Economic analysis of alley farming with small ruminants

J. E. SUMBERG[1], J. McINTIRE[2], C. OKALI[3] and A. ATTA-KRAH[4]
ILCA, P.O. Box 5689, Addis Ababa, Ethiopia

[1]Formerly Agronomist, ILCA, Humid Zone Programme, Ibadan, Nigeria; [2]Economist, ILCA, Addis Ababa, Ethiopia;
[3]Formerly Socio-economist and Team Leader, ILCA, Humid Zone Programme, Ibadan, Nigeria;
[4]Agronomist, ILCA, Humid Zone Programme, Ibadan, Nigeria.

Summary

UNDER ALLEY *cropping leguminous trees or shrubs are grown between alleys of field crops. In some areas it can replace fallow for soil fertility restoration. Alley farming allows the choice between leaving the tree foliage on the soil as mulch, or of feeding it to animals. Economic models of alley farming, alley cropping and fallow use experimental and field data from southwest Nigeria. Principal conclusions are that alley cropping is superior to fallow systems, that alley farming in which leaves are fed to sheep or goats is inferior to basic alley cropping, and that sheep or goat supplementation with leucaena or gliricidia needs to achieve a 30 to 40% increase in net productivity per dam to be competitive with leaving foliage for maize production.*

Introduction

Alley cropping is an agricultural innovation in which crops are grown between rows of densely planted trees. This technique, also known as 'hedgerow intercropping' and 'avenue cropping', is of interest to restore soil fertility in areas where land pressure makes fallow systems increasingly unworkable. The nitrogen- and mineral-rich tree foliage is pruned during the cropping season and applied to the soil as mulch. The trees in an alley farm recycle nutrients from the lower soil profile and produce significant quantities of organic matter, thus playing the same role as the trees, bush and grasses in fallow systems.

The major difference between alley cropping and bush fallow is that soil fertility restoration is concurrent with cropping, thus allowing continuous cultivation. In southwest Nigeria where fallowing is usually practiced, alley cropping based on the leguminous tree *Leucaena leucocephala* has sustained moderate crop yields over 7 years on a sandy soil with low fertilizer inputs (Kang et al, 1981; Kang et al, 1985).

There have been several evaluations of the economics of alley cropping (Raintree and Turay, 1980; Hoekstra, 1982; Verinumbe et al, 1984). None of these analyses have considered livestock. While alley cropping was conceived primarily for crop production, it offers considerable potential for integrating crop and livestock production by supplying mulch for crops and high-quality fodder for animals.

In humid West Africa, sheep and goat production is generally a minor enterprise using few inputs. Production is limited by a viral disease, *peste des petits ruminants* (PPR); control of PPR, especially in goats, can significantly reduce mortality and increase flock growth (Opasina, 1984; Adeoye, 1984; Sumberg and Cassaday, 1985). However, realisation of the potential of small ruminants, following PPR control, may eventually be constrained by feed resources. Alley farming, which is the addition of animals to an alley cropping system, offers the opportunity to realise this potential by producing high-quality feed year round. It would do so without the major new investments sometimes required by specialised fodder production, and without reducing staple crop production.

In this paper, we evaluate alley farming models with small ruminants, based on held and experimental data from southwest Nigeria, and compare them with basic alley cropping and with fallow systems. The analysis is then used to define key management areas within alley farming, as well as areas where further information is needed.

Review of previous work

Previous agronomic work

There has been considerable work on alley cropping for humid areas at the International Institute of Tropical Agriculture (IITA) in Ibadan, Nigeria (IITA, 1978–84; Kang et al, 1981; Kang et al, 1985). This work has focused on soil fertility, alley width, tree pruning, tree species, weed control, mulch decomposition, water relations and labour use. The results, confirmed in other parts of the tropics (Rachie, 1983; Narkhede et al, 1984), generally indicate that the trees can produce sufficient foliage to maintain, and even to increase, crop yields over conventional plots.

Alley widths of 1.5 to 5.0 m have been used experimentally. While narrower alleys of crops permit higher tree populations and increased foliage, they also demand more pruning labour, are more likely to shade the crop, and, at some point, must reduce crop density.

Torres (1982) studied the relationship between alley width and crop density. Assuming a maize density of 53 000 plants/ha and the substitution of 1 row of maize by each row of trees, he found a plot with 4.5-m alleys had only 84% of the maize population of a farming plot without trees. Similar assumptions of reduced maize populations were made in the economic analyses of Hoekstra (1982) and Verinumbe et al (1984).

Previous economic work

Raintree and Turay (1980) and Verinumbe et al (1984) used linear programming models to evaluate alley farming. The former evaluated trees as a nitrogen source for rice production in Sierra Leone. The latter compared alley cropping with five alternate 'zero-tillage' farming systems in southern Nigeria. Both studies concluded that alley farming could be economically attractive. Hoekstra (1982) showed that alley farming could be superior to the traditional system in semi-arid Kenya. Using experimental data, Ngambeki and Wilson (undated) concluded that in spite of a 52% increase in labour use per hectare, the increased maize yield from the alley plots made the system economically attractive.

Justification and structure of models

The models are based on experimental and on-farm research of the International Livestock Centre for Africa (ILCA) and IITA. They represent conditions in humid West Africa (1500 to 2000 mm annual rainfall with a 6- to 8-month growing season). Parameters for crop and tree production are from IITA Annual Reports (IITA, 1978–1984), Kang et al (1981) and ILCA (unpublished data). Animal production parameters are from ILCA's village studies in southwest Nigeria (Mack, 1983; Sumberg and Mack, 1985; Upton, 1985). Daily wages are valued at the minimum wage in Nigeria, maize is valued at the estimated producer price for southern Nigeria, and small ruminant prices are taken from ILCA's market surveys near Ibadan (Okali and Upton, 1985). The exchange rate is ₦ 4 per US$ 1.

The basic fallow model

The fallow model (Table 1) is of a 1-ha plot, cleared and planted to maize for 3 years before it is fallowed. The maize yield is 1000 kg/ha in year 1. This yield declines by 10% in year 2 and by 10% again in year 3 because soil fertility declines. One crop of maize is grown per year without chemical fertilizer.

Table 1. *Assumptions used in four different models.*

BASIC ASSUMPTIONS				
Base maize yield (kg/ha)	1000			
Number of crops/year	1			
Price of maize (US$/t)	125			
Wage of labour (US$/man-day)	1.63			
Discount rate for future values (annual %)	10			
MODEL-SPECIFIC ASSUMPTIONS				
Incremental labour (average man-days/year)	Fallow	Alley cropping	Alley farming	
			Goats	Sheep
Clearing labour	11	0	0	0
Pruning labour	0	18	18	18
Trees				
Foliage output (kg DM/ha/year)	0	3000	3000	3000
Marginal physical product of mulch-N (kg maize/kg mulch-N)				
surface mulch	n.a.[1]	5	5	5
incorporated mulch	n. a.	10	10	10

Breeding animals				
Goats (17 kg LW[2])	0	0	1	0
Sheep (25 kg LW)	0	0	0	1
Price of goats (US$/kg LW)			0.61	
Price of sheep (US$/kg LW)				0.68
Total DM intake as % of LW	n. a.	n.a.	5	5
% of total DM intake from fodder trees	0	0	25	25
Net output (US$/dam/year)				
Goats	n.a.	n.a.	4.62	n.a.
Goats with PPR control	n.a.	n.a.	7.31	n.a.
Sheep	n.a.	n.a.	n.a.	10.9

[1] n. a. = not applicable.
[2] LW = liveweight.

The annual gross value of maize production is calculated over 9 years (three fallow cycles) by multiplying the annual maize yield by the maize price. The incremental cost of producing maize in a fallow system, relative to that in alley cropping is the labour cost of clearing land. Because clearing costs are incurred in year 1 in both the fallow and in the alley cropping system, they are not counted in that year. In the basic fallow model clearing costs are counted in years 4 and 7, that is in the years when a new plot is brought under cultivation. Clearing costs are adapted from Ruthenberg (1976), and are valued at the labour wage and subtracted from the annual gross value of maize production to obtain an annual net value.

The basic alley cropping model without animals

The alley cropping model allows planting leguminous trees to maintain soil fertility with continuous cropping. In the first year, alternate rows of the leguminous trees *Leucaena leucocephala* and*Gliricidia sepium* are direct seeded at 4-m intervals[1] within a recently cleared, newly planted 1-ha maize field. Maize is planted at 1 m x 1 m with 3 plants/hill, for a density of 30 000 plants/ha. This is the traditional planting arrangement and density in the area. Trees are seeded every 25 cm within the rows to give a tree density of 10 000 trees/ha. During the establishment year, tree rows are weeded when the crop is weeded; in most cases, the trees are not pruned during the first 12 months and do not affect crop yield. During subsequent years, the trees are pruned at 0.5 m above the ground at maize planting time, and once or twice during the cropping season.

[1]The experimental and on-farm research upon which the present economic analysis is based used only 4-m alleys. Under conditions in humid West Africa, this alley was considered appropriate for the following reasons: less pruning labour, greater ease of tree pruning and cropping activities, less crop shading and, consequently, more flexible tree management, ability to maintain traditional crop populations, and ability to utilise tractors (which is common in parts of Nigeria). Under experimental conditions foliage yields as high as 6000 kg/ha/year have been obtained.

As in the fallow model, the base maize yield is 1000 kg/ha. The trees produce no usable foliage in the first year of the model; beginning in the second year, they produce 3000 kg/ha of foliage dry matter annually. At a nitrogen content of 3.5%, this foliage contains 105 kg N/ha/year.

If foliage is applied to the soil surface, its marginal physical product (MPP) is 5 kg of maize per kg of mulch-N, and its marginal value product (MVP) is US$ 0.63. If it is incorporated into the soil, its MPP is 10 kg of maize and its MVP is US$ 1.25. Therefore, at a base maize yield of 1000 kg/ha, an annual yield decline of 10%, and with surface application, 20 kg of mulch-N are needed to maintain maize yields at the base level. In this model, all available tree foliage is returned to the soil. After sufficient foliage is returned to maintain maize yields at the base level, the remaining foliage increases crop yield above the base.

The incremental labour cost of alley cropping is for tree pruning, and is estimated at 18 man-days/ha/year. Because the first tree foliage is available in year 2, labour for pruning begins in that year. It is assumed that the trees do not affect labour for weeding or land preparation (Atta-Krah, 1985). It is recognised that there will be incremental labour costs in harvesting the increased maize yield, but these are not modelled.

The alley farming model with goats

This model is identical to the basic alley cropping model except that after sufficient tree foliage has been applied to the soil to maintain base maize yields, the farmer can choose between returning the remaining foliage to the soil, or feeding it to 17-kg breeding does. Daily feed intake is equal to 5% of the animal's liveweight. Tree foliage intake is set equal to 25% or 50% (the 'supplementation rate') of the total daily intake. A 17-kg doe supplemented at 25% would, therefore, eat 213 g of tree fodder per day.

The effect of the tree fodder on animal productivity is expressed as a percentage of the animal's net monetary output (Upton, 1985). Because this percentage is uncertain, a range from 10 to 40% is modelled. At a 10% productivity increase, the MVP of tree foliage-N fed to goats is US$0.17. The annual value of the increased goat output is added to the value of maize production to arrive at the total annual value of alley farming. The labour costs of maintaining the trees are then subtracted from the total annual value, as in the fallow model, to calculate the net annual profits of the system. No additional labour for feeding or for animal care is considered.

The alley farming model with sheep

This fourth model is identical to the third, except that 25-kg breeding ewes are modelled. Because the body weight and market price of sheep are higher than those of goats, there may be substantial differences in results between these two models. At a 10% productivity increase, the MVP of tree foliage-N fed to sheep is US$ 0.27.

Model results

The models are used to answer six questions:

- What is the profitability of alley cropping without animals compared to that of fallow?
- What is the effect of changing the mulching method on the profitability of an alley cropping system?
- What is the profitability of an alley farming system with goats or with sheep compared to alley cropping without animals?
- What are the effects of changing supplementation rates on relative profitabilities of alley farming systems with animals?
- What increases in animal output are necessary to make alley farming competitive with alley cropping?
- What is the effect of PPR control in goats on the competitiveness of alley farming?

Alley cropping or fallow?

The alley cropping model with surface mulching is compared with the fallow model at three base maize yields and five levels of annual maize yield decline (Table 2). The net present value (NPV) of alley cropping is 14 to 59% greater than that of the fallow model. Alley cropping is relatively more profitable at lower base yields and with greater annual yield declines. This trend is similar to that described by Torres (1982). In the present analysis, however, alley farming is profitable at base yields much higher than the 500 kg/ha estimated by Torres.

Table 2. *Ratios of NPV in alley cropping with surface mulching to fallow NPV over ranges of base maize yields and annual yield declines without amendments.*

Annual maize yield decline (%) without amendment	Base maize yield (kg/ha)		
	1000	2000	3000
	————NPV ratio ————		
5	1.47	1.22	1.14
10	1.50	1.23	1.15
15	1.53	1.25	1.16
20	1.56	1.26	1.17
25	1.59	1.27	1.18

Results from alley cropping with mulch incorporation show that incorporation substantially increases alley farming profitability (Table 3). Even if the incremental labour of alley farming is increased by 50% to account for mulch incorporation and labour is decreased by 100% in fallow, alley cropping with mulch incorporation is still 65% more profitable than the basic fallow model.

Table 3. *Ratios of NPV in alley cropping with mulch incorporation to fallow NPV over ranges of labour increases in alley cropping and labour decreases in fallow cropping* [1.]

Labour decrease (%)	Labour increase (%)		
	25	50	100
	——NPV ratio—		
100	1.71	1.65	1.55
75	1.77	1.72	1.61
50	1.85	1.79	1.67
25	1.92	1.86	1.74

[1]All comparisons made with base maize yield of 1000 kg/ha.

Alley cropping or alley farming?

Alley farming with goats or sheep is compared with the basic alley cropping model (Tables 4 and 5). In the absence of PPR control and over a range of livestock and maize prices, the NPV of alley farming with goats or sheep is 80 to 96% and 87 to 111% respectively of the NPV of alley cropping without livestock. This comparison is slightly more sensitive to changes in livestock prices than to changes in maize prices. Sheep contribute more to alley farming than do goats, largely due to higher goat mortality caused by PPR, and to higher prices per kg liveweight.

Table 4. *Ratios of NPV in alley farming with goats to NPV in basic alley cropping.*

Maize price (US$/t)	Goat price (US$/kg LW)				
	0.49	0.55	0.61	0.67	0.73
	————————NPV ratio—————————				
100	0.83	0.87	0.90	0.93	0.96

113	0.82	0.85	0.88	0.90	0.93
125	0.81	0.84	0.86	0.88	0.91
138	0.80	0.82	0.85	0.87	0.89
150	0.80	0.82	0.84	0.86	0.88

Table 5. *Ratios of NPV in alley fanning with sheep to NPV in basic alley cropping.*

Maize price (US$/t)	Sheep price (US$/kg LW)				
	0.54	0.61	0.68	0.75	0.82
	————NPV ratio ————				
100	0.94	0.99	1.03	1.07.	1.11
113	0.92	0.95	0.99	1.03	1.06
125	0.90	0.93	0.96	0.99	1.02
138	0.88	0.91	0.94	0.97	0.99
150	0.87	0.89	0.92	0.94	0.97

The effects of supplementary feeding of leucaena and gliricidia on animal productivity under village conditions are not well documented. Therefore, the NPVs of alley farming are compared to those of alley cropping over a range of increases in net output due to feeding (Table 6). With 50% supplementary feeding, increases in net output of 40% per dam are needed to make alley farming competitive with alley cropping. At the 25% supplementation rate, which allows for the feeding of twice as many animals, increases in net output of 36.8% for goats and of 23% for sheep make feeding competitive with maize production. After control of PPR, the necessary increase in net goat output is reduced to 23%.

Table 6. *Ratios of NPV in alley farming with small ruminants to NPV in alley cropping as affected by feeding and PPR control.*

	Increases (%) in net goat output due to					Increases (%) in net sheep output due to feeding alone			
	Feeding alone				PPR control with feeding[1]				
	10	20	30	40	20	10	20	30	40
Supplementation Rate (%)[2]	———NPV ratio———					———NPV ratio———			

25	0.78	0.86	0.94	1.03	0.96	0.83	0.96	1.09	1.23
50	0.73	0.78	0.82	0.86	0.82	0.76	0.83	0.89	0.96

[1] At 20% increase in net goat output due to feeding.
[2] % total intake contributed by leucaena leaves.

Conclusions

These models indicate that under conditions found in southwest Nigeria maize production with alley cropping is more profitable than with a 3-year fallow system. Alley cropping is less profitable with higher base maize yields. While alley cropping requires more labour than the fallow system, this is more than offset by the increased maize yields, and relative profitability of alley cropping is insensitive to changes in labour requirements.

The amount of tree foliage and the method of mulching affect alley cropping profitability. The models assume a low tree foliage yield of 3000 kg/ha/year based on difficulties of obtaining good tree stands in village conditions. Low foliage yields reflect farmers' hesitancy to plant densely to obtain high populations. Better methods of tree establishment (or better instructional methods) that assure good stands would therefore add to the overall attractiveness of alley cropping. Mulch incorporation, particularly if done at tillage or weeding times and thus not requiring additional labour, can increase the profitability of alley cropping.

With PPR control, particularly for goats, increases in net output of 20 to 30% per dam from 25% supplementary feeding are needed to make small ruminant feeding competitive with maize production. The reproductive *potential* of West African Dwarf goats and sheep has been well documented; the principal goal of future research must be to demonstrate that supplementary feeding of high-quality fodder species such as leucaena and gliricidia is effective in realising this potential.

It is interesting to speculate on the potential of alley farming in other tropical areas, particularly those where fallow has been replaced by continuous cropping. Table 3 indicates that with a 100%*decrease* in clearing labour in the fallow system (continuous cropping) and a 100% *increase* in pruning labour, alley cropping with mulch incorporation is still 55% more profitable. In areas where production is constrained more by land than by labour, alley farming appears to be a technology which should be vigorously investigated.

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