, while in East Africa more attention has been paid to *Pennisetum purpureum* (Napier grass)/*Leucaena* combinations. In the first few years after establishment, alternate rows of *Leucaena* and *Gliricidia* interplanted with *Panicum* produce the most forage (tree plus grass) when trees are pruned twice a year in October and January. Grass yield, from cuts at 6 or 8-weekly intervals, is lower with infrequent tree pruning because of shading, but while the trees are in the first 3 years of growth the difference is more than compensated for by higher tree foliage production. Overall, feed quality is greatly improved by the contribution of protein from the leguminous trees. Growth is more vigorous on older trees, especially those that have remained unpruned for some time and developed extensive root systems. If a more regular pruning regime is not followed, a lack of light may shade out the companion grass (Ezenwa, 1994).

A two-year trial was conducted on sandy soil at the Kenyan coast, where the annual rainfall was 1100 mm, using a combination of *Leucaena* and Napier grass. Napier yield tended to be depressed by the trees, especially during times of low rainfall (Mureithi *et al.*, 1994). Nevertheless, total forage DM and crude protein (CP) production from tree-grass alleys was higher than from separate grass and tree plots.

#### *Tree-only forage production*

Tree-only plots for high protein forage may be attractive to smallholder dairy farmers with limited space for forage production, because dense planting is possible. These plots can supplement the feed produced from alley farms. Planting density (between-row spaces of 0.5-2.0 m, with 25 cm within-row spacing) and pruning interval for *Leucaena* (6-12 weeks) were evaluated over 3 years at Ibadan. Yield was very high initially but declined with time, particularly with more frequent pruning. The highest biomass yield was obtained with long pruning intervals and high planting density, with 38 tonnes DM foliage in year one, declining to 18 tonnes and 15 tonnes in years two and three

respectively. Lengthening the pruning interval produced more robust trees, with thicker trunks and fewer losses (ILCA, 1989).

### *Forage utilization and animal performance*

The main benefit derived from leguminous forage in smallholder grass-based systems comes from raising dietary protein content, which improves total food intake, digestibility and animal performance. The impact on animal performance was quantified with sheep and goats in West Africa, and dairy cattle in east Africa, in order to determine the overall economics of using tree foliage as forage rather than mulch.

*Sheep and goats:* The inclusion of leguminous tree forage in a *Panicum* ration on-station had a significant effect on nutrient intake, raising the productivity of sheep and goats. West African Djallonke sheep are more responsive to supplements than West African Dwarf goats (Reynolds and Adediran, 1988; Reynolds, 1989). Supplementary feeding with *Leucaena* and *Gliricidia* in late pregnancy and lactation increased the proportion of offspring surviving to weaning from below 50% on a diet of *Panicum* to over 95% when they were given a *Leucaena/Gliricidia* mixture as 40% of the total dry matter (DM) intake. Direct supplementation of weaned offspring also increased growth rates, but this had less impact on overall production than supplementing the dams in early lactation, which increased milk production to the benefit of the offspring. Overall, this is the most efficient way to use leguminous tree forage when it is available in limited quantities.

Improved nutrition also increases resistance to diseases such as trypanosomiasis (Reynolds and Ekurukwe, 1988). Any protein-rich supplement would produce similar effects, but farmers do not have access to the feed, or are unwilling to spend cash on supplements. On-farm production of legume forage can be seen as a low-cost route to improved animal performance. Improvements in survival rates of young stock will be of particular interest to farmers, since in village systems with free-roaming goats increased survival has greater economic impact than increased growth (Bosman and Ayeni, 1993).

*Dairy cattle.* Smallholder dairy production, from over 300,000 farmers, provides 80% of Kenya's milk. Production averages 5-6 litres/cow/day, close to the predicted maximum from a grass-only diet. An intensive extension effort over the years has encouraged farmers to grow Napier grass, stall-feed dairy animals and offer purchased concentrates. This has been one of the most successful livestock development projects on the continent but further advances are needed if it is to meet the continuing demands from an expanding population. Purchased concentrates are expensive, and although the economic returns are high, usage is low in the smallholder sector. Dairy production provides about half of farm income in this sector, with the rest coming from crop production. Hence, alley farming with leguminous trees could have a role in meeting farmers' multiple crop and livestock objectives.

The effect of supplementing a dairy cow receiving a Napier grass diet with *Leucaena* forage varies according to the physiological state of the animal. Overall, 1 kg of *Leucaena* DM in the diet gives an extra 0.5 kg of milk. In early lactation the response in

milk production is high, particularly in the dry season when the basal ration of grass is of low nutritive value, but in mid to late lactation the response is more muted (Table 3), with a greater proportion of the additional nutrients being directed towards body tissue rather than milk (Muinga et al., 1992). An improvement in body condition of the cow should increase reproductive performance by raising conception rates and shortening calving intervals, but these have not been studied directly with tree legume forages. This is an applied research area that should receive attention.

Intensive feed production causes a heavy drain on soil nutrient reserves, and recycling manure from the dairy unit will increase sustainability. A high quality diet will produce high quality manure. Beneficial effects of manure application on alley farms have been clearly demonstrated (Mureithi et al., 1994), but it is labour demanding and farmers return less than half of the manure to the fields. In addition to raising soil nutrient levels and increasing forage production, manure improves the water-holding capacity of sandy soils. This has a considerable influence on the survival rate of Napier grass in more marginal areas during years with poor rainfall.

As we will see later, the financial benefits for dairy farmers from growing and feeding *Leucaena* forage are very attractive.

Table 3. Dry matter intake (kg/day) and lactation performance of Ayrshire/Brown Swiss x Sahiwal cows in mid-late lactation during the wet season of 1990 and in early lactation during the dry season of 1992 offered Napier grass with maize bran and *Leucaena* supplements.

Year	Supplement (kg DM/day)		Napier intake	Total intake	Milk yield (kg/day)	Weight change (kg)
	Maize bran	Leucaena				
1990	0	0	7.8	7.8a	4.1a	-50a
	0	2	8.3	10.4b	6.1bc	+2b
	1	0	7.2	8.2a	5.0ab	-13ab
	1	2	8.2	11.4b	6.5c	+4b
1992	0	0	5.1ab	5.1a	3.7a	-38ab
	0	2	5.4b	8.0b	6.0b	-27a
	1	0	4.7a	5.6c	6.9b	-68b
	1	2	4.9a	8.4b	8.6c	-29ab

Within a column and a section, values with differing letters are significantly different (P<0.05).

## On-farm research

Initially, alley farms were established in humid West Africa with individual farmers receiving direct assistance from researchers, but the inability of other villagers to relate to the innovation caused a change in the approach. In order to test the technology with a broader group of farmers, a community approach was adopted, in which farmers were contacted through the extension service and village elders (Okali and Sumberg, 1985).

Crop production was the priority of farmers in West Africa, with sheep and goats taking a secondary role. Researchers realized that higher financial benefits from *Leucaena/Gliricidia* forage would be obtained in dairy systems, as demonstrated in dairy development projects in the Caribbean, Asia and in East Africa. However, there were no dairy farmers in the study area of West Africa. In 1988 a research project was started in East Africa, in association with an existing development project involving smallholder dairy farmers, whose interest in alley farming and multipurpose trees would be more directly linked to animal performance.

### *Alley farming with small ruminants in West Africa*

Adoption and continued use by farmers is the ultimate test of an improved production system. By 1984, ILCA was using a developmental research approach in southwest and southeast Nigerian villages, selected to represent forest and savannah farms and different levels of population density (Atta-Krah, 1985). A community approach encouraged sufficient farmers to establish alley farms so that the biological, social and economic potential of the technology could be determined. By 1991, in loose association with ILCA, 139 farmers in south-west Nigeria had planted 175 alley farms or feed gardens, with 109 farmers and 119 plots established in southeast Nigeria. The topics investigated included tree-crop and tree- livestock interactions, land tenure, labour and gender issues.

*Tree-crop interactions.* Intercropping is the normal practice on farms. Some 45% of alley plots under full farmer management were intercropped with tubers (cassava and/or yam), with a further 34% growing a tuber plus another food crop (including 21% with cassava/maize; Atta-Krah and Francis, 1987). This indicates the direction that applied agronomic research should take to be of relevance to farmers. To confirm on-station results, at the instigation of researchers, farmers established and managed alley farm plots with maize as the sole crop, and applied various proportions of the prunings as mulch in order to determine agronomic parameters on-farm. As in the on-station trials, a linear response in grain yield to mulch was obtained, rising from 1.4 tonnes of grain/ ha without mulch to 2.7 tonnes/ha when all the tree foliage was applied.

Farmers' perceptions of an innovation are important in understanding impact. Farmers with alley farms also cultivate conventional farms. Overall, 96% of the alley farmers reported using inorganic fertilizer on the conventional farm, but only 9% applied it to the alley plots. Hence, the value of mulch as a replacement for fertilizer is well recognized by farmers (Reynolds *et al.*, 1991). Over 85% of farmers had used tree foliage for both mulch and fodder.

*Tree-livestock interaction.* On-farm studies were undertaken with free-roaming goats in two villages in southwest Nigeria over a two-year period. Household wastes and cassava peels and tubers made up the greater part of the supplements offered on both categories of farms (table 4). Cut-and-carry browse-feeding households (defined as those offering browse on more than 10% of visits by enumerators), at an annual rate of 348 kg *Leucaena/Bliricidia* (as fed) per house-holds (defined as those offering browse on more than 10% of visits by enumerators), at an annual rate of 348 kg *Leucaena/Gliricidia* (as

fed) per household (equivalent to less than 12 kg DM/animal/year). An earlier study of 134 farmers found that 75% felt enough tree fodder was going to their animals, and even the researchers believe that the quantities involved were insufficient to have a market impact on performance (Reynolds et al., 1991). Differences in litter size, parturition intervals, growth rate and survival of kids to 12 months were non-significant, but survival rate of adults was 92% for browse feeders, compared to 70% for non-browse feeders. Although doe productivity, expressed as the weight of kids surviving to 12 months of age per doe per year, was not significantly different between categories, herd productivity, which is doe productivity multiplied by doe survival, was 43% higher for browse feeders than non-browse feeders ( $P<0.05$ ). Browse feeding levels were low, but herd productivity improved.

Table 4. Characteristics and performance of village goat herds receiving or not receiving *Leucaena* and *Gliricidia* browse in southwest Nigeria.

	Browse	No browse
Animal (per household)	12.2	6.5
Adult female animals (per household)	6.1	3.5
Frequency of browse offered (% days visited)	30	1
Feed consumed (kg/household/year):		
Browse	398	7
Cassava peel and tubers, household wastes	1031	915
Productivity indices (kg/doe/year):		
Doe productivity <sup>1</sup>	12.3	11.3
Herd productivity <sup>2</sup>	11.3	7.8

<sup>1</sup> Does productivity = kid weight at 12 months post-partum x Kid survival to 12 months  
x 365/kidding interval

<sup>2</sup> Herd productivity = doe productivity x doe survival rate

*Land tenure issues.* Land tenure was expected to be a factor in the willingness of farmers to plant trees (Francis, 1987), and a three-country study (Nigeria, Togo, and Cameroon) was undertaken to test this hypothesis. Farmers must take a long-term view if the benefits from leguminous trees are to feature in their planning, and it was felt that security of tenure was needed for this to be possible. The study concluded that land under divided inheritance, on which the heirs have full control, accounted for a large proportion of the functioning alley farms, while discontinued alley farms were more likely to be found on land under undivided inheritance over which no individual has direct control (Lawry and Steinbarger, 1991). Hence, in Togo and southeast Nigeria, where a large proportion of the land was held under undivided inheritance, alley farming proved less acceptable to farmers than in southwest Nigeria where individual ownership is more common.

However, land tenure was not mentioned by farmers as a reason in their decision to discontinue alley farming; factors such as poor tree growth and changes in the personnel actively farming were the main reasons given.

*Labour issues.* In 1986, the labour requirements for alley farming were felt to be a possible constraint to its adoption. Labour data were collected for the entire crop production cycle on farms producing mixtures of crops. Starting from clearing land on discontinued alley farms which were being brought back into cultivation from fallow (preserving the alleys), and on conventional fallow that had been uncultivated for the same number of years, land clearing, ridging, planting, pruning and weeding required a total of 68 and 76 person-days for alley and conventional no-tree plots respectively. Labour expended on harvesting and carrying was a function of crop yield and the distance of the plot from the household. The total labour required for crop production was not significantly different in the two systems, but the distribution of labour over the year did vary. Pruning and weeding operations may overlap, creating competition for labour, and as the former is judged by farmers to require more skill, obtaining additional labour for pruning may be difficult. Labour productivity under alley farming was higher because of significantly higher yields obtained with little additional costs (Reynolds et al., 1991). Based on the experience of labour-intensive technology in Aisa, alley farming may be advocated for those African farmers who cannot practice the bush fallow system because of shortage of land, and who can only afford minimal inputs.

*Gender issues.* In 1984 it was realized that few women were participating in the on-farm project. Only 12 out of 68 plots were controlled by women, although many women owned small ruminants. A separate women's programme was launched in 1984 with a female research/extension worker, and 27 women planted alley farms. After 2 years that initiative ended and the women were encouraged to join the general group. By 1990 only three out of the 27 alley farms established by the women's group were still functional, whereas all 15 of the plots established by women as part of the general initiative were still in use. It should be noted that fallowing was still being practiced after the alley farms had been established, and it is probable that some of the non-functional alley farms would be returned to cropping in the course of time. Nevertheless, it was concluded that a unified general approach through the village community, reaching both male and female farmers and using both male and female extension staff, would be more effective than approaching the sexes separately (Reynolds et al., 1991).

#### *Smallholder dairy production in East Africa*

When milk production is the objective, livestock may come at the top of a farmer's list of priorities. Milk provides a regular cash income and food for the household, and dairy cows have a high capital value. Thus, farmers with dairy cattle are prepared to allocate resources to protect their investment. Tree/grass combinations for forage production can be expected to have a higher adoption rate on dairy enterprises than with small ruminant farmers.

The promotion of *Leucaena* as feed for livestock in East Africa was started by development projects, rather than by researchers as was the case in West Africa. As a result, there is limited data available that can be analysed in a systematic way. Alley farming was uncommon, but *Leucaena* trees were used as boundary markers or in short rows near the cattle shed. In Tanga, northwest Tanzania, where naturalized *Leucaena*

grows profusely along roadsides, 80 tonnes of dried *Leucaena* leaf meal were produced in 1991 by women and children for sale as animal feed. Surveys across urban dairy farms with a mean herd of two lactating cows showed between 0.5 and 0.6 kg of *Leucaena* leaf meal being offered daily as a supplement.

Across the border in the Coast Province of Kenya, *Leucaena* is less commonly found as a naturalized plant, but its cultivation has been encouraged by the National Dairy Development Programme (Maarse *et al.*, 1990). The research study began in the Coast Province of Kenya in 1988, where a dairy development project has been operational since 1980. In April 1992, following encouraging on-station trials and an enthusiastic adoption by a few innovative farmers, field days were held on farms with well established *Leucaena*, and over 200 farmers requested *Leucaena* seed to plant on their own farms. Establishment, management, production and utilization are being monitored by research and development staff, seeing how farmers have modified recommendations to suit their own circumstances, and the effects of those modifications on production.

Milk yield from crossbred cows on smallholder farms is limited to around 5 kg/animal/day without supplementation. While this is twice to three times as much as a local Zebu cow will yield, it is less than a third of the potential of a crossbred cow. Milk receipts go to meet general household expenses, and little is retained to purchase inputs (feeds, veterinary care) for the cows. On-farm production of high quality supplementary feed from legume trees, used strategically, could allow milk output for the whole lactation increase by 25%. Boundary planting, single lines or tree-only plots are some of the alternatives that farmers are using to incorporate legume trees on the farm, and these may prove more adoptable than alley farming.

Before 1992, *Leucaena* in Africa was free of major pests or diseases. However, reliance on a single species involves risk, which small-scale farmers try to minimize. The *Leucaena* psyllid (*Heteropsylla cubana*), arrived at the East African coast in August 1992, after sweeping through the Asian/Pacific region. The first harvest of *Leucaena* at Mombasa after attack by the psyllid was almost 90% lower than the preceding harvest. Asian experience suggests that although initial damage is severe, the situation stabilizes so that after 6 years little signs of insect damage on *Leucaena* can be seen, although foliage production does not fully return to the original level (van den Beldt, 1992).

Psyllid-resistant *Leucaena* varieties are being developed by the Nitrogen Fixing Tree Association, but seed availability will be a constraint on their dissemination for many years. It would be advisable to have other forage tree options for alley farming. *Gliricidia sepium*, which can be used in combination with *Leucaena*, is less palatable. Palatability can be increased by allowing it to wilt for a few hours, so that it loses its characteristic astringent odour, before offering the feed to livestock (Nitis, 1987). A range of *Gliricidia* accessions have been evaluated, and the most agronomically productive forages were not the most palatable to livestock. Thus, when tree foliage is to be used for fodder, it is important that other parameters besides biomass production be taken into account in the screening process.

The search for alternative tree species must continue.

## Profitability

A number of economic analyses using African data have shown that alley farming, focusing on crop production, is more profitable than conventional bush fallow systems in humid and subhumid conditions (Ngambeki, 1985; Ehui *et al.*, 1990). Alley farming may not be profitable under conditions of land abundance or where fertilizer is readily available, but the inclusion of small ruminants in the system was found to be beneficial, especially on smaller farms (Sumberg *et al.*, 1987; Ashraf, 1990).

The most important factors determining whether prunings should be used for fodder or mulch are the relative prices received by farmers for meat and grain, and the responses of animals and plants to the tree foliage. At low crop yield levels and low crop responses, feeding small stock with part of the foliage is profitable. At higher crop yield and response levels, inclusion of small stock in the system is not profitable. Jabbar *et al.*, (1994) used a capital budgeting procedure to compare the profitability of three land use systems in West Africa: traditional (non-alley) farming, alley farming with fallow, and continuous alley farming (Table 5). The results indicated that continuous alley farming was more profitable than traditional farming or alley farming. A two-year fallow with two years of cropping reduces the rate of mining of soil nutrients and preserves future profitability. The value of lost soil nutrients, based on the cost of those nutrients if they were to be supplied from an inorganic fertilizer, is low compared to the value of the crop offtake. The inclusion of small ruminants significantly increases profitability of alley farming. Alley systems are still profitable when terminal clearing is included as a cost, assuming that trees have a 9-year productive life (Jabbar *et al.*, 1994).

Table 5. Present value of gross margins from three alternative farming systems in southwest Nigeria (Naira/ha/year) over a 9-year period.

	Land use system		
	Traditional farming	Alley farming with fallow	Continuous alley farming
Cropping only	16 325	16 324	21 255
Cropping, allowing for soil nutrient loss	16 176	16 204	21 070
Crops and livestock	16 176	18 794	23 749
Crops and livestock with terminal tree clearing costs	16 074	18 489	23 444

US\$1 = 5 Naira in 1988.

Preliminary economic analysis has been undertaken with smallholder dairying. Between April 1990 and August 1991, covering three cropping seasons, 8.6 tonnes DM *Leucaena* leaf/ha were harvested in an on-station trial at Mombassa. When all the tree prunings

were applied as mulch, maize grain yield increased by 2.1 tonnes. If the same quantity of *Leucaena* were to be fed to lactating cows at a rate of 2 kg/head/day, an estimated 5.2 tonnes of extra milk could be produced. Tree biomass would be more profitably used as animal feed when the price of milk is at least 0.4 times that of grain. In February 1993 milk was over 1.3 times as expensive per kg than grain. Hence, the gross financial return was over 3.3 times higher when all the tree biomass was used for feed than when it was used for mulch. Additional benefits can be obtained from the use of by-products; manure as fertilizer, and maize bran as animal feed. On a typical farm, the additional nitrogen in manure from supplemented cattle, returned to a maize crop as fertilizer, would increase maize yield by 1.0 tonnes/ha. The use of maize bran (0.5 tonnes) as a feed supplement would increase milk output by 0.5 tonnes. When these additional factors are included the return from using *Leucaena* leaf as animal feed is still 2.9 times higher than when the leaf is used as mulch.

## Conclusion

Alley farming is not a panacea; it may be beneficial in some areas, it will be inappropriate in others. By now, there is enough information to indicate the social, economic and biological environment where alley farming is likely to be attractive to farmers and have an impact. Adoption is most likely in areas with high human population density, and high biological potential; applied research should focus on these areas. Livestock will only be the main focus of attention in an alley system if a high-value livestock yield such as milk is produced. There may be specific market niches, such as sales of animals at festival time when prices are high, that provide the incentive to farmers to direct attention to meat animals, but in general meat production systems will be of secondary importance to alley farmers. Thus, although researchers should take a holistic view of the farm, most alley farming systems will be driven by the needs of crops.

Simulation models should be developed, which could be verified using data from individual trials. Tree-based research studies, such as alley farming, take at least 3 years before a foliage harvest is feasible and the first results from mulching/feeding trials are obtained. A model would eliminate the need to repeat work across all potential sites, and allow ex ante evaluation of impact of alley farming before research and development work starts, so that applied research was only started in the most promising situations. Development of the model would need an understanding of the basic processes governing nutrient availability and uptake from soil, and plant growth, together with an understanding of tree-plant interactions above and below ground. Cut-and-carry livestock feeding, rather than direct grazing, is expected so the model should focus on the digestion, absorption and partitioning of nutrients by animals. Modelling the social and economic factors that influence farmers will also be necessary, to allow predictions of the impact of alley farming on a household, village, district, regional or national basis.

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