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Trees on Farms in Malawi: Private Investment, Public Policy, and Farmer Choice

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Summary. — Agricultural intensification in Malawi has proceeded at the expense of the country's extensive woodlands. Rather than clear their farmlands of all trees however, farmers plant or leave preferred species in fields and around households. A number of indigenous and exotic agroforestry species are being promoted through extension. An analysis of potential capital and management costs *vis-à-vis* increased potential production of local and hybrid maize shows that investments in tree planting are most favorable when they involve low costs and low risks. In order to reduce the farmer's costs of tree planting, government introduced a Tree Planting Bonus scheme which has provided cash payments as an incentive for farmers to plant trees. The program has been costly to administer and has had a limited impact. Survey data suggest that existing markets for poles and other wood products probably provide better tree planting incentives. Planners need to carefully consider household resource allocation processes with regard to trees and tree based products before they can expect to achieve a significant impact in encouraging rural afforestation.

1. INTRODUCTION

The rapid disappearance of extensive areas of woodlands in Malawi has been the subject of some concern, particularly at the policy and planning levels. There is somehow an assumption that vast areas have been converted into wastelands as a result of woodland clearance, mostly to support the expansion of arable agriculture, but at a considerable cost to the environment. Relatively little work has been carried out in Malawi on what often follows agricultural intensification in these circumstances: the development of household or community-based tree and woodland management strategies. This important area has been ignored, largely in favor of developing information about household energy use, important in its own right, but unevenly contributing to the broader discussion about natural resource management at the household level.[1]

There has been a tendency to suggest that tree resources, both in woodlands and on farms, are usually left unmanaged. There is a need for a broader view of what consists of "management." (See also FAO, 1985.) The most active forms of management of course involve the growing of seedlings, the planting of trees, or adherence to a woodland management plan. Less active forms of management involve the protection of naturally regenerating seedlings, rotational or selective harvesting of timber, grazing management, and so on. How and why this broadly defined sort of management takes place is a function of economic and social constructs and must be understood in this context.

There have been a number of attempts to do so. Tree management as an agricultural practice is considered more generally in Arnold and Dewees (1995). In Zimbabwe, Wilson (1989) broadly characterized the cultural and social dimensions of tree cultivation and management, Scoones (1989) examined the critical role of woodlands in sustaining livestock populations, and Campbell, Clark and Gumbo (1991) described traditional agroforestry practices. The literature is less well developed for most other countries in southern Africa. In Malawi, Coote, Luhanga and Lowore (1993), and Coote *et al.* (1993) carried out a series of case studies which considered the relationship between woodlands and their management by communities. There is almost no work, however,

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which has been carried out on the role of trees within farming systems in Malawi or which has examined the prevailing, nonproject-related incentives which have encouraged farmers either to plant trees or to retain naturally regenerating trees in their fields.

The objective of this paper is first, to describe the little which has been documented about on-farm tree cultivation and management in Malawi and to interpret this information *vis-à-vis* project and policy interventions. Second, the economic rationale for the adoption of two different agroforesty practices is considered, with a view toward developing an understanding of some of the constraints which smallholders face when making investment decisions involving the planting of trees in their fields. Finally, these findings and their policy implications are examined in the light of an incentive program which was designed to encourage farmers to plant trees on their holdings by providing them with subsidies and credits to do so.

2. THE CULTIVATION AND MANAGEMENT OF TREES IN CUSTOMARY LANDS

What perhaps first strikes the casual observer in Malawi is that trees are in some areas a dominant feature of the agricultural landscape. The extent to which this holds true, and why this is so, is unclear. Many observers discount the prevalence of trees on farms, saying that these are only trees which were left when the original woodland was cleared. At the most, farmers may allow seedlings to regenerate naturally, but it is generally argued that Malawian farmers seldom plant trees and that if they do, it is only in response to the incentives provided by tree planting programs (Malawi, Forest Department, 1993). Tree planting is seen to be a recently introduced innovation (Carr, 1993).

Other studies contradict this view. Mkandawire (1992) for instance argues that, in the context of customary land tenure arrangements, the planting of trees is seen to be an important means for land improvement. Studies in the early 1980s of the predominance of tree planting found that, among rural households surveyed, 29% had planted trees during the previous year (Energy Studies Unit, 1981).

A Smallholder Tree Planting Survey, carried out in 1982, explored farmer attitudes towards tree planting (Energy Studies Unit, 1982). It concluded that farmers mostly understood the problems of woodfuel shortages and environmental deterioration and knew quite well how to plant and maintain trees. Seedlings were thought to be easily available, and few people mentioned that a shortage of land (thought to have been a main constant) prevented them from planting trees.

The view of tree planting as a recently introduced innovation is a common enough bias, rooted in a perception that farmers are somehow not planting "enough" trees of the "right" varieties, in the "correct" way, or with the "best" management.[2] That tree management could be improved is hardly arguable. It is fatuous, however, to suggest that farmers in Malawi don't know how to plant trees, or how to encourage their regeneration, or have only recently done so, or will only do so when offered lucrative incentives. What is lacking is any sort of understanding of how these practices fit into the rural agricultural economy: who are the beneficiaries of these investments, what benefits do farmers receive, how costly is it for them to engage in woody biomass management, how can these management systems be improved, how can trees more effectively alleviate constraints to crop production or otherwise lessen the impacts of food insecurity? Whether planted or not, woody biomass is cultivated and managed in cropland. The more compelling question is how trees on farms have contributed to the stability of farming systems in Malawi.

Tree planting and management on Malawian smallholdings involves the incorporation of several exotic timber and fruit tree species into the agricultural landscape, as well as numerous indigenous trees. The principal exotic species, introduced over many decades through successive extension initiatives, mirror the Forest Department's industrial approach: *Eucalyptus sp.*, *Pinus sp.*, *Gmelina arborea*, and *Toona ciliata.* Many exotic fruit tree species are also common, particularly varieties of citrus, mango, and guava. These are, for the most part, regenerated from unimproved local stock.

The management of indigenous tree species on farms is prevalent in some areas. Indigenous fruit trees such as *Uapaca kirkiana* are highly valued though are probably infrequently planted. *Uapaca* is a common component of open canopy *Brachystegia* woodlands. When woodlands are cleared for cultivation, fruit trees may be left in fields. In some areas, they tend to colonize cleared woodland sites (Hursh, 1960). Other indigenous fruit trees found in fields include *Parinari curatellifolia*, *Strychnos spinosa*, *Bauhinia thonningii*, and *Ficus sp.* Minae (1992a) has found that these species often have multiple characteristics which make them favored for retention or regeneration in fields (Table 1).[3]

The prevalence on farms of agroforestry species was noted nearly 60 years ago by Hornby (1934). More recent observers describe indigenous agroforestry systems in some detail:

> ... Several species of *Sesbania* ... were found growing in different localities... *Sesbania sesban* ... (was) introduced, probably by Arabs several hundred years ago, (and) ... has been carried throughout Nyasaland by natives and distributed by the streams from the western ranges to the lakeshore... Another common *Sesbania* ... is grown extensively by natives for small poles both in

Table 1. *Uses for indigeneous fruit trees found on farms in Lilongwe and Mchinji districts*

Species	Percent of farmers surveyed reporting uses for indigenous fruit trees							
	Fruits	Soil fertility	Fodder	Medi-cine	Building material	Fuel	Timber	Other
Adansonia digitata	2.4	··	··	7.3	··	2.4	··	2.4
Azanza garkeana	51.2	··	2.4	4.9	24.4	··	2.4	19.5
Bauhinia petersiana	9.8	··	7.3	4.9	14.6	··	··	4.9
Bauhina thonningii	73.2	36.6	46.3	46.3	34.1	··	1.9	41.5
Bridelia micrantha	17.1	··	4.9	9.8	9.8	··	··	2.4
Cussonia kirkii	26.8	4.9	9.8	12.2	2.4	2.4	··	9.8
Diospyros mespiliformis	2.4	2.4	··	··	2.4	··	··	2.4
Ficus natalensis	31.7	14.6	22.0	14.6	··	··	··	9.8
Ficus sycomorus	36.6	9.8	26.8	12.2	7.3	··	··	17.1
Fiscus verruculosa	··	··	17.1	··	··	··	··	··
Flacourtia indica	19.5	··	2.4	9.8	2.4	··	··	2.5
Garcinia huillensis	2.4	··	2.4	2.4	2.4	2.4	··	··
Lannea discolor	17.1	··	··	4.9	9.8	··	··	2.4
Oncoba spinosa	4.9	··	··	4.9	7.3	··	··	··
Parkia filicoida	9.8	··	4.9	2.4	7.3	··	··	··
Sclerocarya birrea	17.1	··	4.9	24.4	9.8	··	··	7.3
Strychnos spinosa	56.1	2.4	4.9	19.5	9.8	··	··	··
Syzigium cordatum	9.8	··	2.4	2.4	4.9	··	··	··
Tamarindus indica	··	··	2.4	2.4	··	··	··	··
Uapaca kirkiana	7.3	··	··	4.9	2.4	··	2.4	··
Vagueria infausta	17.1	··	··	7.3	4.9	··	··	2.4
Vitex doniana	4.9	··	··	2.4	··	··	··	··
Ximenia caffra	9.8	··	··	4.9	7.3	··	··	··
Zahna africana	19.5	··	··	9.8	7.3	··	··	2.4

·· not reported as a use. Source: Minae (1992a). Used with permission.

> rows between rotating fields of maize, tobacco and groundnuts on Master Farms and broadcast promiscuously with maize in the unplanted gardens where the stems are left during cultivation and mature during the dry season (Hursh, 1960, p. 37).

Poulson (1981) reported that in some locations *Leucaena leucocephala* was being grown by cattle farmers as a fodder crop, and that in the Lower Shire Valley it was becoming an important cash crop as its leaves were being sold for fodder.

Recent inventories of woody cover on farms in Lilongwe ADD identified an astonishing diversity of tree species. Around 50 species were recorded in transects across five representative sites in the division. Both indigenous and exotic fruit trees featured prominently in the inventory (Table 2). Mango trees (*Mangifera indica*), for instance, were the most commonly found of all species, accounting for 35% of the tree population, while *Bauhinia thonningii* was the most common indigenous tree (Minae, 1992a). Management is likely highly intensive, and these trees are bound to be far more productive in terms of timber, fruit, and fodder output than are trees which are found in conventional plantation configurations or in woodlands.

Other studies have confirmed a similarly high diversity of species found on farms. In an inventory of trees used by farmers, Maghembe and Seyani (1991), for instance, reported 71 species which are retained in croplands. Farmers reported that fewer useful species (28) were found in uncultivated fallows. The most valuable species were concentrated on farm boundaries, around homesteads, in fields, and on uncultivated land immediately around farmers' fields.

Oddly, these findings have apparently had little influence on the formation of policy or on the design of project interventions. Little effort seems to have been made to encourage these types of practices. Policies and incentives have generally been geared toward the adoption of new, unproven and somewhat risky practices instead of strengthening existing, proven, and accepted tree management systems. It is an astonishing, but common, characteristic of rural forest policy development more generally that this linkage is seldom made.

One of the economic arguments in favor of incorporating trees into farming systems is that families can diversify their sources of inputs into the household economy. Adaptive strategies which have diversification as a key element, are particularly important from the perspective of households in dryland areas which are most prone to risk of crop failure during dry years.

From the farmer's perspective, the process of diversifying is itself potentially risky, entailing sometimes large investment costs in the face of uncertain returns. Rural forestry planners have seldom acknowledged

Table 2. *Frequency and canopy cover of trees found in croplands in Lilongwe ADD*

Species	Mean canopy diameter (m)	Number per 100 ha	Canopy per 100 ha (m^2)	Species	Mean canopy diameter (m)	Number per 100 ha	Canopy per 100 ha (m^2)
Acacia macrothysa	2.7	4	23	*Gmelina arborea*	4.1	136	1796
Acacia polyacantha	3.2	40	322	*Kigelia africana*	3.1	64	483
Albizia lebbeck	4.5	8	127	*Inula glomerata*	1.8	48	122
Allophylus africana	1.1	24	23	*Longocarpus capassa*	2.0	40	126
Azanza garckeana	1.3	208	276	*Mangifera indica*	3.2	1648	13245
Bauhinia thonningii	2.1	428	1482	*Markhamia obtusifolia*	2.1	100	346
Cassia didymobotrya	1.8	4	10	*Melia azederach*	1.5	48	85
Cassia petersiana	1.0	4	3	*Parinari curatellifolia*	4.5	20	318
Cassia siamea	1.8	224	570	*Pericopsis angolensis*	3.4	72	654
Combretum collinum	3.4	168	1525	*Psidium guajava*	1.8	12	31
Combretum zeyheri	2.4	12	54	*Psorospernum febrifugum*	..	16	..
Commiphora mossambicensis	..	4	..	*Pterocarpus angolensis*	4.5	20	318
				Rauvolfia caffra	2.4	68	308
Cordyla africana	1.1	24	23	*Ricins communis*	2.5	4	20
Cussonia kirkii	1.8	40	102	*Salvadora persica*	..	4	..
Dichrostachys cinerea	1.9	44	125	*Steganotaenia araliacea*	0.9	28	18
Diplorynchus condylocarpon	2.7	4	23	*Strychnos spinosa*	2.8	108	665
				Syzygium cordatum	0.5	4	1
Dombeya rotundifolia	2.1	28	97	*Terminalia sericea*	4.5	12	191
Erythrina abyssinica	3.4	264	2397	*Toona ciliata*	2.2	64	243
Euphorbia tirucalli	1.4	12	18	*Trichelia emetica*	3.6	4	41
Faidherbia albida	6.7	40	1410	*Vaguelia amygdalina*	1	36	28
Ficus natalensis	2.9	84	555	*Vaguelia infausta*	1.5	40	71
Ficus sycomorus	4.4	80	1216	*Vitex doniana*	..	24	..
Ficus verruculosa	5.4	28	641	*Ximenia americana*	0.9	4	3
Gliricidia sepium	0.9	96	61	*Zahna africana*	..	20	..

Source: Minae (1992). Used with permission.

this, and when they have, the response has seldom been appropriate.

The following section considers the economic rationale for two particular land-use strategies which incorporate trees in fields to maintain soil fertility. *Faidherbia albida* is an agroforestry species indigenous to Malawi which can return substantial amounts of nitrogen to the soil. *Leucaena leucocephala* is an introduced fast-growing leguminous tree species which has been extensively tested on field stations and is considered to have good potential as an agroforestry species. These two systems are being compared both in terms of their real impacts on soil fertility, as well as in terms of the costs of establishing and maintaining these systems *vis-à-vis* the range of potential benefits which could be expected from these investments.

3. THE ECONOMICS OF AGROFORESTRY SYSTEMS

(a) *Food security and the smallholder farming sector*

The economic viability of agroforestry systems has to be considered with regard to the inputs they could provide to smallholder agriculture in Malawi. *Leucaena* and *Faidherbia* could principally increase nutrient availability, improving crop output and contributing to food security. Food security is a clear concern in Malawi. This section discusses some of the contributing factors and perceived solutions to problems of food insecurity.

Rapid expansion of the tobacco farming sector in Malawi in the 1970s and 1980s was a very successful means of generating growth in exports and in the economy as a whole. It had little impact, however, on improving productivity in the smallholder subsector. Although Malawi usually produces a marketed surplus of maize and occasionally exports, apparent food security at the national level masks widespread food insecurity at the household level. Smallholder production of food crops in per capita terms has been declining since the mid-1970s. Malawi has high rates of stunting among children and the fourth highest rate of infant mortality in the world. Around 15% of children die before reaching one year of age.[4]

Food insecurity, and particularly the inability of the smallholder sector to maintain or to increase levels of food output, has been attributed to serious shortages of arable land, the low levels of technology practiced by most smallholders, and weaknesses in the delivery of agricultural services. Although these constraints have dominated much of the debate about how food insecurity can be best addressed through development initiatives, there are no clearcut approaches to the solutions. Food insecurity, and the malnutrition which results, is the outcome of complicated social, cultural, and economic interactions.

The most promising areas for improvement have been in the rates of adoption of better inputs. In 1980–81, around a quarter of smallholders used fertilizers. By 1991, this proportion had increased to around 45%. In 1990–91 hybrid maize seed sales totalled around 5,000 tons, or enough to sow about 15% of the total maize area. In that year, hybrid maize production accounted for around 30% of total output (Agrisystems, 1992).

Mostly because of high transportation costs, Malawi has one of the highest nitrogen-to-maize price ratios in the world. Despite subsidies of up to 30%, its high cost has inhibited both the uptake of fertilizer as well as the use of hybrid maize. Fertilizer use has been heavily skewed toward households that operate larger holdings. Increased fertilizer use, by itself, would fail considerably to reduce household food insecurity. On a "small" holding in the Southern Highlands, for instance, fertilizing all local maize grown would increase the food self-sufficiency ratio from the present 48% to 54%. Combining increased fertilizer use with the adoption of hybrid maize would increase the self-sufficiency ratio to 91%.

Even in the face of rapid increases in fertilizer use, productivity has remained low mostly because its use has not been combined with the adoption of hybrid maize. By 1990–91, the supply of subsidized fertilizer was sufficient to provide 60% of all smallholder food crops with the full recommended dosage of fertilizer. Expected increases in the purchase of hybrid maize seed and in average maize yields were not forthcoming largely because subsidized fertilizers were used on cash crops such as tobacco or vegetables (Agrisystems, 1992).

Despite fertilizer subsidies, many farmers are unable to afford to purchase and apply the optimal amounts. Labor remains an important constraint for planting, weeding, and fertilizing during a narrow prime period. There is little advice available about the tradeoffs farmers can make, for instance, with regard to the timing of fertilizer applications or for farmers who are unable to purchase and apply the recommended amounts.

High fertilizer costs erode farmers' gross margins, particularly when cropping conditions are suboptimal, giving the most risk-averse farmers some incentive to leave crops unfertilized. Recent evaluations have noted that returns to fertilizer use are highly variable, and dependent in large part on optimal weather conditions (Conroy, 1993). High variability in returns suggest that the use of chemical fertilizers can be extremely risky.

Most analysts assume that local varieties of maize are expected to show a yield response of around 14 kg of maize for every kg of chemical fertilizer nutrient N, while hybrid varieties are expected to show a yield response of around 30 kg of maize for every kg of nutrient N (World Bank, 1990). Recent studies, however, have suggested that maize response coefficients, particularly for hybrid maize, are much lower. Data from a number of surveys in Kasungu and Lilongwe in the 1990–91 season gave average nitrogen response rates of only 21 kg for hybrid maize (Conroy, 1993).

The principal advantages of an agroforestry system which would increase nutrient availability are that the costs per unit of nutrient would be lower than costs for chemical fertilizers; the risks of losing the benefits from chemical fertilizer would be lower in the event of the failure of the rains; soil structure would be improved by the addition of organic matter; and the increased availability of other outputs such as firewood and fodder. The principal disadvantages relate to the relatively long time period involved before benefits are realized, the sometimes labor-intensive requirements of agroforestry management, problems of establishment, and the importance of the timing of planting out.

This analysis examines two very different tree cultivation and management systems. The point is, largely, to compare one system against the other using similar measures and assumptions. The advantages and constraints of using particular units of analysis, such as benefit-cost ratios or internal rates of return (IRR) are well known and are described in most basic texts about the economic analysis of projects (for example, Gittinger, 1982). One of the principal advantages of using benefit-cost ratios is that they allow the analyst to examine how much the cost of an investment could rise before it would be uneconomic. The principal advantage of using an internal rate of return is that it reflects the returns an investment would yield in order to break even. If the IRR is above a farmer's discount rate, the investment would appear to be a productive use of capital, land and labor. If the discount rate is above the IRR, a farmer would be disinclined to make the investments necessary.

In this analysis, we are primarily concerned with the sensitivity of returns to investment costs, recurrent costs, and to differences in yields. We are less concerned about the impact of a high discount rate on a farmer's decision to adopt a particular practice because we are asking, instead, at a given discount rate, how does one agroforestry strategy compare against another. Still, for comparison, internal rates of return to "base case" investments are also estimated.[5]

(b) *Intercropping with* Faidherbia albida

Faidherbia albida is an indigenous, leguminous tree typically found on deep alluvial soils, though it has a very broad range in Malawi. Its limiting constraint is that its roots must be able to reach groundwater during the dry season. It has the unique characteristic of shedding its leaves during the wet season (limiting light competition with crops during this period), and its leaf litter can greatly contribute to improving soil fertility during this time of year. *Faidherbia* is also a high quality browsing tree for livestock.

Typically, it grows very slowly. For the first five years or so, growth above ground is unimpressive, and much energy has gone to extending the taproot. Even among seedlings produced from the same parent tree, the species shows huge variability in its growth rate. The need for a means of producing seedlings with similar growth characteristics is considerable, as returns to the planting of individual trees must be more certain before it could be expected that farmers would adopt the tree in considerable numbers. There are, of course, ways around this problem, typically by overplanting, and then by thinning out the less productive trees.

The benefits of planting annual crops under fully grown trees are well documented in Malawi and elsewhere, and among smallholders, these benefits are quite well known. Despite clear and substantial yield improvements which can be brought about by planting crops under *Faidherbia*, management in Malawi tends to be opportunistic. While farmers may encourage regeneration of naturally germinating trees, tree planting is less common. One of the biggest problems for smallholders with regard to tree planting is that it takes a long time before benefits from the slow-growing *Faidherbia* can be realized.

There have been a number of studies of yield improvements under traditional *Faidherbia* management systems in Malawi (Bunderson *et al.*, 1991a and 1993; Selenje, Mgomezulu and Mukunuwa, 1991) and these have been used as the basis for several economic and financial analyses (Hayes, 1991; Selenje, Mgomezulu and Mukunuwa, 1991; Simler, 1993; Barbier and Burgess, 1992). What is evident from the attention which has been given to *Faidherbia* is that it is gaining increasing currency among many agriculturalists as a viable and suitable local technology for improving crop yields. This is not surprising. Bunderson *et al.* (1991a) and Selenje, Mgomezulu and Mukunuwa (1991) both reported that maize yields under *Faidherbia* were at least 40% higher, and in some instances more than twice, what they would be in fields without the tree or without other fertilizers.

Estimated costs and benefits of planting *Faidherbia* to improve crop yields are summarized in Table 3. The principal costs which farmers would have to bear would be for establishment. These costs are quite low. Subsequent management costs are nil. Farmers need to establish a stand of only 25 trees per ha in order to gain maximum benefits from having trees in fields. Seedling costs for the Forest Department are estimated to be around MK 0.12 per seedling (World Bank, 1992b), though farmers who grow their own seedlings are likely to be able to produce them more cheaply.[6] In the model in Table 3, it was assumed that a farmer would plant 100 seedlings, each costing MK 0.20, that this would take two days to accomplish, and that another day per year would be required to protect the seedlings through the fifth year. Labor was costed at MK 3.30 per person-day. Establishment costs would total, then, little more than MK 40 per ha. The least productive seedlings would be thinned out over the next several years, leaving a stand of 25 trees per ha.

There is little information about the speed with which the trees would begin to benefit crops. By the time the trees were fully mature in the 25th year, however, it was assumed that yields of local maize varieties would be increased by 15% and that yields of hybrid maize would be increased by 50%, over initial yields of 850 kg and 1,020 kg per ha, respectively. Yield benefits would slowly accrue during the first five years, more quickly accruing between the fifth and 15th years, and then slowing down again from the 15th year. It was estimated that half of the yield increases would be felt by the 12th year.

To produce similar maize yields using the best crop management and chemical fertilizers instead of *Faidherbia*, a farmer would have to use at least 20 kg of chemical fertilizer nutrient N per ha every year. Under poor crop management, as much as 63 kg per ha would be required. At current prices, this would cost at least MK 67 for the 43 kg of urea which would be required in the former instance, or at most, MK 212 for the 134 kg of urea which would be required under poor management. Compared with a one-time capital cost of MK 40 per ha for tree planting, at these very high annual costs for chemical fertilizers, the use of *Faidherbia* for increasing crop yields makes an enormous amount of sense.

Added benefits which are not considered here include the production of fodder and of firewood. Seed pods from *Faidherbia* are extremely good as fodder. Selenje, Mgomezulu and Mukunuwa (1991) reported that pod production varies from 6 to 15 kg per mature tree per year. Lopping branches for firewood could reduce leaf litter production, but conceivably, around 0.1 to 0.5 m^3 per ha could be extracted annually without significantly affecting leaf litter yields.

Because of higher yields, additional labor would be required for harvesting and shelling incremental maize production. These costs were assessed at a rate of 12 person-days per ton for harvesting, and 5.5 person-days per ton for shelling.

Using these assumptions, and a 15% discount rate, benefit-cost ratios 2.3 and 5.3 could be expected for local and hybrid maize, respectively, grown under planted *Faidherbia*.[7] Internal rates of return are 23.8%

Table 3. *Cost and benefit stream for planting* Faidherbia albida *and intercropping with local and hybrid varieties of maize, per ha*

Year	Tree management costs*	Percent of yield benefits †	Maize yields (kg/ha)‡		Incremental benefits (MK)§		Incremental labor costs (person-days)¶		Incremental labor costs (MK)‖		Total incremental costs (MK)		Total incremental benefits (MK)		Net benefits or costs (MK)	
			Local	Hybrid	Local	Hybrid	Local	Hybrid	Local	Hybrid	Local	Hybrid	Local	Hybrid	Local	Hybrid
1	29.9	0%	850	1020	0	0	0	0	0	0	30	30	0	0	(30)	(30)
2	3.3	1%	851	1023	0	2	0	0	0	0	3	3	0	2	(3)	(2)
3	3.3	1%	851	1026	1	3	0	0	0	0	3	4	1	3	(3)	0
4	3.3	2%	852	1029	1	5	0	0	0	1	3	4	1	5	(2)	1
5	3.3	3%	854	1035	2	8	0	0	0	1	4	4	2	8	(1)	4
6	..	5%	856	1044	3	14	0	0	0	1	0	1	3	14	3	12
7	..	8%	860	1059	5	22	0	1	1	2	1	2	5	22	5	19
8	..	12%	865	1081	9	34	0	1	1	4	1	4	9	34	8	31
9	..	18%	873	1113	13	52	0	2	1	5	1	5	13	52	12	47
10	..	27%	884	1157	19	77	1	2	2	8	2	8	19	77	17	69
11	..	38%	898	1213	27	108	1	3	3	11	3	11	27	108	24	97
12	..	50%	914	1275	36	143	1	4	4	15	4	15	36	143	32	128
13	..	62%	929	1337	44	178	1	6	5	18	5	18	44	178	40	159
14	..	73%	943	1393	52	209	2	7	5	22	5	22	52	209	47	187
15	..	82%	954	1437	58	233	2	7	6	24	6	24	58	233	52	209
16	..	88%	962	1469	63	252	2	8	6	26	6	26	63	252	56	226
17	..	92%	968	1491	66	264	2	8	7	27	7	27	66	264	59	237
18	..	95%	971	1506	68	272	2	9	7	28	7	28	68	272	61	244
19	..	97%	974	1515	69	277	2	9	7	29	7	29	69	277	62	249
20	..	98%	975	1521	70	280	2	9	7	29	7	29	70	280	63	252
21	..	99%	976	1524	71	282	2	9	7	29	7	29	71	282	63	253
22	..	99%	977	1527	71	284	2	9	7	29	7	29	71	284	64	254
23	..	100%	977	1528	71	284	2	9	7	29	7	29	71	284	64	255
24	..	100%	977	1529	71	285	2	9	7	29	7	29	71	285	64	256
25	..	100%	977	1529	71	285	2	9	7	29	7	29	71	285	64	256
26	..	100%	977	1530	71	285	2	9	7	29	7	29	71	285	64	256
27	..	100%	977	1530	71	285	2	9	7	29	7	29	71	285	64	256
28	..	100%	977	1530	71	286	2	9	7	29	7	29	71	286	64	256
29	..	100%	977	1530	71	286	2	9	7	29	7	29	71	286	64	256
30	..	100%	977	1530	71	286	2	9	7	29	7	29	71	286	64	256

* Assumes original planting of 100 seedlings in year 1, at a cost of MK 0.20 per seedling; two person-days required for planting; one day of protection per year for the first five years; labor costs at MK 3.3 per day. Stand is eventually thinned to 25 stems per ha. Thinning costs are assumed to be nil.

† There is little empirical evidence to suggest how quickly benefits will accrue. In this model, benefits are expected to accrue slowly in the first five years, more quickly between the fifth and the 15th year, and more slowly until the trees reach maturity by the twenty-fifth year. In this model, benefits are expected to accumulate on a notional logistic basis which can be expressed in the form $1/(1+e^{(-z)})$ where z is a combination of independent and lag variables.

‡ Maize yields for local varieties are expected to increase by 15% by the time trees are mature. Yields for hybrids are expected to increase by 50%. The models make no allowance for likely declines in maize yields in the absence of additional fertility inputs.

§ Incremental benefits are the increased amount of maize produced, compared with the first year, valued at MK 0.56 per kg.

¶ Incremental labor is the amount of additional labor which would be required to harvest and shell incremental yield. It is estimated that 12 person-days per ton are required for harvesting, and 5.5 person-days per ton are required for shelling.

‖ Labor costed at MK 3.30 per person-day.

Given a 15% discount rate, in these models, the benefit-cost ratio for local maize is 2.3 and the benefit cost-ratio for hybrid maize is 5.3. The IRR is 23.8% for local maize and 41.4 for hybrid maize.

for local maize and 41.4% for hybrid maize. Benefit-cost ratios are most sensitive to *Faidherbia* establishment costs, and to the proportionate increases in yields which could be expected. The sensitivity of benefit-cost ratios to changes in establishments costs, and to changes in projected yield increases were tested. The results from the sensitivity analysis are shown in Figure 1.

Under these assumptions, investments in *Faidherbia* make good sense, regardless of the long time before benefits accrue. For local maize, investments are viable if yield increases of at least 20% can be expected. Benefit-cost ratios are greater than 2.00 if establishment costs are kept below MK 40 per ha, and if 20% yield increases can be expected. If 30% yield increases are expected, establishment costs of up to MK 100 can be incurred before benefit-cost ratios fall below 2.00. Empirical studies have shown that yield increases of at least 20% could be expected, and that these are very conservative. For hybrid maize, investments are viable under similar conditions, but if first year costs are kept below MK 50 per ha. With 40% yield increases, first year costs of up to MK 125 per ha could be incurred before benefit-cost ratios fall below 2.00. Empirical studies suggest that these yield increases are quite conservative. If measured yield increases of 70–120% are any indication, there is little reason why investments in *Faidherbia* would not be extremely high yielding.

Faidherbia is one of several indigenous agroforestry systems found in Malawi. The use of *Sesbania sp.* for instance, has been noted in other studies (Hursh, 1960). *Sesbania* management systems are under intense study at a number of research stations. Much of this research appears to have been geared toward the development of systems which are largely inappropriate for resource-constrained farmers. The need for more economically appropriate adaptive research in Malawi could hardly be clearer. Recent initiatives to explore the potential for "relay" cropping with *Sesbania* are moves in this direction.

Very few other indigenous trees found in farmlands have been evaluated for their potential for improving soil fertility. Recent studies have sought to clarify the potential impact of a number of common farm trees (*Bauhinia, Erythrina abyssinica, Pericopis angolensis,* and *Mangifera indica*) on soil fertility. This research is in its earliest stages, and is not conclusive (Minae, 1992b). There is clearly scope for a much more intensive and focused effort at characterizing potential returns to on-farm species.

Most other research and extension initiatives which have been geared toward increasing soil fertility and food security through agroforestry have focused on three particular exotic species: *Leucaena leucocephala, Cassia spectabilis,* and *Gliricidia sepium.* They have all shown some potential. *Leucaena* has

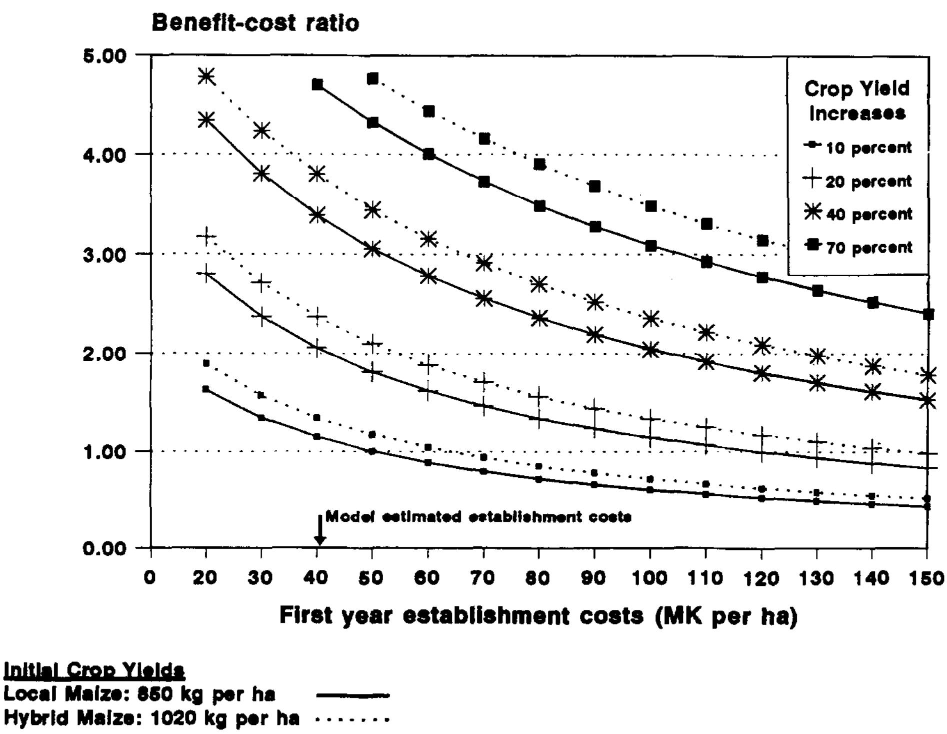

Figure 1. *Sensitivity of returns to local and hybrid maize grown under planted* Faidherbia.

been the most well-researched of these species. Current views are that the potential of *Leucaena* has been limited because of low yields brought about by termite and grazing damage (Carr, 1993). Probably the most limiting factor, however, has been that the management models which have been proposed have been very labor intensive. The next section explores the economic potential of *Leucaena* for increasing crop productivity in the face of smallholder labor constraints.

(c) *Returns to* Leucaena leucocephala *alley cropping*

Leucaena is one of the favorites of agroforestry researchers, in part because it has all the characteristics of what is perceived to be a "good" agroforestry species: it is fast growing, it coppices well, it can have multiple uses (fodder, fuelwood, improving soil fertility, and so on), it can be relatively easily regenerated and planted out from seedlings, it has a long life, and is especially well-adapted for examining in the research station context. It has three particular niches in Malawi: as a fodder crop for livestock, as an alley crop for improving soil fertility and maize productivity, and as an alley crop for improving tobacco production.[8]

The date of its introduction into Malawi is unclear. Unimproved cultivars may have been introduced decades ago. In a number of Eastern and Southern African economies, *Leucaena* was first introduced as a green manure species for plantation agriculture. In coastal areas of Kenya, for instance, it has become naturalized and is widely considered to be a weed.

In any event, by the time the first wave of contemporary interest in agroforestry gained momentum in the late 1970s, *Leucaena* was already under cultivation in Malawi. The widespread use of dry *Leucaena* leaf as a livestock feed supplement prompted researchers to consider its potential in this respect (Munthali, 1991). Live weight gains for steers fed with *Leucaena* were found to be comparable with those from cottonseed cake (Addy and Thomas, 1977). Malindi (1977) considered it a traditional agroforestry practice and reported that farmers in Ngabu widely planted it in small woodlots or in hedgerows along field boundaries to produce leaves for stall feeding. Commercial buyers such as the Grain and Milling Company purchased leaves for inclusion in stock feed (Chiumia, 1991). Poulson (1981) reported extensive small-scale, commercial production of *Leucaena* fodder in the Lower Shire Valley. It has been tested as a livestock feed supplement, as well as a supplementary feed for chickens and for fish (Msiska, 1993).

Leucaena was first recommended and promoted as an alley crop in the early 1980s, though extensive on-

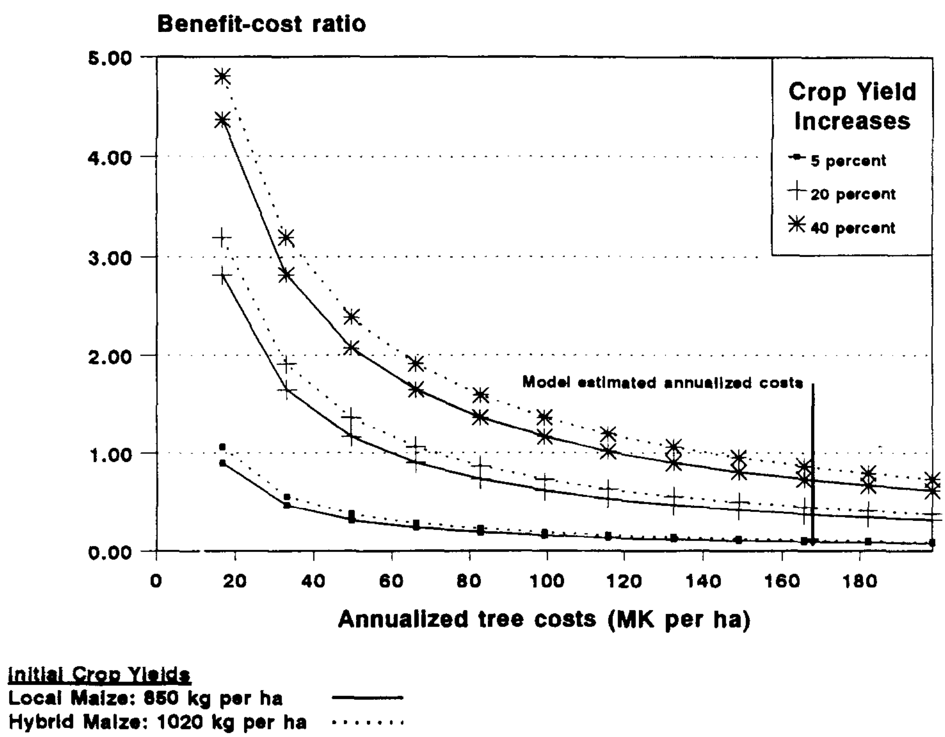

Figure 2. *Sensitivity of returns to local and hybrid maize intercropped with* Leucaena leucocephala.

Table 4. *Cost and benefit stream for planting* Leucaena leucocephala *and intercropping with local and hybrid varieties of maize, per ha*

Year	Seedling cost (MK)*	Planting labor (person-days)†	Planting labor costs (MK)‡	Total establishment costs (MK)	Tree management labor costs (person-days per ha)¶				Tree management labor costs (MK per ha)				Total *Leucaena* costs (excluding labor) (MK)	Total *Leuca* costs (incluc labor) (MK)
					Leaf applications		Pruning		Leaf applications		Pruning			
					First	Second	First	Second	First	Second	First	Second		
1	556	9.3	30.6	586.16	0	0	0	0	0	0	0	0	556	586
2	83	1.4	4.6	88	9	0	7	0	29.7	0.0	23.1	0.0	83	141
3	56	0.9	3.1	59	9	2	7	7	29.7	6.6	23.1	23.1	56	141
4	..	..	..	..	9	2	7	7	29.7	6.6	23.1	23.1	..	83
5	..	..	..	..	9	2	7	7	29.7	6.6	23.1	23.1	..	83
6	..	..	..	..	9	2	7	7	29.7	6.6	23.1	23.1	..	83
7	..	..	..	..	9	2	7	7	29.7	6.6	23.1	23.1	..	83
8	..	..	..	..	9	2	7	7	29.7	6.6	23.1	23.1	..	83
9	..	..	..	..	9	2	7	7	29.7	6.6	23.1	23.1	..	83
10	..	..	..	..	9	2	7	7	29.7	6.6	23.1	23.1	..	83
11	..	..	..	..	9	2	7	7	29.7	6.6	23.1	23.1	..	83
12	..	..	..	..	9	2	7	7	29.7	6.6	23.1	23.1	..	83
13	..	..	..	..	9	2	7	7	29.7	6.6	23.1	23.1	..	83
14	..	..	..	..	9	2	7	7	29.7	6.6	23.1	23.1	..	83
15	..	..	..	..	9	2	7	7	29.7	6.6	23.1	23.1	..	83
16	..	..	..	..	9	2	7	7	29.7	6.6	23.1	23.1	..	83
17	..	..	..	..	9	2	7	7	29.7	6.6	23.1	23.1	..	83
18	..	..	..	..	9	2	7	7	29.7	6.6	23.1	23.1	..	83
19	..	..	..	..	9	2	7	7	29.7	6.6	23.1	23.1	..	83
20	..	..	..	..	9	2	7	7	29.7	6.6	23.1	23.1	..	83

* Assumes the planting in year of 1 of 4,630 seedlings per ha (at a spacing of 0.4 m apart on ridges every 5.4 m), at a cost of MK 0.12 per seedling. Fifteen cent are replaced in the second year, and another 10% are replaced in the third year.

† Based on 20-person-days per 10,000 seedlings.

‡ Priced at MK 3.30 per person-day.

§ Seedling and labor costs.

¶ One leaf application and one pruning in the second year, at nine person-days per ha and seven person-days per ha respectively, and two per year from the tl year. The second leaf application takes only two person-days per ha-yr.

‖ The accumulation of yield benefits varies, but generally, few benefits are observed before the third year. In this model, *Leucaena* is expected to increase yi of local maize by 10%, from the fifth year, and of hybrid maize by 50% from the fifth year. Unfertilized yields without *Leucaena* are estimated, in this model be 850 kg per ha for local maize and 1020 kg per ha for hybrid varieties.

station research had not been carried out at this stage to determine the most appropriate spacings, management practices, or potential yields. Though widely promoted, it was an unproven technology with uncertain soil fertility benefits. In the end, it basically failed to meet extensionists', researchers', and farmers' high expectations. Rates of farmer adoption have been poor (Franks, 1992).

Poor rates of farmer adoption have been attributed to:

- — high labor requirements for alley cropping using the recommended management practices in the face of labor constraints at critical periods in the cropping cycle;
- — tenure constraints, principally the lack of clear rights to exclude cattle from grazing in fields during the dry season, resulting in damage to young trees;
- — technical constraints, such as poor growth in acid and infertile soils and in colder regions, aphid and termite problems, and the need for proper rhizobia inoculants;
- — perceptual and attitudinal constraints among land-constrained farmers who, while understanding the need to improve soil fertility and to limit erosion, are uncertain of the utility of taking land out of production to adopt an as yet unproven (from their perspective) technology; and
- — institutional constraints, having to do with the effectiveness of resource-constrained extension agencies (Carr, 1993; Mwakalagho, 1991).

There are a number of studies of maize yield responses under *Leucaena*. Bunderson *et al.* (1991b) reported hybrid maize yield increases of between two and 3.5 times on seriously depleted soils. On moderately fertile soils, yield increases were reported to be between 18 and 77%. Kwapata *et al.* (1991) found that, in the fifth season after trials were started, on infertile and seriously depleted soils, yields of hybrid maize under *Leucaena* were around 20% higher than yields without. There are few reports of yield response rates of local maize varieties to *Leucaena*-produced N nutrient, but these are believed to be around 10%.

Percent of yield benefits ‖	Maize yields (kg/ha)		Incremental benefits (MK)**		Incremental labor costs, harvesting and shelling (person-days)††		Incremental labor costs, harvesting and shelling (MK)		Total incremental costs (MK)		Total incremental benefits (MK)		Net benefits or (costs) (MK)	
	Local	Hybrid	Local	Hybrid	Local	Hybrid	Local	Hybrid	Local	Hybrid	Local	Hybrid	Local	Hybrid
0%	850	1020	0	0	0.0	0.0	0.0	0.0	586	586	0	0	(586)	(586)
10%	859	1071	5	29	0.1	0.9	0.5	2.9	141	144	5	29	(136)	(115)
50%	893	1275	24	143	0.7	4.5	2.5	14.7	144	156	24	143	(120)	(13)
90%	927	1479	43	257	1.3	8.0	4.4	26.5	87	109	43	257	(44)	148
100%	935	1530	48	286	1.5	8.9	4.9	29.5	87	112	48	286	(40)	174
100%	935	1530	48	286	1.5	8.9	4.9	29.5	87	112	48	286	(40)	174
100%	935	1530	48	286	1.5	8.9	4.9	29.5	87	112	48	286	(40)	174
100%	935	1530	48	286	1.5	8.9	4.9	29.5	87	112	48	286	(40)	174
100%	935	1530	48	286	1.5	8.9	4.9	29.5	87	112	48	286	(40)	174
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100%	935	1530	48	286	1.5	8.9	4.9	29.5	87	112	48	286	(40)	174
100%	935	1530	48	286	1.5	8.9	4.9	29.5	87	112	48	286	(40)	174
100%	935	1530	48	286	1.5	8.9	4.9	29.5	87	112	48	286	(40)	174
100%	935	1530	48	286	1.5	8.9	4.9	29.5	87	112	48	286	(40)	174
100%	935	1530	48	286	1.5	8.9	4.9	29.5	87	112	48	286	(40)	174
100%	935	1530	48	286	1.5	8.9	4.9	29.5	87	112	48	286	(40)	174
100%	935	1530	48	286	1.5	8.9	4.9	29.5	87	112	48	286	(40)	174
100%	935	1530	48	286	1.5	8.9	4.9	29.5	87	112	48	286	(40)	174
100%	935	1530	48	286	1.5	8.9	4.9	29.5	87	112	48	286	(40)	174

** Incremental maize yields are priced at MK 560 per ton.

†† Incremental labor is required for harvesting and for shelling maize, at rates of 12 person-days per ton and 5.5 person days per ton respectively.

At these costs and benefits, the benefit-cost ratio for intercropping local maize with *Leucaena* is 0.19. For hybrid maize, the ratio is 1.06. The internal rate of return for local maize is negative. The IRR for hybrid maize is 17%.

Annualized tree costs are obtained by using the equation $AC = NPV * i/[1-(i+1^{-n})]$ where AC is the annualized cost, NPV is the Net Present Value, i is the discount rate and n is the number of years. Seedling costs alone account for MK 93.09 per year on an annualized basis. Labor for establishment and for management (pruning and leaf application) adds anouther MK 72.75 per year to annualized costs, bringing total tree costs to MK 165.66 per ha. Even if seedling costs were nil, other labor costs would make this agroforestry practice prohibitive. Annualized yields are calculated in a similar way. For instance, in this model, yields increase from 850 kg per ha for local maize to 935 kg per ha. On an annualized basis over 20 years and at a 15% rate of discount, yields are 909 kg per year.

In contrast to the *Faidherbia* systems described in the previous section, *Leucaena* is very management-intensive, and considerable costs have to be incurred to recover the highest margins. *Leucaena* production and management costs are evaluated in Table 4.

The model in Table 4 considers an alley cropping system where *Leucaena* is planted at a spacing of 0.4 m on ridges spaced every 5.4 meters apart (the recommended spacing, or around 4,600 seedlings per ha). Seedling costs are estimated to be MK 0.12 per seedling, and so investment costs (including the filling of gaps in years 2 and 3) total around MK 700 per ha (undiscounted). Labor for planting out is added to this figure, at a rate of MK 3.30 per day. Management inputs are calculated on the basis of nine and two days per ha for two leaf applications per year from the third year, and two prunings requiring seven days from the third year. Establishment costs account for around 60% of all discounted tree-associated costs. If all tree-associated establishment and management costs are converted to reflect what would have to paid annually using this management system, costs total MK 166 per ha per year.

Benefits are difficult to evaluate. Most studies of *Leucaena* alley cropping systems note that yields remain depressed for the first several years after alleys have been established. Benefits begin to be observed in the third or fourth season after planting, and are fully felt by the fifth year. In the model in Table 4 alley cropping with local and hybrid maize varieties was assumed to increase yields by 10 and 30% respectively.

Heavy establishment and management costs for alley cropping give disappointing returns. Returns to cultivating local and hybrid maize varieties with *Leucaena* are consistently poor, with benefit-cost ratios generally less than 1.00. Under these assumptions, the internal rate of return for intercropping *Leucaena* with local maize is negative; for hybrid maize the IRR is 17% (marginally above the discount rate used in the benefit-cost calculations of 15%).

It could be argued that this model is a very high-cost management system, and that the benefits assumed are too low. In order to test the sensitivity of returns to establishment and management costs, and to different yield assumptions, the model was recalculated.[9] The results are shown in Figure 2. For local maize varieties, it would be very difficult to argue that investment in *Leucaena* alley cropping makes any sense. Yields would have to increase by around 25% to get a positive rate of return, and would have to increase well in excess of 50% before the benefit-cost ratio exceeded 2.00. Yield increases at these levels, for local maize varieties, are unrealistic.

The situation is only marginally more promising for hybrid maize varieties. If annualized costs are reduced to around MK 70 per ha (from levels of around MK 166 in the original model), yields would have to increase by around 20% to achieve positive rates of return, and by around 50% before the benefit-cost ratio exceeded 2.00. From empirical studies, these yield increases are realistic. The problem really is finding a way to reduce management costs. Labor has been costed at MK 3.30 per person-day. This is probably higher than what most *ganyu* labor goes for, especially during the low season, but is likely lower than the opportunity cost of labor during peak seasons, when most silvicultural treatments have to be undertaken. *Leucaena* is also not risk free. Termites and grazing have caused high seedling mortality considerably increasing establishment costs. It is far more likely that higher management and establishment costs than those assumed would more correctly characterize the system.

In light of this analysis, *Leucaena* as an alley crop should be promoted in only the most promising of conditions, on the right soils and principally among larger-scale farmers who have already adopted hybrid maize varieties and who can find and afford cheap labor for management. These circumstances are not easily obtainable in Malawi.

Careful consideration, however, should be given to two other possible *Leucaena* management practices: the growing of *Leucaena* in woodlots or hedgerows as a fodder crop, and the use of *Leucaena* for improving soil fertility on tobacco estates. In the first instance, in some areas farmers evidently have adopted *Leucaena* as a fodder crop, and in this particular niche, there must be considerable utility in having done so. The potential for using *Leucaena* on tobacco estates has not been tested on farms.[10]

(d) *Economic considerations and the incorporation of trees into farming systems in Malawi*

Food insecurity, and particularly the inability of the smallholder sector in Malawi to maintain or to increase levels of food output, has been attributed to serious shortages of arable land, the low levels of technology practiced by most smallholders, and weaknesses in the delivery of agricultural services. The adoption of inputs such as chemical fertilizers and hybrid maize varieties has been among the most promising areas of improvement. Even so, a high nitrogen-to-maize price ratio has inhibited both the uptake of fertilizer as well as the use of hybrid maize. Returns to fertilizer use can be highly variable, suggesting that its use can be extremely risky, particularly during periods of low rainfall.

The analysis here has considered potential returns to the management of local and hybrid maize in conjunction with *Faidherbia albida* and *Leucaena leucocephala*. Where long-term investments are made in the planting of *Faidherbia*, maize yield improvements far outweigh the costs of tree establishment, both for local and hybrid varieties of maize. Establishment costs can be kept low because of the low tree density required to achieve optimal results. Once trees have been planted, there are few management requirements.

In contrast, *Leucaena*/maize intercropping involves relatively costly and complicated management inputs. The large number of trees required per ha, and the poor suitability of *Leucaena* except under a limited number of circumstances, coupled with high management costs, work against its widespread adoption. It is unlikely that *Leucaena* intercropping will ever be viable in Malawi except under the best conditions.

4. SCOPE AND IMPACT OF INCENTIVES TO ENCOURAGE FARMERS TO GROW TREES ON THEIR HOLDINGS

Though the rationale for tree cultivation and management is poorly understood, it is a clear feature of smallholder practice in Malawi. Both the prevailing type of tree management practices which are found on small farms, and the analysis of two agroforestry practices in the preceding section, suggest that farmers are most likely to be interested in low-risk, low-cost rural forestry innovations.

Rural afforestation extension initiatives in Malawi have in some circumstances been designed to introduce specific tree planting incentives with the objective of reducing farmers' costs and risks. The ways these incentives have operated, however, have been poorly understood. Of special relevance are questions of,

- —how prevailing economic, social, cultural, and environmental conditions are related to the costs, benefits, and risks which smallholders associate with growing trees;
- —how project or policy introduced incentives have altered the pattern of on-farm capital, land, and labor resource allocation in a way which encourages smallholders to cultivate and manage trees; and
- —the financial and administrative implications of different types of incentive approaches for the public sector.

Project and policy interventions, through development assistance projects or through government action, can change physical and socioeconomic conditions in a way which can encourage tree growing. In Malawi,

- government has worked to improve the farmer's technical knowledge about tree growing through extension and education programs;
- government and nongovernment organizations (NGOs) have provided inputs such as seedlings and tools to encourage farmers to plant trees, decreasing the farmer's costs of tree growing. Seedling production has been subsidized to a very considerable extent;
- farmers have been paid for growing trees, sometimes in conjunction with other land-use improvements and with food aid;
- government has sought to improve the legislative environment for tree growing, with the objective of guaranteeing tree tenure to those who plant and/or protect trees on land to which they have cultivation rights; in the estate sector, leases have included requirements that a minimum area be kept under tree cover;
- government has sought to increase its control over the woodfuel market, confiscating illegal production, increasing stumpage rates, and increasing rates of royalty collection for indigeneous wood harvested from customary lands.

This section principally considers the impact of incentive payments which have been intended to encourage farmers to plant trees. It is clear from these experiences that farmers and aid agencies use very different criteria for determining whether or not particular activities make sound economic sense. The effectiveness of any intervention has depended on the farmer's receptivity to it within the constraints of the rural economy, rather than on whether the intervention makes economic sense in the abstract. Incentives which may effectively support farmer tree planting, and which make sound economic sense from the farmer's perspective, may neither be sound to the national economy or financially sustainable within the constraints of the public sector.

(a) *The Tree Planting Bonus Scheme*

The Tree Planting Bonus Scheme was developed as a result of the experience gained with the World Bank-financed first phase of the Wood Energy Project. That project was strongly oriented toward woodfuel production, and was based on the premise that farmer tree planting would be the most cost-effective means of dealing with the "fuelwood crisis."

> ...(T)ree planting by rural households is by far the lowest cost way to deal with the fuelwood crisis. Supplying farmers with subsidized seedlings through retail nurseries is a highly cost effective way for the Government to promote tree planting. However, for this approach to be successful, it is necessary to ensure that financial incentives exist for farmers to plant trees. The experience under the Project demonstrates that merely providing subsidized seedlings is not enough (World Bank, 1989, p. 21).

These assumptions were largely conjectural, and were not based on a critical analysis of why farmers plant trees in the first place, or their incentives for doing so (or not). What was never really questioned were the real dimensions of the woodfuel crisis in the first instance, and whether farmers (rather than planners) perceived that tree planting would have been their most effective response. In short, a confusion among planners between the physical scarcity of woodfuel and its economic scarcity, and the best ways of responding to these scarcities, had led to dubious interventions in the woodfuel market and to a distorted program of tree planting subsidies and incentives.

In fact, tree planting on small farms was not unpopular as project management assumed. Surveys undertaken by the Energy Studies Unit (1981) showed that fully 29% of rural households surveyed had planted trees during the previous year. Planting rates have been shown to have been higher in areas of greatest pressure (Energy Studies Unit, 1985). Around 40% of households which had planted trees on National Tree Planting Day had obtained seedlings from sources other than government nurseries. During the rest of the year, 87% of households which had planted trees obtained seedlings from sources other than Government nurseries. Clearly the problem was not that farmers weren't planting trees, but that they weren't planting the Project's trees.

Firewood scarcities have had little influence on encouraging people to plant trees. Around 3% of rural households surveyed nationally reported planting trees through the National Tree Planting Program (NTPP) solely for firewood. In contrast, around 22% of households who participated in the National Tree Planting Program (NTPP) intended to use their planted trees solely for poles. Far more powerful incentives to plant trees are related to the potential for multiple uses from them, and to the potential for income. Around 35% of households reported they anticipated using trees planted through the NTPP for firewood and poles for both domestic uses and for sale.

These results are somewhat misleading. The NTPP principally provided seedlings of *Eucalyptus*, a species not known for providing much other than firewood or polewood. The tautology of top-down forestry extension initiatives is problematic. If farmers are provided with seedlings for trees which make good poles, and then are surveyed for their reasons for planting trees, the likelihood is extremely high that they will respond that they anticipated using their trees for poles.

It is against this background that the rationale for the Tree Planting Bonus Scheme can be examined. It was envisaged that,

> ... In order to encourage tree planting for fuelwood and maintenance of fuelwood trees under conditions of distorted stumpage rates, incentives would be provided to farmers which would consist of a bonus of five tambala per tree to be provided to farmers for each tree surviving two years after planting or of some other agreed upon payment in cash or kind. Such payments would make tree planting financially attractive relative to both crops (particularly on marginal agricultural land) and firewood collection (World Bank, 1986, p. 15).

The bonus was determined by calculating the costs of growing trees in a woodlot, benefits which would come from the sale of firewood at prevailing, government-set, stumpage rates, the costs of crop production foregone if the same site were used for annual crops, and the level of payment two years after establishment which would be needed to equate returns to crop production with returns to tree growing. Conceptually, it was an interesting approach, but there was no empirical evidence at the time the project was designed to suggest such an approach would actually work. It wasn't proposed as a "pilot" scheme (although it was to be undertaken in only nine priority districts), nor were the costs of its administration fully considered.

Experience with the scheme has proven it to have been badly misconceived. The objective was to encourage farmers to grow trees for firewood, yet there was little means of ensuring that this actually happened. Tree uses are often fungible. Poles are usually more highly valued than firewood, and it is far more likely that most of the trees which were planted as a result of the program were, in the end, used for poles. This, of course, is not a bad thing, particularly in light of rural housing shortages and high prices for building material which result. The question then becomes one of why, in light of higher pole prices, should the government be subsidizing pole production.

There was an underlying assumption in the design of the bonus scheme that stumpage rates, fixed and set by the government, reflect the actual value of firewood on the stump. An increase in stumpage rates, it was thought, would increase the real economic value of firewood. In reality, it reflects only the stumpage value for firewood for which royalties can be collected, which is surely a small proportion of total wood energy consumed. In the end, government's stumpage rate increases have done little to increase the real economic value of firewood in Malawi.

Other issues seem not fully to have been considered. Why, for instance, in circumstances of considerable food insecurity, were farmers being paid to plant trees on cropland? What were the equity and distributional impacts of the scheme? Wouldn't the market, in the end, be a better determinant of the value of the trees? Even if the bonus scheme had the potential for increasing the incentive to plant trees, the bonus remained at a level determined during project appraisal. Inflation has considerably eroded the benefits from the scheme which would have been possible. Another concern has been the effect of government payments to farmers on local perceptions of tree tenure. Farmers may perceive that, because government paid them for planting trees, the trees do not belong to them but to the government. Unimpeded rights of tenure are clearest when the costs of establishment and protection are borne by the person planting the tree.

Recent evaluations of the scheme have pointed out its considerable administrative costs. It cost around MK 580,000, for instance, to administer payments totalling MK 230,000 against the planting of 4.6 million seedlings, or an average of 13 tambala for every seedling payment of five tambala. The scheme did not necessarily promote good silvicultural management. A land-constrained farmer, for instance, was more likely to plant trees at close spacing in order to get the highest bonus per land unit (World Bank, 1992b).

The Forest Department has recently carried out several studies to evaluate the impacts of the bonus scheme in its nine priority extension districts. Of households surveyed in these districts, 30% had participated in the bonus scheme. Only around 10% of these households, however, indicated that their principal reasons for planting trees was because of the bonus scheme (Nyirongo and Mhango, 1993). Because of the high cost of administration, and its marginal impact in encouraging farmers to plant trees, the bonus scheme will be phased out.

(b) *The potential for incentive schemes and subsidies*

Other schemes which have been designed to provide incentives for farmers to undertake tree planting in Malawi have been similarly disappointing (Franks, 1992; Agrisystems, 1992). There appears to be little scope for pursuing these types of initiatives as they have been conceived and implemented. Arguably, the manipulation of government-set stumpage prices to encourage people to plant trees has similarly had only a distorting impact.[11]

The market may be providing a much greater incentive for farmers to plant trees. Data do show that where there are good markets for products such as poles, firewood, and fruit, some farmers have an added incentive to plant trees, and that household demands also provide a considerable stimulus for tree cultivation and management. The need for subsidies and incentive schemes to encourage people to plant trees in Malawi has not been firmly established. Where farmers are able to grow seedlings by themselves, there is little role. The clearest role for subsidy programs is to encourage the adoption of new species, or of genetically improved stock. Moves otherwise to reduce or to eliminate tree planting subsidies and incentive schemes should be encouraged.

5. CONCLUSIONS

There is considerable evidence that farming households in Malawi highly value trees within their farming systems. Preliminary surveys show a huge range of tree species found on farms. Farmers have encouraged the regeneration of trees in fields and around their households by protecting naturally regenerating indigenous trees, by planting tree seedlings, and by leaving favored trees in fields when woodlands were originally cleared prior to cultivation.

Several indigenous and introduced agroforestry practices have been supported through extension initiatives in order to provide low-cost fertility inputs to maize production systems. *Leucaena leucocephala*, an introduced fast-growing agroforestry species, has proven to be extremely costly to incorporate into alley farming systems, principally because of the heavy capital costs which must be incurred to establish these systems, and because of the high labor costs required for management and maintenance. In contrast, *Faidherbia albida*, an indigenous species widely distributed throughout Malawi, holds good promise as an agroforestry tree mainly because of low establishment and management costs. This is particularly the case if we consider that farmers in Malawi have adopted tree cultivation and management practices which generally involve low costs, and low risks.

In an effort to reduce these types of costs and the risks, the government has sought to encourage farmers to grow trees by offering subsidies and cash bonuses for tree planting. The results from these initiatives have been discouraging, and strongly suggest there are better uses for public funds. These programs have been poorly designed and have seldom been based on any real understanding of the reasons why households plant and manage trees on their farms in the first instance.

Far too little is known to provide good information for policy making about rural afforestation. An inability to characterize in any detail the extent of on-farm tree cultivation and management practices, the proportion of households in different regions which have undertaken these practices, or their rationale for doing so points to the larger difficulty of developing a fuller understanding of their economic basis. Meaningful analyses of resource use, undertaken to develop sound policies in this regard, must focus in the first instance on these issues. Subsequent studies should then consider which households have adopted these practices, when, and under what conditions.

A better understanding of household allocation processes could be gained by empirically examining household economies *vis-à-vis* tree and woodland use. Studies in other rural economies which have accounted for differential access to assets and farming inputs have made it clear that poorer households are often much more heavily dependent on woodlands and on trees for food, soil nutrient inputs, income, and so on (Scoones, 1989; Wilson, 1990; McGregor, 1991). These types of dependencies need to be better clarified by much more comprehensive household-level studies in Malawi.

NOTES

1. See for instance, Energy Studies Unit (1981, 1984, 1985, 1986); French (1986); FORINDECO (1989); and de Lucia and Associates (1992).

2. See for instance the discussion in French (1986).

3. Minae's work, summarized in Tables 1 and 2, is important for a number of reasons. It is perhaps the only work which has attempted to evaluate the extent to which agricultural land in Malawi is used for cultivating and managing trees, and which seeks to explore the reasons why this is so.

4. Much of this section is based on World Bank (1990).

5. The problem of using an internal rate of return in the analysis of returns to *Leucaena* is complicated by a methodological concern that the analysis captures the impact of variability in annualized costs, which are themselves dependent on a fixed discount rate. It is far more straightforward to recalculate a benefit-cost ratio holding the discount rate constant while varying the level of annualized costs, than it is to vary the discount rate, while at the same time varying establishment costs and recurrent costs in different proportions and at different rates.

6. All costs are in May 1993 Malawian kwacha (MK), valued at the time at around MK 4.22 per US dollar.

7. The choice of discount rates was somewhat arbitrary, but reflects current practice in investment project design in Malawi. At a discount rate of 10%, benefit-cost ratios increase to 3.6 and 6.8 for local and hybrid varieties of maize respectively. At a discount rate of 20%, benefit-cost ratios fall to 1.4 and 3.9 for local and hybrid varieties of maize respectively.

8. *Leucaena* has not been adopted on any scale by the estate sector for improving the fertility of tobacco stands or for providing fuelwood for tobacco curing. Its use by the estate sector is largely conjectural, though recent studies by the Tobacco Research Institute have shown it to be effective in improving yields (Kalengamaliro, 1991a and 1991b).

9. Tree-associated establishment and management costs are converted in this analysis to reflect total costs which would have to be paid on an annual basis.

10. Research on the Kandiya Research Station in the 1989–90 season showed that the application of four tons of *Leucaena* leaf litter per ha would increase gross margins for tobacco by 20%, compared with the application of 32 kg of fertilizer N per ha, which would increase gross margins by 35% (Kalengamaliro, 1991b).

11. Some studies suggest that small relative increases in the government's stumpage rates have brought about large increases in private tree planting (World Bank, 1992a). There are no data of sufficient quantity or of adequate quality on which to base this view. The link between the government-set-stumpage and the real value of wood on-the-stump remains tenuous at best.

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