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FINANCIAL ANALYSIS OF AGROFORESTRY PRACTICES

Fodder shrubs in Kenya, woodlots in Tanzania, and improved fallows in Zambia

1. INTRODUCTION

Over the last two decades, researchers and farmers in east and southern Africa have combined their expertise and knowledge to develop improved agroforestry practices that improve livelihoods and provide important environmental services. Much of the research has focused on increasing biophysical productivity (Sanchez, 1996; Cooper, Leakey, Rao, & Reynolds, 1996), but, during the last 10 years, there has been greater emphasis on social and economic considerations. For example, much work has been done to assess the profitability of these practices and their feasibility and acceptability to farmers (Franzel, Coe, Cooper, Place & Scherr, 2001; Place, Franzel, DeWolf, Rommelse, Kwesiga, Niang et al., 2002).

Analyzing the economics of agroforestry practices is more complicated than that of annual crops for two main reasons. First, agroforestry practices are complex because they involve both trees and crops. Devising field trials to assess agroforestry practices and compare them with other practices is extremely difficult, requiring large plots and, at times, large spaces between the treatments. Second, there is usually a period of several years between the time the trees are established and the impact of agroforestry practices can be measured. Conducting trials and surveys with farmers over several years is expensive and problematic. For example, the greater the length of the trial, the more likely that individual farmers will want to change trial parameters in response to changing circumstances or preferences. The more changes that each farmer makes, the less likely it is that treatments can be compared across farms (Coe, 1998; Franzel et al., 2001).

The objective of this chapter is to assess the financial[1] returns to farmers of three practices: fodder shrubs in Kenya, rotational woodlots in Tanzania, and improved fallows in Zambia. Each practice has a different objective for farmers: fodder shrubs

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are for increasing milk production, rotational woodlots provide firewood, and improved fallows are for improving soil fertility. In each case, the implications of the analyses for researchers, extensionists, and policy makers are discussed. Finally, conclusions are drawn concerning the attractiveness of agroforestry practices for farmers and research challenges for enhancing their profitability.

2. DESCRIPTION OF THE AGROFORESTRY PRACTICES ANALYZED

2.1. Fodder shrubs, Kenya

The low quality and quantity of feed resources is a major constraint to dairy farming in central Kenya, where farm size averages 1-2 hectares (ha) and about 80% of households have stall-fed dairy cows, averaging 1.7 cows per family. The dairy zone ranges in altitude from 1300 meters (m) – 2000 m and rainfall occurs in two seasons, averaging 1200 millimeters (mm) – 1500 mm annually. Soils, primarily Nitosols, are deep and of moderate to high fertility. The main crops are coffee, produced for cash, and maize and beans, produced for food. Most farmers also grow Napier grass (*Pennisetum purpureum)* for cutting and feeding to their cows. But Napier grass is insufficient in protein so milk yields are low, about 6 kilograms (kg) per cow per day (Murithi, 1998). Commercial dairy meal is available, but farmers consider it expensive and most do not use it (Wambugu, Franzel, Tuwei, & Karanja, 2001; Franzel, Wambugu, & Tuwei, 2003).

Researchers and farmers tested several fodder shrubs around Embu, Kenya in the early 1990s and *Calliandra calothyrsus* emerged as the best performing and most preferred by farmers. The research was led by the National Agroforestry Research Project, a collaborative effort of the Kenya Agricultural Research Institute, the Kenya Forestry Research Institute, and the World Agroforestry Centre. Farmers plant the shrubs in hedges along internal and external boundaries, around the homestead, along the contour for controlling soil erosion, or intercropped with Napier grass. When pruned at a height of 1 m, the shrubs do not compete with adjacent crops. Farmers are easily able to plant 500 shrubs, at a spacing of 50 centimeters (cm), around their farms, and are able to begin pruning them within a year after planting. Five hundred shrubs are required to provide a cow throughout the year with 2 kg dry matter per day, adding about 0.6 kg crude protein. On-farm feeding trials confirmed that the farmers could use the shrubs as a substitute for dairy meal or as a supplement to increase their milk production. Dissemination began in earnest in 1999 and by 2003, about 23,000 farmers had planted *calliandra* or three other recommended species of fodder shrubs (Wambugu et al., 2001; Franzel et al., 2003).

2.2. Rotational woodlots, Tanzania

Tabora Region, western Tanzania, is an area of undulating plains and an average annual rainfall of 880 mm, falling over 5-6 months. Soils are 800-900 g (grams) per kg sand, low in organic carbon, nitrogen, and available phosphorus (Otsyina, Minae, & Cooper, 1996a). Land is a public commodity but farmers have secure user rights to the land they use. Farm size averages about 20 ha, most of which is uncultivated (Otsyina et al., 1996a). Farmers use hand hoes for cultivation. They make extensive use of hired laborers, who migrate to Tabora during the cropping season. Livestock are few, only about 5% of the farmers own cows. (Otsyina, Msangi, Gama, Ramadhani, Nyadzi, & Shirma, 1997). Tobacco is farmers' main cash crop; other crops grown for both food and cash include maize, the main food crop, groundnuts, rice, and sorghum. About 60% of the farmers grow tobacco, averaging 1.0 ha per farm. Firewood for tobacco curing is scarce; most farmers hire trucks and cut and transport firewood themselves from the forest. Farmers do not grow trees traditionally because, until recently, wood was plentiful and because they lack information on tree growing and planting material. Both policy makers and farmers are concerned about the rapid deforestation because an important natural resource is being destroyed and because the cost of collecting firewood is increasing as the distance to sources increases (Ramadhani, Otsyina, & Franzel, 2002).

Research on woodlots in Tabora began in 1993/94 at the Agricultural Research and Training Institute, Tumbi (ARTI-Tumbi). In the rotational woodlot system, farmers intercrop food crops with leguminous trees during the first 2-3 years, to maximize returns to their scarce labor. Then they leave the trees to grow, harvest them in about the fifth year, and replant food crops (Otsyina, Msangi, Gama, Ramadhani, Madulu, & Mapunda, 1996b). The most promising species tested by the farmers, in terms of growth, is *Acacia crassicarpa*, a legume. The food crops grown following the tree harvest benefit from the increase in organic matter, nutrient recycling, and nitrogen fixed by the leguminous trees (Ramadhani et al., 2002). Dissemination began in 1997 and by 2000, 961 farmers had planted woodlots.

2.3. Improved tree fallows, Zambia

The plateau area of eastern Zambia is characterized by a flat to gently rolling landscape and altitudes ranging from 900 to 1200 m. Rainfall averages about 1000 mm per year with about 85% falling in 4 months, December-March. The main soil types are loamy sand or sand Alfisols interspersed with clay and loam Luvisols. About half of the farmers practice ox cultivation, the others cultivate by hand hoe. Average cropped land per farm is 1-1.6 ha for hand hoe cultivators and 2-4 ha for ox cultivators. Maize is the most important crop accounting for 60% of cultivated area; other crops include sunflower, groundnuts, cotton, and tobacco. Surveys in the late 1980s identified soil fertility as the farmers' main problem; fertilizer use had been common during the 1980s but the collapse of the parastatal marketing system and the cessation of subsidies caused fertilizer use to decline by 70% between 1987 and 1995. Farmers had a strong felt need for fertilizer but lacked cash for purchasing it (Peterson, 1999; Franzel, Phiri, & Kwesiga, 2002b).

In 1987, the Zambia/ICRAF Agroforestry Research Project began on-station research on improved fallows, using *Sesbania sesban.* Results were encouraging and on-farm trials began in 1992. By 1995, several hundred farmers were involved in a range of different trials, testing and comparing different options. In researcher-led trials, farmers chose among 3 different species and 2 different management options (intercropping with maize vs. growing the trees in pure stands) and compared their improved fallows with plots of continuously cropped maize with and without fertilizer. In farmer-led trials, farmers planted and managed the improved fallows as they wished. Most farmers opted for a 2-year fallow and planted their main food crop, maize, for 2 to 3 seasons following the fallow. Extension activities began in 1996 and by 2001; over 20,000 farmers in eastern Zambia had planted improved fallows (Kwesiga, Franzel, Mafongoya, Ajayi, Phiri, & Katanga, in press).

3. METHODOLOGY FOR ASSESSING PROFITABILITY

3.1. General methods

Farmers using new agroforestry practices obtain increased financial benefits, relative to their existing practices, either through increased biophysical productivity or through reduced input costs. Both are important in all three of the practices examined in this paper. Researchers assessed biophysical productivity and financial net benefits by comparing results on treatment plots in on-farm trials with those on control plots, which represented farmers' existing practices. In all three cases, the trials were designed by researchers, in consultation with farmers, and they were managed by farmers. Researcher-designed trials are more suitable than farmer-designed ones because plot sizes are standardized, facilitating the collection of labor data, and practices are more uniform, permitting comparisons across farms. Farmer-managed trials are preferred to research-managed ones because data on costs and returns will more accurately reflect what farmers experience. The returns to agroforestry practices are highly sensitive to the timing and quality of certain practices, such as pruning. Thus, farmer management helps ensure that the outcomes of these trials are representative of what farmers can obtain on their own (Franzel et al., 2001).

Financial analyses were based on the costs and returns that farmers faced. The analyses did not use time series data taken from trial farmers because the time between planting and harvesting benefits was too long, 5 years in the case of woodlots and improved fallows. Rather farmers at different stages of a practice were monitored in the same year and composite farm budgets were constructed. Enterprise budgets were used for assessing the financial benefits and costs of improved fallows and woodlots, because these practices involved major changes in the maize enterprises they were being compared to. In enterprise budgets, all costs and returns of an enterprise are assessed. On the other hand, partial budgets were drawn up in the case of fodder trees because the practice had limited impacts on the costs and returns of dairy enterprise. A partial budget is a technique for assessing the benefits and costs of a practice relative to not using the practice. It thus takes into account only those changes in costs and returns that result directly from using a new practice (Upton, 1987).

Detailed information on labor use among participating farm households was collected using two main methods: including farmers' recall just after a task was completed and monitoring of work rates through observation. Prices were collected from farmers and from local markets.

Financial analyses often calculate returns to only one resource, land, ignoring the fact that labor and capital are far greater constraints than land in many farming systems. Therefore, we calculated the net returns to land, which was relevant for farmers whose most scarce resource was land and the net returns to labor, relevant for those who lacked household labor. In calculating returns to land, land was not valued but household labor was valued at its opportunity cost as estimated by hired labor prices. Returns are expressed on a per-hectare basis. For returns to labor, household labor was not valued and returns were expressed per unit of labor, that is, per workday. Net returns to capital for agroforestry practices are often extremely high or infinite because little or no capital is used in implementing them. This finding explained the attractiveness of many of the options because the alternatives, for example, fertilizer to improve crop yields or dairy meal concentrate to increase milk yields, were very expensive for farmers.

Data for a single period are usually inadequate for evaluating the performance of an agroforestry practice. Therefore, cost-benefit analyses, also called investment appraisals (Upton, 1987), were developed for estimating costs and benefits over the lifetime of an investment. Average values for costs and returns across a sample of farmers were used to compute net present values. Also, in the case of improved fallows, net present values were calculated for each individual farm based on its particular costs and returns. This latter method allowed a better understanding of the variation in returns and thus the risk of the practices.

Whereas cost-benefit analyses are useful for determining the net present value of an enterprise that has costs and returns over many years, they do not show the increase in annual income generated. To assess increases in annual income, farm models were developed in which the farm was partitioned, to contain specified portions of land devoted to each phase (corresponding to a season or year) of the practice. For example, in the model of improved fallows in Zambia, the farm was assumed to have equal portions of area in each of the practice's four phases: planting of the improved fallow (year 1), maturing of the fallow (year 2), the first post-fallow maize crop (year 3), and the second post-fallow maize crop (year 4). The net returns of this farm were compared to two other farms having the same amount of labor (the main constraining resource): one planting fertilized maize and the other planting unfertilized maize, both continuously without fallow. The model was thus useful for estimating the impact of improved fallows on annual net farm income and maize production (Franzel et al., 2002b).

3.2. Fodder shrubs

The data on the planting and management of the shrubs are from on-farm trials conducted in the early- and mid- 1990s and are described in Franzel, Arimi, and Murithi (2002a). In these trials, farmers planted and managed the shrubs as they wished; researchers monitored farmers' experiences. The trials could thus be described as farmer-designed and farmer managed. On the other hand, the feeding trials for determining milk yields were researcher-designed and farmer-managed, that is, researchers designed the treatments, in consultation with farmers, and the farmers managed the trials. These trials were conducted in 1994 and 1995 and are described in Patterson, Roothaert, Nyaata, Akyeampong, and Hove (1996).

Partial budgets were drawn up to show the effects of using fodder shrubs on farmers' net income under two scenarios: using *calliandra* 1) as a supplement to the normal diet and 2) as a substitute for purchased dairy meal. The base analysis assumes a farm with 500 trees and 1 zero-grazed dairy cow and covers a 10-year period. In fact the productive life of the tree appears to be longer, farmers who have had their trees for 10-12 years have not yet noticed any reduction in productivity. The benefits included in the analysis are the effect of *calliandra* on milk production (in the supplementation case) and the cash saved by not purchasing dairy meal and interest on cash freed up (in the substitution case). Costs are those for producing the seedlings and labor for planting, cutting, and feeding *calliandra* in 2001. Estimates of these costs were made by interviewing farmers shortly after they had completed the tasks. All costs for producing the seedlings are for labor, except for the cost of hand tools, which are used for other enterprises as well, and for seeds, which are valued at the market rate but which many farmers obtain for free from their own trees, those of neighbors, or from organizations. Therefore, in most cases, no cash expenditures are required for producing fodder shrubs. It is assumed that dairy meal and *calliandra* are fed 365 days per year as is recommended, whether the cow is in lactation or not.

Coefficients, prices, and sources of data used in the economic analysis are shown in Appendix A. Milk output per day per unit of *calliandra* or dairy meal is likely to be higher during the rainy season than during the dry season because there is more available basal feed during the rainy season. As the feeding trials were conducted during the dry season, the milk yields and profits that farmers can get from using *calliandra* or dairy meal may be lower in this study than what farmers can actually get on an average annual basis. The variability of financial returns could not be statistically assessed because a complete set of input-output data was not available for each individual farm. However, sensitivity analysis was conducted to determine the effects of changes in key parameters on profitability.

3.3. Rotational woodlots

For the on-farm trial, tobacco farmers were chosen randomly from 3 tobacco-growing villages in 3 districts, using lists of farmers available at village offices. The selected farmers were then visited to see if they were interested in hosting the on-farm trial. Five farmers planted in 1993/94 (the planting season extends from December to February), 10 in 1994/95, 8 in 1995/96, and 37 in 1996/97. The trial involved three tree species but only the best performing one, *Acacia crassicarpa,* is included in the economic analysis. Seedlings were raised in a nursery and transported to farmers' fields. The trial was researcher-designed and farmer-managed; researchers marked out plots and advised on management but farmers conducted all operations. The trial included 3 plots, 1 for each species, planted at a spacing of 4 m by 4 m (625 trees/ha). Plot size ranged from 0.07 ha to 0.16 ha depending on the land the farmer had available; thus each farmer planted about 44 to 100 trees of each species. Farmers planted maize between the newly planted trees during the first 2 years after the trees were planted. They were also advised to weed, dig micro-catchments around each tree, and apply compound fertilizer, which is recommended for maize. In fact, weeding and applying fertilizer to maize are common practices in the area. Farmers were also trained on how to prune the trees. Wood yield was measured from 4 of the 15 farmers who planted in 1993/94 and 1994/95; only 1 other farmer had harvested their trees. Otsyina et al. (1996b) and Ramadhani et al. (2002) provide more details on the trial.

The profitability of rotational woodlots was assessed by comparing it with a maize-fallow rotation, because farmers planted woodlots on fields that they indicated would have been used for growing maize for 2 years followed by a 3-year fallow. Enterprise budgets for both rotational woodlots and maize-fallow rotations were drawn up over a 5-year period, using data on inputs, outputs, and prices obtained from the farmers and other key informants (Appendix B). The analysis assumes that farmers harvest the woodlots in the fifth year. Wood prices were valued at the price farmers pay to have wood trucked in from the forest for curing their tobacco. Labor inputs and wage rates were obtained from a formal survey of 30 trial farmers in 1997. Maize seed and harvest prices were averages of market prices over the period 1995/96-1996/97. Maize yields with and without trees were not measured, but the trees were estimated to have no effects on maize yields in the first year and to reduce maize yields by 40% in the second year, based on results from an on-station trial and observations (Otsyina et al., 1996b).

A farm-level model was drawn up to assess the impact of rotational woodlots on farm profitability. In the first scenario of the model, the farmer uses 75 workdays year^{-1} to grow 1.33 ha of rotational woodlots, planting one-fifth of this amount, 0.27 ha, each year, the area needed to provide sufficient firewood each year for domestic use and for curing 1 hectare of tobacco. In the second scenario, the farmer uses the same amount of labor to cultivate maize. As in the case of fodder trees, sensitivity analysis was used to assess how changes in key parameters affected profitability.

3.4. Improved fallows

During 1996-98, data were collected on costs and returns from 12 selected farmers planting *sesbania* improved fallows in researcher-designed, farmer-managed trials.

All trials included an improved fallow plot and plots continuously cropped with and without fertilizer. Data from these trials were supplemented by data from other farmers, local markets, and secondary sources. The 12 were the only ones who had complete sets of yield response data from the improved fallow trials during 1995/96 and 1996/97. Enterprise costs and returns were drawn up for the 12 farms and used to calculate net present values per hectare to assess returns to land and net returns to labor. The analysis covered a period of 5 years: 2 years of fallow and the 3 subsequent years for which it is assumed that maize yields would be affected. Maize yields following *sesbania* fallows were available for 5 farmers for 1996 and 7 farmers for 1997. Average data on costs were used in each individual farmer's budget; maize yields from different treatments were measured on each farm and were thus specific to each farm. Where costs were a function of yield, as in the case of harvesting labor, they were adjusted in relation to yield. Sensitivity analysis was conducted to show the effects of changes in parameters on the results of the economic analysis.

Farm models were drawn up to assess the impact of adopting improved fallows on annual income, as mentioned above. Models were drawn up for the same three scenarios as for the enterprise budgets: farms that adopt improved fallows (planting a portion of their maize area to improved fallows each year, so that each portion is in a different phase of improved fallows), farms that cultivate unfertilized maize, and those with fertilized maize.

4. RESULTS AND DISCUSSION

4.1. Fodder shrubs

Partial budgets for *calliandra* as a supplement to farmers' basal feed and as a substitute for dairy meal in 2001 are shown in Tables 1-2. Tree establishment costs (including the costs of producing bare-rooted seedlings[2] in a nursery and transplanting them) are modest, $US 7.14/500 trees. Beginning in the second year, harvesting and feeding 2 kg dry *calliandra* per day as a supplement throughout the lactation period increases milk production by about 372 kg[3]/yr., an increase of about 12% over base milk yields. Incremental benefits per year after the first year are over 9 times higher than incremental costs. The net present value (NPV) assuming a 20% discount rate is $US 260. Net benefits per year after year 1 are $US 79.

In the partial budget assessing *calliandra* as a substitute for dairy meal, establishment, cutting, and feeding costs are the same as in the preceding analysis. By feeding *calliandra*, the farmer saves the money he would have spent buying and transporting 730 kg dairy meal during the year. Incremental benefits per year after the first year are over 13 times higher than incremental costs. Milk production does not increase but net benefits are slightly higher than in the supplementation case. The NPV assuming a 20% discount rate is $US 413. The net benefits per cow per year after year 1 are $US 125. Therefore, using *calliandra* increases farmers' annual income by about $US 79 to $US 125 per cow per year after the first year, depending

Table 1. Partial budget: Extra costs and benefits of using calliandra as a supplement for increasing milk production, central Kenya ($US/yr, 2001).

	Extra cost		*Extra benefit*		*Net benefit*
Year	*Item*	*$US*	*Item*	*$US*	*$US*
1	Tree seedlings	3.85			
	Planting labor	3.3			
	Subtotal	7.14		0	-7.14
2	Cutting/feeding labor	10.03	Extra milk produced (372 kg)	89.18	79.16

Net Benefit = extra benefits minus extra costs. Years 3-10 same as year 2. Net present value at 20% discount rate = $US 259.95 per year; Net benefit per year after year 1 = $US 79.16; Annualized net benefit treating establishment costs as depreciation = $US 76.77. Note: Base farm model: The farm has 500 calliandra trees and one dairy cow. The cow consumes a basal diet of 80 kg Napier grass per day and produces 10 kg milk/day. Coefficients are from Appendix A.

Table 2. Partial budget: Extra costs and benefits of using calliandra as a substitute for dairy meal in milk production, central Kenya ($US/yr, 2001)

	Extra cost		*Extra benefits*		*Net benefit*
Year	*Item*	*$US*	*Item*	*$US*	*$US*
1	Tree seedlings	3.85		0	
	Planting labor	3.3			
	Subtotal	7.14			-7.14
2	Cutting; feeding labor	10.03	Saved dairy meal cost	129.72	
			Saved dairy meal transport	4.02	
			Interest on capital	1.11	
	Subtotal	10.03		134.85	124.82

Years 3-10 same as year 2. Net present value at 20% discount rate = $US 413.36. Net benefit per year after year 1 = $US 124.82. Annualized net benefit treating establishment costs as depreciation = $US 122.44. Note: Base farm model: Same as in Table 1. Coefficients are from Appendix A.

on whether the farmer is supplementing or substituting. As the average farmer owns 1.7 cows, *calliandra* has the potential to increase a farmers' income by about $US 134 to $US 212 per year representing an increase of roughly 10% in total household income (Murithi, 1998).

The net benefits per cow per year after the first year are somewhat lower than those calculated for the years 1996-1998, as reported in Franzel et al. (2002a). Net benefits for 1996-1998 (expressed in 2001 dollars after adjusting for inflation) ranged from $US 114 to 183 per cow per year after the first year, depending on whether *calliandra* was used for supplementation or substitution. The 2001 figures, $US 79 to $US 125, represent a reduction of about 30% as compared to the 1996-98 figures. The main causes of the decline were an adjustment in the input-output coefficient (the amount of milk produced from *calliandra*) and a reduction in milk prices, associated with a decline in processing facilities following the collapse of Kenya's dairy marketing parastatal in the late 1990s.

The analyses confirm that the costs of establishing, maintaining, and feeding *calliandra* are low. In both the substitute and supplement scenarios, farmers recover their costs very quickly, in the second year after planting. In order to break even, a farmer using *calliandra* as a supplement needs to obtain only 0.08 kg of milk from 1.0 kg of *calliandra* (dry), rather than the 0.62 kg milk per kg (dry) of *calliandra* obtained in on-farm trials and assumed in the analysis (Paterson et al., 1996).

Several intangible or otherwise difficult to measure benefits and costs have been omitted from this analysis. *Calliandra* provides benefits to some farmers as firewood, in erosion control, as a boundary marker, a fence, and as an ornamental. It also increases the butterfat content of milk, giving it a richer taste and creamier texture. When used as a supplement, *calliandra* may improve animal health and fertility and reduce the calving interval. Finally, several farmers noted that *calliandra* had important benefits relative to dairy meal: it was available on the farm, cash was not needed to obtain it, and its nutritional content was more reliable than that of dairy meal. These views support the thesis that farmers prefer enterprises and practices that do not rely on uncertain governmental or market mechanisms (Haugerud, 1984). The main cost not assessed was the opportunity cost of the land occupied by the shrubs. However, this cost is likely to be low or none, especially when *calliandra* replaces or is added to an existing hedge or bund, is planted on contour bunds to conserve soil, or when *calliandra* hedges border on homesteads, roads, paths, or field boundaries. Another possible cost is the effect on nearby crops. But, because the shrubs are nitrogen fixing and are usually maintained at heights of only 1 m, they have little or no negative effects on adjacent crops. In a survey of *calliandra* growers, only 7% felt that the shrubs reduced the yields of nearby crops (Franzel et al., 2002a).

Sensitivity analysis was conducted to determine how changes in key parameters would affect the results (Table 3). A 30% reduction in the milk price would reduce the NPV by 35%. However, using *calliandra* would still be profitable. In the substitute scenario, changing the milk price would not affect the profitability of *calliandra* relative to dairy meal. A change in the price of dairy meal does not affect the use of *calliandra* as a supplement. However, in the substitution scenario, a 30% increase in dairy meal price raises the NPV by 32%. A reduction of price by 30% reduces the NPV by 32%. Overall, the sensitivity analysis shows that the net benefits of using *calliandra* as a supplement or as a substitute are very stable. Despite the range of negative situations tested, net present values and net benefits remain positive.

Table 3. Sensitivity analysis showing the effect of changes in key parameters on the profitability of using calliandra, central Kenya ($US per cow per year).

	Dairy meal supplement		*Dairy meal substitute*	
	Net present	*Annualized*	*Net present*	*Annualized*
Base Analysis	260	77	413	122
Milk price + 30%	350	103	413	122
Milk price –30%	170	50	413	122
Dairy meal + 30%	260	77	545	162
Dairy meal – 30%	260	77	281	83
Discount rate = 10%	408	77	644	122
Discount rate = 30%	178	76	286	122
Using potted seedlings	250	73	404	119
1 kg shrubs give 30% more milk	350	103	413	122
1 kg shrubs give 30% less milk	170	50	413	122
Labor cost + 30%	249	73	402	119
Labor cost – 30%	271	80	425	126

Note: Base analyses are shown in tables 1 and 2.

Fodder trees appear to be appropriate for smallholder dairy farmers throughout the highlands of eastern Africa – *calliandra*, for example, can grow at altitudes between 0 and 2200 m, requires only 1,000 mm rainfall, can withstand dry seasons up to four months long, and is suitable for cut-and-carry feeding systems or for grazing systems (Roothaert, Karanja, Kariuki, Paterson, Tuwei, Kiruiro et al., 1998). It is also suitable for dairy goat production, which is growing rapidly in Kenya. The potential impact of fodder trees thus appears to be very large. If all 625,000 smallholder dairy farmers were to adopt *calliandra* or similar fodder shrub species, the benefits would amount to about US $ 84 million per year. Moreover, fodder trees are being planted by dairy farmers at numerous other sites in east and southern Africa. Over 10,000 farmers have adopted fodder trees in Uganda and Tanzania; farmers are also planting them in Rwanda, Ethiopia, Malawi, and Zambia.

4.2. Rotational woodlots

Additional costs involved in rotational woodlots, relative to the maize-fallow system, included costs associated with producing tree seedlings, reduced maize yields, and labor for transplanting, gapping, pruning, and wood harvesting (Table 4). In the woodlot treatments, maize costs and yields are lower in the second year than in the first year because maize is planted at a lower density, less fertilizer is used, and because the trees interfere with the maize. In the maize fallow system, maize costs and yields were only measured during the first year of the cultivation; values in the second year are assumed to be the same as in the first year. Labor use in the woodlots system over the 5-year period is over 2.5 times that of the maize fallow system, primarily because of the labor required for wood harvesting in year 5, which accounts for over half of total labor. The total discounted input costs of rotational woodlots were 52% higher than for the maize-fallow system, mainly because of the costs of producing the potted seedlings and of harvesting the trees.

In the first year, the rotational woodlot incurred losses of $US 37 while the maize-fallow system's net benefits were $US 40. Additional benefits of the woodlots included the value of pruned wood in year 2 and wood yields in year 5. The payoff period for the woodlot, that is, the period required to earn positive net benefits, is 5 years as compared to less than 1 year for the maize-fallow system.

Table 4. Financial analysis of rotational woodlot as compared to a maize allow system, Tabora District, Tanzania ($US/ha). [a]

	Rational woodlots[b]			*Maize fallow system*[c]	
Benefits and costs	*Year 1*	*Year 2*	*Year 5*	*Year 1*	*Year 2*
Benefits					
Maize grain yield	142.54	88.85		158.39	158.39
Wood yield			806.62		
Pruning yield		23.53			
Total benefits	142.54	112.38	806.62	158.39	158.39
Labor costs					
Land preparation	8.59	8.59		8.59	8.59
Planting	2.53	1.9		2.53	2.53
Weeding	9.41	9.41		9.41	9.41
Fertilizer application	1.18	1.18		1.18	1.18
Harvesting	7.12	6.05		7.12	7.12
Threshing	3.71	2.33		4.12	4.12
Transplanting, watering, and digging microcatchments	4.18				
Gapping	1.42				
Pruning		5.18			
Wood harvesting			93.14		
Total	38.13	34.64	93.14	32.94	32.94
Other costs					
Tree seedlings	56.3				
Maize seed	4.62	3.7		4.62	4.62
Fertilizer	80.67	64.54		80.67	80.67
Total	141.6	68.24		85.29	85.29
Summary data					
Grand total cost	179.72	102.87	93.14	118.24	118.24
Discounted costs	275.11			180.64	

(Table 4, cont.)

	Rational woodlots[b]			Maize fallow system[c]	
Benefits and costs	*Year 1*	*Year 2*	*Year 5*	*Year 1*	*Year 2*
Net benefit	-37.17	9.51	713.48	40.16	40.16
Workdays	0.11	0.1	0.27	0.09	0.09
Net benefit to labor	0.96	44.14	806.62	73.1	73.1
Net ben. to labor/workday	0.02	0.75	5.09	1.31	1.31
Net present value	388.52			61.36	
Discounted workdays	0.31			0.14	
Discounted net benefit to labor	498.25			111.68	
Discounted net benefit and workday	2.67			1.31	

[a]Prices and quantities of inputs and outputs are from Appendix B.
[b]Maize is intercropped with the trees during the first two years. There are no benefits or costs during years 3 and 4. All costs and benefits are discounted over a 5 year period.
[c] Maize is cultivated for two years followed by three years of fallow. There are no benefits or costs during years 3 through 5. All costs and benefits are discounted over a 5 year period.

In spite of its higher costs and longer payoff period, the rotational woodlot's net present value is $US 388/ha, over 6 times higher than that of the maize fallow system. Returns to labor are more relevant to Tabora farmers than returns to land, because labor is much scarcer than land. The woodlot's returns to labor, expressed in discounted net benefits per discounted workday, were $US 2.67, over double that of the maize-fallow system.

An important advantage of the woodlots is that they allow farmers to substitute land and labor for cash, which they have great difficulty obtaining. Tobacco farmers can obtain firewood for curing only by purchasing it, whereas with the rotational woodlots, they can use their land and labor to produce it, using little if any cash in the process. The labor required for harvesting the wood is considerable but it can be spread over a long period during the farmers' slack season. The extra labor required for planting and maintaining the trees is relatively little.

Sensitivity analysis showed that the performance of rotational woodlots relative to the maize-fallow system is fairly stable across a wide range of changes in important parameters (Table 5). Increases or decreases of 50% in the price of maize, wood, or labor, or in the yields of maize or wood do not affect the superiority of rotational woodlots. Increasing the discount rate from 20% to 30% or reducing it to 10% also does not affect the rankings. Among the variables examined, the profitability of the woodlots is most sensitive to changes in the wood price and yield. The profitability of the maize-fallow system is sensitive to changes in maize price and yield.

The farm model (Table 6) shows that a household with 1.33 ha under woodlot, planting and harvesting 0.265 ha each year, would be able to provide enough wood to meet its tobacco curing and domestic needs each year. Such a household would use 75 workdays and earn $US 182, over triple the net returns that a family would earn using the same amount of labor to produce maize.

Table 5. Sensitivity analysis of the results of the financial analysis of rotational woodlots to changes in key parameters, Tabora District, Tanzania.

Parameter	Rotational woodlots		Maize without trees	
	Returns to land (Net present value, $US/ha)	*Returns to labor ($US/ workday)*	*Returns to land (Net present value, $US/ha)*	*Returns to labor ($US/ workday)*
Base analysis (from Table 4 data)	389	2.67	61	1.31
50% decrease maize yield	272	2.1	-56	-0.12
50% increase maize yield	476	3.49	179	2.56
50% decrease maize price	298	2.19	-60	-0.11
50% increase maize price	479	3.15	182	2.72
50% decrease wood yield	155	1.42	61	1.31
50% increase wood yield	622	3.92	61	1.31
50% decrease wood price	155	1.42	61	1.31
50% increase wood price	622	3.92	61	1.31
50% decrease wage rate	443	2.67	86	1.31
50% increase wage rate	334	2.67	36	1.31
30% discount rate	302	2.51	55	1.31
10% discount rate	510	2.84	70	1.31

Table 6. Farm models comparing net returns to labor of a farmer practicing rotational woodlots (planting a portion of the farm to rotational woodlots each year) to those of a farmer allocating the same amount of labor to cultivating maize without trees, Tabora District, Tanzania.

Farmer with rotational woodlots[a]				*Farmer using same amount of labor to cultivate maize*			
Crop	*Area (ha)*	*Labor (workdays)*	*Net returns to labor/ year ($US)*	*Crop*	*Area (ha)*	*Labor (workdays)*	*Net returns to labor/ year ($US)*
Woodlot, 1st year; intercropped with maize	0.265	17	-9.86				
Woodlot 2nd year; intercropped with maize	0.265	16	2.52				
Woodlot 3rd year	0.265	0	0				
Woodlot 4th year	0.265	0	0				
Woodlot 5th year	0.265	42	189.21				
Total: Woodlots	1.33	75	181.87	Maize	1.34	75	53.64

[a]*A household with one hectare of tobacco produces about 610 kg tobacco leaves, requiring about 37.2 t yr^{-1} of firewood for curing and 3.3 t yr^{-1} for domestic use (Ramadhani et al., 2002). The woodlot produces 152.7 t wood per five years. Therefore, by planting 0.265 ha yr^{-1} of woodlot each year, a household meets its firewood needs.*

4.3. Improved fallows

The benefits of improved fallows, relative to continuously cropped maize, were labor saved in years 1 and 2 because maize was not planted, firewood production in year 2, increases in maize yields in years 3 through 5, and reduced land preparation and weeding costs in the first post-fallow maize crop. Added costs included *sesbania* seed, labor for establishing the nursery, transplanting, and maintaining the fallow, and labor for harvesting and threshing the increased maize produced.

Maize yields in the year following the improved fallows averaged 3.6 t/ha, as compared to yields of 1.0 t/ha for continuous, unfertilized maize and 4.4 t/ha for continuous, fertilized maize. The post-fallow plot out-yielded the unfertilized plot on all 12 farms and the fertilized plot on 4 of the 12 farms. Results of the economic analysis of the 12 farms, using average values across farms, are summarized in Table 7; the detailed budgets for improved *sesbania* fallows and fertilized and unfertilized maize are shown in Appendix C. Over the 5-year period, a hectare under the improved fallow treatment required 13% less labor than a hectare of unfertilized maize and 33% less labor than fertilized maize (Table 7). Relative to unfertilized maize, the improved fallow increases total maize production per hectare over the 5-year period by 52%, even though it does not produce maize during the first 2 years of the fallow. But fertilized maize gives the highest yield over the 5-year period, triple that of improved fallows (Table 7). The value of firewood produced in the fallow was low, only about 3% of the value of maize following the improved fallow.[4]

Table 7. Labor requirements, maize production, and returns to land and labor of Sesbania sesban improved fallows and continuously cropped maize over a 5-year period, using an average farm budget, eastern Zambia.

Option	*Work-days per ha*	*Tons Maize per ha*	*Returns to land: net present value ($US/ha)*	*Returns to labor: discounted net returns ($US/ workday)*
	Over a 5-year period[b]		*1996*	*1996*
Continuous fertilized maize	499	4.8	5	0.42
Improved 2-year Sesbania fallow	433	7.3	115	0.85
Continuous fertilized maize	649	21.9	203	0.93

[a] *The means of values from individual budgets of the twelve trial farmers were used. Details on budgets and coefficients are provided in Appendix C.*
[b] *A 5-year period is used because that is the period needed to complete a cycle of the improved fallow practice; two years of fallow and three years of cropping.*

Net present values (NPVs) per hectare for fertilized maize were 76% higher than those of improved fallows; both were much higher than for unfertilized maize. Five of twelve farmers obtained higher NPVs for improved fallows than for fertilized maize; 11 obtained higher NPVs for improved fallows than for unfertilized maize. NPVs were low relative to other years because 1996 was a year of high maize yields and thus low maize prices.

A main disadvantage of improved fallows relative to continuous maize is that farmers have to wait until after the fallow to recoup their investment; in continuous maize, farmers earn positive net benefits in the first year. The payback period, that is, the period required for improved fallows to yield higher cumulative net present values than unfertilized maize, was 3 years for 10 of the 12 farmers. This indicates that even if a farmer does not get higher yields than unfertilized maize during the second and third post-fallow maize harvests, improved fallows were still more profitable than unfertilized maize for these farmers.

Assessing returns to labor is more relevant to most Zambian farmers than returns to land, because labor tends to be scarcer than land. On returns to labor, improved fallows outperformed unfertilized maize by a wide margin and performed almost as well as fertilized maize, using average values across the 12 farms and 1996 prices (Table 7). Improved fallows gave higher net returns to labor than for unfertilized maize on 11of the 12 farms and higher net returns to labor than for fertilized maize on 7 of the 12 farms. Even assuming no maize yield response to improved fallows in year 4 and year 5, returns to labor on improved fallows were higher than those for unfertilized maize on 10 of 12 farms. In summary, improved fallows had much higher returns to land and labor than unfertilized maize but lower returns to land than fertilized maize. On returns to land, the improved fallows performed almost as well as fertilized maize.

One important farmer innovation in improved fallows is the intercropping of the trees with maize during the first year of fallow establishment. The maize and the trees compete in the plot and reduce maize yields by about 20% compared to unfertilized maize in pure stands (Franzel et al., 2002b). But farmers benefit from harvesting a maize crop from the tree plot. In fact the practice has significant financial benefits: the farmer reduces her first year losses from $US 52 to $US 35 and the NPV increases from $US 115 to $US 129/ha.

The performance of improved fallows relative to continuous, unfertilized maize is fairly stable under a wide range of possible changes in parameters (Table 8). For example, improved fallows have returns to land and labor at least double those of unfertilized maize under most tested changes, including a 50% increase or decrease in the discount rate, and the prices of fertilizer and labor. An increase in post-fallow maize yield of only 1.1 t/ha is needed in the third year to cover the costs of establishing and maintaining the fallow, relative to unfertilized maize, in terms of returns to land or labor. In contrast, the performance of improved fallows relative to continuous, fertilized maize is sensitive to changes in some key parameters. Increases in maize prices (such as occurred between 1996 and 1998) raise the returns to fertilized maize at a much faster rate than they raise the returns to

Table 8. Sensitivity analysis showing the effects of changes in parameters on the profitability of improved fallows, eastern Zambia ($US).

	Continuous unfertilized maize		*Improved fallows*		*Continuous fertilized maize*	
	Returns to land	*Returns to labor*	*Returns to Land*	*Returns to labor*	*Returns to land*	*Returns to labor*
Base analysis	5	0.42	115	0.85	204	0.93
Maize price + 50%	101	0.74	239	1.34	639	2.06
Maize price – 50%	-90	0.1	-9	0.37	-231	-0.2
Labor price + 50%	-54	0.42	68	0.88	126	0.93
Labor price – 50%	65	0.42	162	0.8	280	0.93
Discount rate 30% instead of 20%	4	0.34	80	0.64	166	0.76
Discount rate 10% instead of 20%	7	0.53	167	1.172	258	1.18
Seedling cost +50%	5	0.42	110	0.81	203	0.93
Seedling cost -50%	5	0.42	120	0.9	203	0.93
Fertilizer price + 50%	5	0.42	115	0.85	-10	0.37
Fertilizer price – 50%	5	0.42	115	0.85	417	1.48

improved fallows. Similarly, the relative profitability of the two practices is highly sensitive to the price of fertilizer; a 50% increase in price would make improved fallows much more profitable than fertilizer on returns to both land and labor. Changes in the discount rate and in the cost of labor and seedlings have little effect on the performance of improved fallows relative to fertilized maize.

The risk of drought is critical for farmers in Zambia; unfortunately the effects of drought in the season following an improved fallow cannot be assessed using the data collected for this study. But there are four reasons why improved fallows are likely to be much less risky than fertilized maize. First, in the event of a complete crop failure, a farmer using the recommended fertilizer rate would lose his investment in fertilizer, US$ 149/ha whereas a farmer with improved fallow would lose his investment in planting and maintaining the trees, only about US$ 52/ha (The actual savings would be less since farmers apply fertilizer at less than the recommended rate). In addition, both farmers would lose their investment in growing maize that year. Second, whereas nearly all of a farmer's investment in fertilizer is in cash terms, improved fallows require little or no cash input. The opportunity cost of cash is extremely high and if the farmer buys fertilizer on credit, loss of the maize crop may result in substantial losses in productive capacity in order to repay the loan. Third, the benefits of improved fallow are likely to be spread over a 3-year period whereas those of nitrogen fertilizer take place in a single year. Thus in the above case where a farmer's crop fails in the first post-fallow season, there is likely to be a substantial response the following year. Fourth, improved fallows improve the soil structure and organic matter content of the soil, thus enhancing the soil's ability to retain moisture during drought years (Kwesiga et al., in press). Finally, it is important to note another important risk of relying on fertilizer. In some years, fertilizer may be delivered too late in the season to have an effect on yields.

The analyses of profitability presented thus far assess returns per hectare and per workday; but how will adoption of improved fallows affect farm income once they have been incorporated into the farming system? A farm household cultivating manually and having 1.4 ha and 120 workdays available for cultivating maize would fully adopt improved fallows by planting 0.28 ha per year to improved fallows, she would thus have an equal portion of the area under a different phase of improved fallow each year. The farmer could earn US$ 189 per year using fertilized maize, US$ 118 per year growing improved fallows, or only US$ 50 cultivating continuous maize without fertilizer (Table 9). Even if there is no residual effect on maize yields in the third year following improved fallows, earnings are still almost twice as high as on unfertilized maize.

Table 9. Farm models comparing net returns to labor per year of a 1.4 ha farm practicing Sesbania sesban *improved fallows with farms cultivating continuous maize, with and without fertilizer, eastern Zambia*[a].

Crop	*Area (ha)*	*Workdays/yr*	*Kg maize produced/yr*	*Net returns/yr $US*
Farming practicing improved fallows (farm adds 0.28 ha of improved fallow/yr)				
Fallow1st yr	0.28	35	0	-1
Fallow 2nd yr	0.28	1	0	2
Maize 1st post fallow	0.28	27	1,019	61
Maize 2nd post fallow	0.28	28	570	32
Maize 3rd post fallow	0.28	29	448	23
Total	1.4	120	2,037	118
Farm with unfertilized maize				
Maize	1.2	120	1,159	50
Farm with fertilized maize				
Maize	0.92	120	4,077	262

[a] *Household is assumed to have only 119 workdays available during the cropping season for maize production; the amount needed to manually cultivate 1.2 ha maize without using fertilizer. Costs and returns are from Appendix 1. Improved fallows are two years in length and are followed by three years of maize crops.*

Whereas the above analyses assess the profitability of alternative soil fertility practices, farmers do not necessarily view them as alternatives. For example, a farmer may use fertilizer, manure and improved fallows, allocating each to a different part of her farm. Researchers have found that there are important synergies between organic and inorganic inputs for improving soil fertility (Palm, Myers, & Nandwa, 1997). However few Zambian farmers apply mineral fertilizer following an improved fallow, probably because they lack sufficient soil fertility inputs for covering their entire cultivated area (Keil, 2001).

5. CONCLUSIONS

The three agroforestry practices assessed in this chapter have different objectives: feeding livestock, providing firewood, and improving soil fertility. They were adopted in very different environments ranging from semi-arid, low population density areas of Tanzania to the sub humid, high-density highlands of Kenya. Nevertheless, each provided important financial returns and is being adopted on a large scale. Full adopters of fodder shrubs in Kenya, rotational woodlots in Tanzania, and improved fallows in Zambia earn $US 68 – $US 212 per year more from these practices than from alternative, available practices. Actual benefits are lower, because most farmers do not, or have not yet, fully adopted. In addition to the financial returns, there are several other intangible types of benefits. First, in all three cases, the practices provide by-products and services which are difficult to value. For example, fodder shrubs serve as border markings, improve animal health and calving rates, provide firewood and curb soil erosion. Improved fallows improve soil structure and moisture retention and provide firewood. Rotational woodlots reduce deforestation, as home-produced firewood is substituted for firewood cleared from the forest and trucked to the farm.

Second, all three practices involve relatively low investments of land and labor in exchange for substantial cash savings. As most farmers have difficulty earning cash and have multiple demands on the small amounts of cash they earn, they greatly appreciate being able to invest home-sourced land and labor as substitutes for purchasing cash inputs. Farmers in Zambia mentioned that the profitability of mineral fertilizer is almost irrelevant to them; they simply did not have cash to purchase it. Women noted that even if credit were available, they would not purchase fertilizer because they would then risk losing their productive assets if there was a drought and they were unable to pay back their loan (Peterson, 1999). This highlights a third benefit of the agroforestry practices: they help reduce risk from uncertain rainfall. The benefits of improved fallows are spread over a 2-3 year period (or longer in the case of newly introduced species such as *Gliricidia sepium* which may be coppiced), whereas nitrogen fertilizer provides benefits for only a single year. A farmer experiencing a crop failure would lose her investment in fertilizer whereas a farmer planting maize following an improved fallow would lose only her investment in planting the trees (about one-third of the fertilizer cost). Finally, agroforestry practices in the three case studies help farmers minimize risk in input markets. Fertilizer and dairy meal prices fluctuate considerably and farmers appreciate being able to produce substitutes for them on their farms. Farmers also complain about timely availability of purchased inputs and, in the case of dairy meal, the quality of the purchased product.

The case studies also highlight several methodological issues concerning assessment of financial benefits. On-farm trials are useful for measuring benefits, because agroforestry practices can be readily compared with alternative ones. Researcher-designed, farmer-managed trials appear most appropriate for financial analysis. Because these trials are designed by researchers (in consultation with farmers), non-experimental practices (such as weeding) are relatively uniform across treatments. This uniformity ensures that differences among treatments are caused by the practices being tested and not by extraneous variables. The standardization of plot size and purchased inputs in such trials also helps facilitate the collection of data on the use of labor, the most complex input to measure. In contrast, farmer-designed trials vary greatly among farms in size, types of inputs, and management and are thus less conducive to assessing profitability. Farmer-managed trials are preferred to research-managed ones, because measurement of inputs and outputs more realistically reflects farmers' experiences with the practices (Franzel et al., 2001).

Calculating returns to labor is another critical feature of the case studies; these are especially important where land is relatively abundant, as in Tabora district. In Zambia, fertilizer offers much greater returns to land but improved fallows' performance in terms of returns to labor helps explain its attractiveness.

Finally, NPVs are useful for comparing the results of practices that have costs and benefits over a series of years. But NPVs do not provide information on how farmers' annual incomes are affected by a practice, and their interpretation is not intuitively obvious to policy makers. Calculating the effect of the practice on annual incomes is done in two ways. In the case of fodder shrubs, where establishment costs are relatively low and costs and benefits vary little following the first year, two measures are calculated: the annual benefit after year 1 and the annualized net benefit treating establishment costs as depreciation. In the case of rotational woodlots and improved fallows, benefits are not generated during the first 2-4 years and costs and benefits vary among years. Therefore an alternative method is used to assess annual income: a farm is assumed to adopt the practice in phases, allocating equal-sized plots of land to each phase of the practice each year. Thus a farmer with rotational woodlots would plant a portion of woodlot to his farm each year, thus ensuring that he harvests what he needs each year. This permits an assessment of the effect of the practice on annual income.

The results from the case studies also have important implications for researchers, extensionists and policy makers. Reducing labor costs is an important avenue for increasing profitability in all of three systems. For example, using bare-rooted seedlings has important benefits over potted seedlings in fodder shrubs and improved fallows; intercropping with maize reduces tree performance in improved fallows and rotational woodlots but has very positive benefits to farmers in increasing returns to labor and land. Researchers and extensionists need to emphasize to reducing labor costs in all three practices and farmers' own innovations are often the greatest source of such modifications in technology. In Zambia, for example, farmers were the first to use bare-root seedlings and to intercrop their trees with maize; researchers followed with experiments to confirm the effectiveness of these practices, and they are now widely used by farmers (Kwesiga, Akinnifesi, Mafongoya, McDermott, & Agumya, 1999).

Several features of the financial analyses suggest that credit for establishing agroforestry is not required. Establishment costs are low, $US 7 for planting sufficient numbers of fodder shrubs to feed a cow and $US 6 and $16 for 0.25 ha of improved fallows and rotational woodlots, respectively. In all three cases, all, or nearly all, of the establishment costs are for labor; no, or almost no, cash is required. Moreover, farmers can and do adopt in increments, beginning on a small scale and gradually increasing the areas they allocate to the practices (Franzel et al., 2002a; Ramadhani et al., 2002; Kwesiga et al., in press). These findings suggest that there is little justification for providing credit to smallholders for agroforestry, because they can adopt easily without access to finance. Payback periods were also relatively low in these case studies, 2 years for fodder shrubs, 3 years for improved fallows, and 5 years for rotational woodlots.

Finally, the assessments presented have two important limitations. First, they emphasize enterprise-specific budgets and thus may miss important interactions among enterprises within the farming systems. Whole-farm analyses, while more costly, can help avoid this pitfall. Second, analyses of profitability should not be considered as the sole criterion for assessing the feasibility, acceptability, and adoption potential of an agroforestry practice to farmers. Profitability is certainly an important criterion but other factors such as cultural taboos, farmer preferences, resource bottlenecks, policy constraints, and market failures also play important roles. Assessments of profitability need to be complemented by other types of studies to identify and assess these and other issues that farmers face in using agroforestry practices.

6. NOTES

[1] While financial analysis generally refers to analysis of profitability from the farmers' perspective, economic analysis refers to profitability analysis from society's perspective (Gittinger, 1982).

[2] Bare-rooted seedlings are grown in raised seedbeds instead of in polythene pots and are thus much cheaper to produce. Following transplanting, they may have lower survival rates than potted seedlings, depending on moisture availability and other factors.

[3] 1 kg of milk is about equal to 1 liter of milk.

[4] The value of sesbania wood varies: in some areas, farmers burn the wood in the field to get rid of it whereas in other areas, they carry it to the homestead to use as firewood.

7. APPENDIX A: COEFFICIENTS AND PRICES USED IN THE FINANCIAL ANALYSIS OF CALLIANDRA FOR INCREASING MILK PRODUCTION, CENTRAL KENYA

Items	*Values*	*Data sources*
Coefficients		
Period of analysis	10 years	Assumption
Lactation period	300 days	Paterson et al., 1996
Days fed *calliandra*	365 days	Assumption
Days fed dairy meal	365 days	Assumption
Calliandra quantity fed per cow per day	6 kg fresh (equiv. to 2 kg dry)	Paterson et al., 1996
Dairy meal quantity fed per cow per day(substitution scenario, equivalent to 6 kg fresh *calliandra*)	2 kg	Paterson et al., 1996
Milk output per day from 1 kg dry *calliandra*	0.62 kg	Paterson et al., 1996
Calliandra leafy biomass yield per tree in year 1	0 kg	Farmers' experience
Calliandra leafy biomass yield per tree per year, year 2-5	1.5 kg (dry)	Paterson et al., 1998
Trees required to feed 1 cow per year	500	Computed from above.
Tree survival rate	80%	Survey data
Calliandra planting labor	20 trees per hour	Farmers
Calliandra cutting and feeding labor	15 minutes per day	Farmers
Discount rate	20%	Rough estimate of value of capital in alternative uses
Interest on capital freed up by using *calliandra* instead of purchasing dairy meal	Capital tied up for an average of 2 weeks, 20% annual interest rate.	
Prices		
Milk	$US 0.240/kg	Farmers in 2001
Dairy meal	$US 0.178/kg	Farmers in 2001
Transport of dairy meal	$US 0.005/kg	Farmers in 2001
Seedling cost (bare-rooted)	$US 0.005/seedling	S. Koech (personal communication, 2003)

APPENDIX A, (cont.)

Items	*Values*	*Data sources*
Labor cost	$US 0.110/hour	Farmers in 2001 (3/4 of daily wage)
Milk price (farm gate)	0.24/kg	Farmers in 2001
	US 2.39	Use of capital recovery formula* (Spencer et al., 1979)
1 $US = 78 Kenya Shillings		Average exchange rate, 2001

* *$K=(rv)/(1-(1=r)^{-n})$ where K is the annual service user cost, V is the original (acquisition) cost of the fixed capital asset, r is the discount rate, and n is the expected life of the asset. This procedure allows both the depreciation on capital and the opportunity cost of capital to be costed out.*

8. APPENDIX B: COEFFICIENTS AND PRICES USED IN THE FOR ROTATIONAL WOODLOTS, TABORA DISTRICT, TANZANIA

Variable	*Amount ($US)[a]*	*Source of information*
Maize		
Maize seed price	$US 0.18/ha	Average of 1995/96 and 1996–/97 market prices
Maize seed rate year 1	25 kg/ha	Farmers' estimates
Maize seed rate year 2	20 kg/ha	Farmers' estimates
Fertilizer rate	4 bags urea/ha	Research recommendation
Fertilizer cost	$US 20.17/bag	Market price 1996/1997
Threshing	$US3.70/100 kg[-]	Farmers' estimates
Maize yield, pure stand	1943 kg/ha	On-station data adjusted
Maize yield with trees, yr. 1	1749 kg/ha	On-station data adjusted
Maize yield with trees, yr. 2	1090 kg/ha	On-station data adjusted
Maize price	$US 0.081/kg	Average market price 1995/96 and 1996/97
Trees		
Transplanting, watering, and digging micro-catchments	88 trees/day	Farmers' estimates
Transplanting cost	$US 4.18/ha	On-farm trial data
Mortality rate	34 percent	On-farm trial data
Gapping rate	34 percent	On-farm trial data
Tree population	625 trees/ha	On-farm trial data
Wood price	$US 5.28/Mg	Avg. cost of wood cut and transp. from forest, 1995/96 and 1996/97
Wood yield	152.7 t/ha	On-farm trial data, fresh weight
Wood harvesting	$US 93.14/ha	On-farm trial data
Tree seedling price	$US0.067/ seedling	Market price 1995/96 and 1996/97

APPENDIX B, (cont.)

Variable	*Amount ($US)*[a]	*Source of information*
Other		
Wage rate	$US 0.59/day	Farmers' estimates
Discount rate	20%	Researchers' estimate
Labor requirements (work days/ha)		
Land preparation	14.6	Labor survey data 1997
Maize sowing	4.3	Labor survey data 1997
Weeding	16	Labor survey data 1997
Fertilizer application	2	Labor survey data 1997
Maize harvesting	12.1	Labor survey data 1997
Maize threshing	6.3	Labor survey data 1997
Tree seedling transplanting	7.1	Labor survey data 1997
Tree seedlings gapping	2.4	Labor survey data 1997
Tree pruning	8.8	Labor survey data 1997
Wood cutting	36.5	On-farm trial data
Wood chopping	121.9	On-farm trial data

[a] *$US 1 = Tshs 595 (1997).*

9. APPENDIX C. COST BENEFIT ANALYSIS OF IMPROVED FALLOW AND CROPPING OPTIONS, EASTERN ZAMBIA ($US/ha, 1996)

	Maize cropping without fertilizer					*Two-year sesbania fallow*					*Maize cropping with fertilizer*				
	Year 1	*Year 2*	*Year 3*	*Year 4*	*Year 5*	*Year 1*	*Year 2*	*Year 3*	*Year 4*	*Year 5*	*Year 1*	*Year 2*	*Year 3*	*Year 4*	*Year 5*
Maize (mz) yields (kg/ha)	964	964	964	964	964	0	0	3638	2037	1601	4384	4384	4384	4384	4384
COSTS															
Cash costs															
Maize seed	22.24	22.24	22.24	22.24	22.24			22.24	22.24	22.24	22.24	22.24	22.24	22.24	22.24
Nursery costs						2.93									
Fertilizer								0	0	0	142.82	142.82	142.82	142.82	142.82
Fert. transport								0	0	0	6.4	6.4	6.4	6.4	6.4
Total	22.24	22.24	22.24	22.24	22.24	2.93		22.24	22.24	22.24	171.46	171.46	171.46	171.46	171.46
Labor costs															
Tree nursery						10.52									
Land preparation	12	12	12	12	12	12		9	12	12	12	12	12	12	12
Ridging	4	4	4	4	4	4		3	4	4	4	4	4	4	4
Planting mz	2	2	2	2	2	0		2	2	2	2.8	2.8	2.8	2.8	2.8
Planting trees	0	0	0	0	0	11.24		0	0	0	0	0	0	0	0
1st weeding	8	8	8	8	8	8		6	8	8	10	10	10	10	10
2nd weeding	4	4	4	4	4	4		3	4	4	6	6	6	6	6
Tree cutting	0	0	0	0	0	0	2.08	0	0	0	0	0	0	0	0
Harvesting mz	5.96	5.96	5.96	5.96	5.96	0	0	8.63	7.03	6.6	9.58	9.58	9.58	9.58	9.58
Mz shelling	3.96	3.96	3.96	3.96	3.96	0	0	6.63	5.03	4.6	7.58	7.58	7.58	7.58	7.58
Total labor	39.92	39.92	39.92	39.92	39.92	49.76	2.08	38.28	42.07	41.2	51.96	51.96	51.96	51.96	51.96

9. APPENDIX C. COST BENEFIT ANALYSIS OF IMPROVED FALLOW AND CROPPING OPTIONS, EASTERN ZAMBIA ($US/ha, 1996)

	Maize cropping without fertilizer					*Two-year sesbania fallow*					*Maize cropping with fertilizer*				
Total costs	62.16	62.16	62.16	62.16	62.16	52.68	2.08	60.51	64.31	63.44	223.42	223.42	223.42	223.42	223.42
Labor days	99.8	99.8	99.8	99.8	99.8	124.4	5.2	95.7	105.2	103	129.9	129.9	129.9	129.9	129.9
BENEFITS															
Maize	63.74	63.74	63.74	63.74	63.74	0	0	241.56	135.27	106.28	291.11	291.11	291.11	291.11	304.11
Firewood	0	0	0	0	0	0	6.4	0	0	0	0	0	0	0	0
Total benefits	63.74	63.74	63.74	63.74	63.74	0	6.4	241.56	135.27	106.28	291.11	291.11	291.11	291.11	304.11
Net benefit (nb) to labor	41.5	41.5	41.5	41.5	41.5	-2.93	6.4	219.32	112.98	84.04	119.64	119.64	119.64	119.64	132.66
Net ret to lab/day	0.42	0.42	0.42	0.42	0.42	-0.02	1.23	2.29	1.07	0.82	0.93	0.93	0.93	0.93	1.02
Net benefits	1.58	1.58	1.58	1.58	1.58	-52.68	4.32	181.04	70.96	42.84	68.07	68.07	68.07	68.07	80.7
Workdays	499					433					649.5				
NPV	4.74					115					203.58				
Discounted days	298					255					386				
Discounted nb to lab	124.12					217					357.8				
Discounted nb/disc days	0.42					0.85					0.93				
Quantity mz	4.8	t/5 yr				7.3	t/5 yr				21.9	t/5 yr			

9.1. Notes to Appendix C

Annual Maize yields for fertilized and unfertilized maize are average yields across the years of the trial. Fourth year and fifth year maize yields in the improved fallow treatment are 56% and 44% of third year yields, respectively, as reported in an on-farm trial involving 48 farmers (Kwesiga, Franzel, Place, Phiri, & Simwanza, 2003).
Prices are from local markets for the 1996 cropping season. Exchange rate: US$1.00=1250 Zambian Kwacha (ZK) in 1996 and 1683 ZK in 1998.

Cash costs
Maize seed: Seed rate of 20 kg/ha. Cost : 1340 ZK/kg
Nursery cash costs: Total costs per seedling, including cash and labor costs, are 1.4 ZK, median from cost analysis of 8 farmer nurseries. Mean cost was 1.9 ZK, standard deviation (sd), 1.2. It is assumed that 12000 seedlings are raised in order to achieve a density of 10,000 seedlings/ha in the field. Nursery cash costs accounted for 22% of the total cost of the nursery and included rent of land in valley bottom and purchase of a watering can.
Fertilizer: the recommended rate is 112-40-20 kg of N-P_2O_5-K_2O per ha. In 1996, it required 200 kg of D compound purchased at 459 ZK/kg and 200 kg of urea purchased at 433 ZK/kg. 1998 prices were 580 ZK/kg and 520 Zk/kg, respectively.
Fertilizer transport: estimated at 1,000 ZK/50 kg bag, from Chipata to farm in 1996 and 1,350 ZK/bag in 1998.
Labor: Labor data for maize cultivation are assembled from several sources cited in Franzel et al. (2002b) and from survey farmers. Labor data concerning trees are from surveyed farmers.
Labor cost: Costed at 500 ZK/workday in 1996. A workday is assumed to involve 7 hours of work. Hiring labor is not common; reported wage rates were highly variable. 500 ZK per day represents the approximate average returns per labor in maize production for 1996, that is, the value of labor at which a farmer growing maize without fertilizer breaks even. In 1998, this value was about 1300 Kw/workday.
Nursery: See 'nursery cash costs' above. Activities included collecting and threshing seeds, constructing beds, collecting sand, compost, and soil, planting, covering with grass, watering, weeding, digging out the seedlings, and transporting them to the field. Mean number of workdays required to produce 12,000 seedlings, sufficient to plant and gap up one hectare, was 26.8. (sd 22.7)
Land preparation and ridging: 30 and 10 workdays/ha, respectively. They are 25% less during the year after the improved fallow, according to estimates of trial farmers.
Planting maize: 5 workdays/ha. When applying fertilizer, 7 workdays/ha.
Planting trees: 420 trees per day, median of data from 12 farmers (mean=499, sd =424).
Weeding: Assumed to be the same for trees as for maize, as claimed by farmers. Weeding requirements decline by 25% during the year after the improved fallow, according to estimates of trial farmers. Weeding requirements are assumed to increase 33% with fertilizer use.
Harvesting and post-harvest: Labor varies with quantity. A yield of 1 t/ha requires 15 workdays for harvesting and 10 days for post-harvest activities (shelling and transportation). A yield of 4.6 t/ha is estimated to require 60% more harvest labor and 90% more post-harvest labor.

Benefits
Eleven of the twelve trial farmers had two year fallows; one had a three year fallow. For the purpose of comparison with the other sample farms for drawing up enterprise budgets, we assumed that Phiri had a two-year fallow. This assumption increased the net present values in Table 7 by 1% and the net benefit/day by 1%.
Maize: Yields are from the twelve trial farmers for the season following the improved fallow and are compared with yields on continuously cropped adjacent fields, with and without fertilizer (Table 7). For the continuously cropped maize fields, yields are assumed to be constant over the 5-year period (964 kg ha-1 without fertilizer and 4,384 kg ha-1 with fertilizer). Maize yields following the improved fallows are as measured in on-farm trials. The maize price is 83 ZK/kg, the estimated farm-gate price during the harvest period, 1996. The 1998 price was 167 Kw/kg. Firewood: Firewood is not normally sold; yield is estimated at 4 t/ha and price at 2000 ZK/t. Discount rate: 20%

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11. AUTHOR'S NOTE

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