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Improved Fallows in Eastern Zambia: History, Farmer Practice and Impacts

A paper prepared for the IFPRI Workshop on "Successes in African Agriculture," Lusaka, Zambia, June 10-12, 2002

Freddie Kwesiga, Steven Franzel, Paramu Mafongoya, Olu Ajayi, Donald Phiri, Roza Katanga, Elias Kuntashula, Frank Place, and Teddy Chirwa

2033 K Street, NW, Washington, DC 20006-1002 USA • Tel.: +1-202-862-5600 • Fax: +1-202-467-4439 • ifpri@cgiar.org
www.ifpri.org

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ABSTRACT

The decline in soil fertility in smallholder systems is a major factor inhibiting equitable development in much of sub-Saharan Africa. Some areas fallow in order to strength soil fertility for later planting, but as populations increase, demand follows. and continuous cropping becomes the norm and there is a reduction in yields.

This case study summarizes the development of improved tree fallows by researchers and farmers in eastern Zambia to help solve the problem of poor soil fertility. Many farmers are finding that by using improved fallows, they can substitute relatively small amounts of land and labor for cash, which they would need to buy mineral fertilizer.

The study has three phases: the historical background (phase 1); an assessment of problems, description of the technology, and how it was developed (phase 2); and how the improved fallows practices were disseminated and spread (phase 3). This paper will describe each phase, the goals, and results.

Keywords: Zambia, fallows, crop yields, soil fertility

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1. INTRODUCTION

SCOPE OF THE CASE STUDY

The decline in soil fertility in smallholder systems is a major factor inhibiting equitable development in much of sub-Saharan Africa. Smaling et al. (1997) estimates that soils in sub-Saharan Africa are being depleted at annual rates of 22 kg/ha for nitrogen, 2.5 kg/ha for phosphorus, and 15 kg/ha for potassium. In many areas, farmers periodically fallow their land, that is, allow it to lie idle for one or more seasons primarily to restore its fertility. As population increases, fallowing and fallow periods are reduced, continuous cropping becomes more frequent, and crop yields often decline. Cultivation is extended to marginal areas, causing soil degradation. The recent removal of subsidies on fertilizers in many countries has exacerbated these problems by causing fertilizer use to decline and consequently leading to reduced farm incomes (Boserup 1981; Cooper et al. 1996; Sanchez et al. 1997).

This case study summarizes the development of improved tree fallows by researchers and farmers in eastern Zambia (Figure 1) to help solve the problem of poor

[1] Principal Scientist/Regional Coordinator, World Agroforestry Centre, Makoka Agricultural Research Station, PO Box 134, Zomba, Malawi, f. kwesiga@cgiar.org. ICRAF-Southern Africa region.
[2] Steve Franzel, s.franzel@cgiar.org, Frank Place, f.place@cgiar.org, ICRAF, Nairobi, Kenya
[3] Paramu Mafongoya, p.mafongoya@cgiar.org, Olu Ajayi, o.ajayi@cgiar.org, Roza Katanga, r.katanga@cgiar.org Elias Kuntashula, e.kuntashula@cgiar.org, Teddy Chirwa, t.chirwa@cgiar.org, ICRAF-Zambia
[4] Mskera Research Station, Ministry Staff
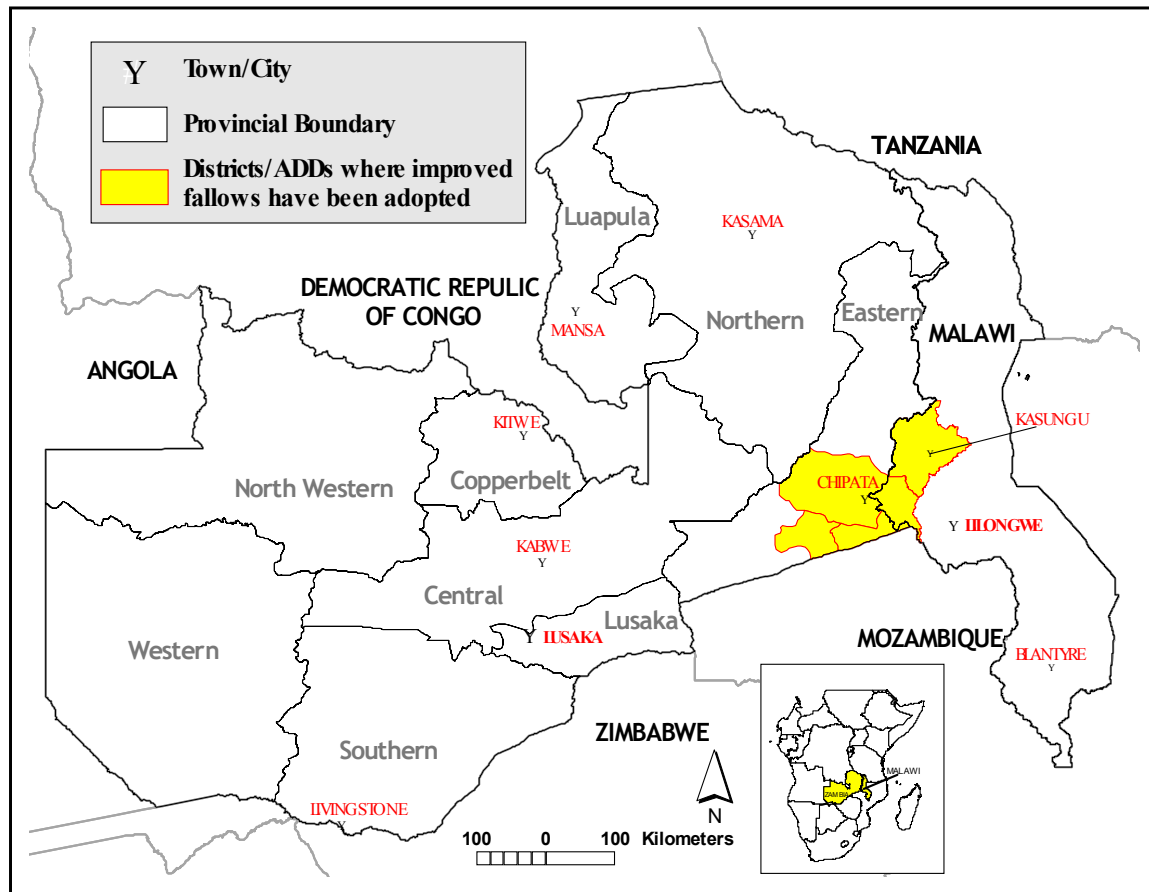
soil fertility. Many farmers are finding that by using improved fallows, they can substitute relatively small amounts of land and labor for cash, which they would need to buy mineral fertilizer.

Figure 1—Location of improved fallow adoption in eastern Province, Zambia

Three distinct phases are defined in the case study. The study begins by describing the period from 1964 to 1986, a period of increasing population, decreasing soil fertility, and government-financed fertilizer subsidies. Phase 2 begins in 1986, when ICRAF and NARS researchers conducted diagnostic surveys to identify farmers' problems and assess whether agroforestry practices could help them and were of interest to them. In 1987, research trials on improved fallows began at Msekera research station in Chipata, Zambia and experimentation with farmers began in 1991. The third phase began in 1995/96 when researchers started disseminating the practice to farmers. By the 2000/01 cropping season, over 20,000 farmers were planting improved fallows.

Improved fallows are considered a success story because of three sets of factors: (1) their effects on improving household welfare, (2) the various environmental services they provide, and (3) the development of an institutional mechanism, an adaptive research and dissemination network of government, NGO, and farmer organizations, to sustain adoption of the practice. Concerning household welfare, improved fallows increase maize yields while requiring about the same land and labor inputs as farmers' main cropping strategy: continuous cropping without fertilizer. Fertilizer use also increases yields but requires cash, which farmers have great difficulty in obtaining. Peterson et al. (1999) found that only about one-third of farmers in Eastern Province used fertilizer, that the quantities applied were only a small proportion of what researchers recommended, and that the main constraint limiting fertilizer use was lack of cash, followed by perceptions that fertilizer depletes the soil and farmers' fear of losing their investment in fertilizer if rainfall is inadequate.

In addition to increasing crop yields, improved fallows provide benefits to farmers in terms of reduced risk from drought, increased fuelwood and other byproducts, such as insecticides made from tephrosia (*Tephrosia vogelii*) leaves. The main environmental benefits are improved soil physical properties, such as better infiltration and aggregate soil stability, which reduce soil erosion and enhance the ability of the soil to store water. Fallows may also help reduce pressure on woodlands for fuelwood. An adaptive research and dissemination network in eastern Province enhances collaboration and exchange of germplasm and information among many different types of organizations. It also ensures that the demise of any organization will not affect the overall progress in the development of options and the spread of the practice among farmers.

HISTORICAL BACKGROUND (PHASE 1)

A flat to gently rolling landscape and altitudes ranging from 900 m to 1200 m characterizes the plateau area of eastern Zambia. Seasonally waterlogged, low-lying areas, known locally as *dambos*, are also common. The main soil types are loamy-sand or sand Alfisols, interspersed with clay and loam Luvisols. The Alfisols are well-drained and relatively fertile but have low water and nutrient-holding capacities (Zambia/ICRAF 1988; Raussen et al. 1995). Rainfall averages about 1,000 mm year^{-1} with about 85 percent falling in four months, December through March. Rainfall is highly variable; the area received less than 600 mm in two of eight years between 1990 and 1997. The growing season lasts for about 140 to 155 days. Average air temperatures range from 15° to 18° C. during June-July to 21° to 26° C. in September-October (Zambia/ICRAF 1988).

Population density varies between 25 to 40 persons km^{-2}. About one-third of the farmers own oxen; most of the others cultivate by hand-hoe. Average cropped land ranges from 1.1-1.6 ha for hoe cultivators to 2.3-4.3 ha for ox cultivators. The two groups are mixed among each other and grow similar crops, though ox cultivators tend to use more purchased inputs. Maize is the most important crop accounting for about 60 to 80 percent of total cultivated area. Other crops include sunflower, groundnuts, cotton, and tobacco. Average numbers of cattle per household range from 1.5 to 3, depending on the district, and goats are also common. The main ethnic groups are the *Chewa* and the *Angoni*. Rural households are concentrated in village settlements of up to 100 homesteads, a legacy of government-sponsored village regrouping programs (Zambia/ICRAF 1988; ARPT 1991; Celis and Hollaman *199*1; Jha and Hojjati *199*3; FSRT 1995; Peterson, et al. 2000).
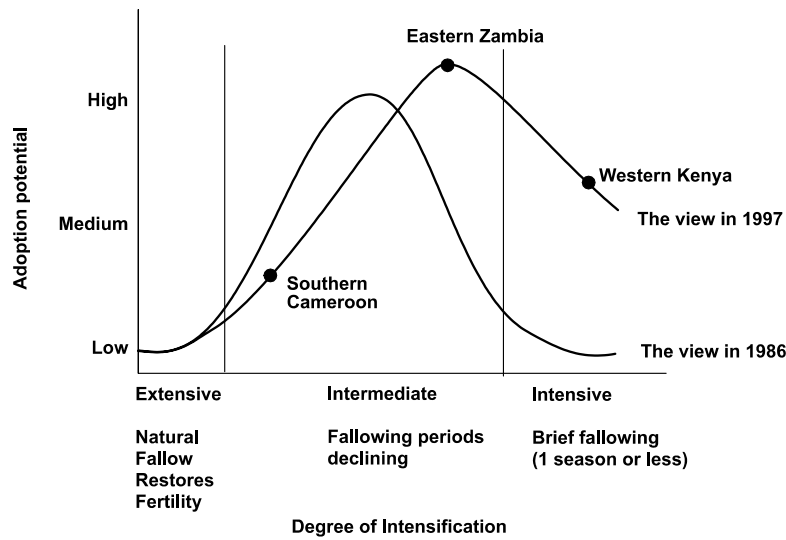
A diagnostic survey in Katete and Chipata Districts of Eastern Province (Ngugi 1988) revealed a serious breakdown of traditional strategies to sustain production of food, fodder, and fuelwood. Farmers and researchers identified declining soil fertility as the major problem responsible for low yields of maize — the main staple food crop. Nitrogen deficiencies are widespread, and large responses to mineral fertilizers are common. Soils of low fertility are similarly reported throughout Zambia (Kwesiga and Kamau 1989). The traditional fallows on which farmers relied to restore soil fertility have been shortened by land pressure and are now inadequate to restore soil fertility. In fact, most farmers continuously crop their fields, even if they have uncultivated land (Kwesiga and Chisumpa 1992; Peterson, et al. 2000). Their reasons, which researchers confirm, are that short term natural fallows of 1-3 years do not result in increases in yield. The consequences of the decline in long fallow periods are a decline in crop yields and household food security.

Zambia's post-independence agricultural strategy focused on increasing maize production through broad interventions in input and output markets, including subsidized fertilizer and credit, a parastatal monopoly on maize marketing, and a network of depots in rural areas to supply inputs and purchase maize. Fertilizer subsidies were introduced in 1971 and by 1982, averaged 60 percent of landed costs. Fertilizer use expanded from 20,000 t of nutrient per year in the mid-1970s to 85,000 t in the mid 1980s (Howard and Mungoma 1996). Fertilizer use was common among farmers in Eastern Province during the 1980's but the removal of subsidies and collapse of the parastatal marketing system in the late 1980s and early 1990s had dramatic effects. The ratio between the price of nitrogen and the price of maize increased from 3.1 in 1986/87 to 11.3 in 1995/96;

fertilizer use in Zambia declined by 70 percent (Howard et al. 1997). The decline in the smallholder sector was probably even greater.

The breakdown in subsidies and credit programs and the subsequent reduction in fertilizer use marked a key turning point in farmers' socioeconomic environment. Farmers had "tasted fertilizer"; but after the breakdown in support systems promoting its use, they were left with a huge "felt need" for soil-fertility improving practices but simply could not afford to buy fertilizer. At the same time most still had uncultivated land, they thus could afford to fallow parts of their land, although natural fallows of 1-3 years made little difference in the their crop yields. As shown in figure 2, farmers were thus in the intermediate stage of land intensity (Raintree and Warner 1986): they had begun to perceive a decline in soil fertility but still had some fallow land. The time was ripe for developing an improved fallow practice that with relatively low inputs of labor could increase the productivity of their farms.

**Figure 2—The adoption potential of improved fallows at different stages of
intensification**

Source: Franzel (1999)

2. PROCESS

DESCRIPTION OF THE TECHNOLOGY AND HOW IT WAS DEVELOPED (PHASE
2)

Given the generally large farms (e.g., three to five hectare) and the use of grass

fallows in eastern Zambia, a solution to address the declining soil fertility problem

needed to consider fallowing as the entry point. Improved fallow systems, utilizing fast

growing, N_2-fixing leguminous trees were hypothesized not only to provide readily

available nutrients for the subsequent crop, but also to increase soil organic matter and

hence improved soil physical conditions.

The strategy was to use leguminous fallows to accumulate N in the biomass and

recycle it into the soil, to act as a break crop to smother weeds (De Rouw 1995), and to

improve soil physical and chemical properties (Juo and Lal 1977). Nitrogen availability

would be increased through N_2 fixation by trees (Sprent 1987; Giller and Wilson 1991).

The other essential nutrients such as P could be cycled to some degree through plant biomass and returned to the soil during litter decomposition thereby converting nutrients to more available forms (Sanchez and Palm 1996).

Since planting of trees to improve soil fertility was unknown in Zambia, the challenge was to identify a tree that was well adapted to increase soil fertility during the fallow period. Such a tree must grow fast and be out of reach of free-ranging livestock by the first dry season, be resistant to annual fires, and be tolerant of periodic droughts. The selected tree must grow and survive under N-limiting conditions prevalent in most small-scale farms in Zambia. Sesbania, an indigenous tree, was identified as a potential species because of its wide distribution in Zambia (Kwesiga 1990), fast growth, ease of propagation and removal, and because it nodulates easily, fixes N, and produces high biomass (Evans and Rotar 1987).

Direct sowing is the cheapest method of propagating sesbania. However, seedlings established by direct sowing grow slowly because of unreliably low and erratic rainfall. Such slow-growing seedlings would be susceptible to browsing and would need a longer fallow period before farmers could expect benefits. With these considerations, the initial trials were established using nursery-raised, potted seedlings. Although this option resulted in fast growth, it was very expensive for small scale farmers. At the recommended spacing of 1 m by 1 m, or 10 000 seedlings ha^{-1}, a farmer would need to spend at least US$100 ha^{-1}.

Bare-root, nursery-raised seedlings were tested as a cheaper alternative that eliminated the need for polythene pots. Our approach in promoting sesbania production was to build upon farmers' knowledge of raising seedlings of other crops. Many small-

scale farmers in Zambia know how to set up and manage small nurseries for tobacco, kale, or fruit tree seedlings. They use bare-root seedlings that are easy and cheap to produce and, with precaution, are also easy to transport in baskets or ox-drawn carts. We opted to use raised beds in order to overcome the problem of root damage when transferring from sunken nursery beds. Costs were reduced to about US $37 ha^{-1}.

Farmers found these innovations easy to implement, and they modified them — an example being the construction of several phased beds to cater for fluctuations in the onset of the rains and planting dates. Inoculation was achieved using soil from well-established stands of sesbania. Where this was not available, we supplied topsoil from well-established stands of sesbania at the station as the inoculum.

AGRONOMIC PERFORMANCE OF ON-STATION RESEARCH TRIALS

Field studies conducted on-station since 1987 have shown that sesbania improved fallows have a great potential to increase maize yields with or without application of mineral fertilizers. Maize grain yields of 5.0 and 6.0 tons/ha were obtained in 1990 and 1991 following 2- and 3-year sesbania fallows, respectively. This compared to 4.9 and 4.3 tons/ha from continuously cropped maize with fertilizer (112 kg N/ha) and 1.2 and 1.9 tons/ha without fertilizer. The fallows had strong residual effects on maize yields, and total yield in the four cropping seasons following the 2-year fallow was 12.8 tons/ha compared to 7.6 tons/ha for six seasons of continuous unfertilized maize. In addition, 15 and 21 tons/ha of fuelwood were harvested after 2- and 3-year fallows, respectively (Kwesiga and Coe 1994).

With these initial encouraging results, we decided in 1991 to experiment under farmers' field conditions, using researcher-designed and managed trials. The trials were

laid out in farmers' fields at Feni and Kagoro camps in Chipata and Katete Districts, respectively. The two fields had been abandoned due to low yields. We used potted seedlings and a phased-entry experimental design to compare maize yields after 1- and 2-year sesbania improved fallows against the farmer control of continuous maize monocropping without fertilizers. The results were mixed. At Feni, maize yield following two years of improved fallows was 4.0 tons/ha compared to 0.15 tons/ha obtained from the control plots. But at Kagoro, sesbania failed to grow due to shallow soils and much lower rainfall.

In order to avoid dangers associated with developing a technology based on a narrow genetic base, a range of other species and provenances were evaluated alongside sesbania fallows. Other species included tephrosia, *Sesbania macrantha*, and pigeonpea (*Cajanus cajan*), which have an important advantage in that they can be sown directly, saving the labor required for establishing a nursery and transplanting seedlings. These species were nodulated by the native soil rhizobia. Grain yield of hybrid maize after a 2-year sesbania fallow was 5.4 tons/ha as compared to 4.0 tons/ha for fertilized maize following maize monocropping. Two-year fallows of sesbania, tephrosia, and *S. macrantha* had residual benefits on maize in the second season after the fallows.

Experiments with 3-year fallows included species that could coppice, thereby providing a possibility of eliminating the need for fallow re-establishment. These were *Calliandra calothyrsus, Flemingia macrophylla, Gliricidia sepium, Leucaena leucocephala*, and *Senna siamea.* After 3-year sesbania fallows, maize grain yield was 5.6 and 7.4 tons/ha in two experiments. Fully fertilized maize yielded 4.1 and 6.9 tons/ha in the experiments. Gliricidia emerged as the second best improved fallow species after

sesbania, producing 3.8 and 6.1 tons/ha of maize grain in the season after the fallow. Sesbania fallows were also found to greatly reduce the occurrence of striga weeds, which generally thrive under conditions of low soil fertility (Kwesiga et al. 1999)

FINANCIAL ANALYSIS OF ON-STATION RESEARCH TRIALS

The results from the trials above were very promising from a biological point of view. However, economic analyses were required to evaluate

i)   whether improved fallows were still attractive after considering their costs,

ii)   the duration of the payback period of the improved fallows, and

iii)   differences in profitability across the different fallowing options.

Because the improved fallow was demonstrating strong residual yield effects, the economic analyses utilized the data from the 6-year, on-station trial that ran from 1988 to 1993 (Kwesiga et al. 1999). The costs and benefits of continuous maize cropping without fertilizer and with the recommended dose of chemical fertilizer (112 kg N ha^{-1}) were compared with 1-, 2-, and 3-year sesbania fallows followed by continuous maize cropping without fertilizer.

The fertilizer option generated a surplus (US$ 1303 ha^{-1}) over the 6-year period — far greater than that from the other options. The control of continuous unfertilized maize yielded the lowest discounted net benefit of US$307 ha^{-1}.   The 1- and 2-year fallows generated 78 and 92 percent more wealth respectively, than the control with continuous unfertilized maize. The 3-year fallow was only marginally better than the control (2 percent) because it permitted cropping in only three of a possible six seasons and one of the three cropping seasons was poor due to drought.

In addition to total financial returns, the timing of the cash flows is important. There was a considerable lag before financial returns from the improved fallows exceeded those of the control of continuous maize. By the end of the fourth year, the 1-year and 2-year fallows became more profitable than the control while the 3-year fallow did not become as financially attractive as the control until the end of the sixth year.

Returns to labor, as opposed to land, may be a more appropriate indicator of financial attractiveness to farmers, especially in areas where labor is relatively scarcer than land. An examination of the returns to labor (the discounted net cash flow divided by discounted labor days) showed that the fallows were attractive. Compared with the average daily wage rate of US$0.6 in the area, the return to labor from a 2-year fallow was a respectable US$3.45/day, which was 70 percent above that from continuous maize without fertilization. Although the control did not perform as poorly in the analysis of returns to labor as in the analysis of returns to land, it was again the least attractive option.

Numerous sensitivity analyses were undertaken. They included changes in the wage rate, cost of seedling, maize yields, and fuelwood prices and an investigation into how changing occurrences of drought affected fallow performance. In virtually all reasonable scenarios, the fertilizer option remained the most profitable. Similarly, the 2-year fallow was shown to be more attractive than the unfertilized maize control in every scenario except for one with an extremely high discount rate (> 0.4).

In order to translate the above results into a 'real-farm' situation in eastern Zambia, we looked at how an operational improved fallow system might perform on a typical farm of three hectares. Assuming that two hectares are cultivated with maize and

one hectare is under fallow (i.e., one-half hectare of trees are planted every year on a rotating basis), the net benefits to the farmer are equal to the average of the actual (non-discounted) net returns for each year. That is, on one-half hectare, the farmer will incur a negative return due to the planting of a fallow and on the other field with the more advanced fallow the farmer will again not harvest any maize. On the remaining fields under maize, the farmer will receive different benefits depending on the stage of the rotation, earning the greatest return from the field that has just come out of the fallow.

If we use the returns from a drought free year, a typical household would receive an annual return of US$ 746 yr^{-1} by operating a rotating 2-year fallow system. Viewed from the farm-level perspective, each of the fallow systems is considerably superior to the continuous maize control option, with the 2-year fallow achieving a surplus of 205 percent.

The financial analyses of the on-station improved fallow results were in summary very encouraging. Two important lessons were used in subsequent research. First, a 3-year fallow appeared to be less attractive than the 1- or 2-year fallows (even if drought had not occurred) and therefore should be given less attention. Second, the cost of the seedlings was a major consideration in overall profitability and length of payback period, suggesting that cheaper methods of establishment be considered in future work. Based on the favorable agronomic and financial results, it was then felt that the practice was ready to be tested by a larger number of farmers to evaluate the feasibility, profitability, and acceptability of improved fallows in an on-farm situation (Kwesiga et al. 1999).

ON-FARM RESEARCH

Testing a new technology with the potential users is a critical link between research and development. On-farm research on improved fallows in eastern Zambia served to:

1. assess biophysical and economic responses under farmer management,
2. expose the technology to potential extension agents and farmers and obtain their feedback on problems and performance, and
3. assess how farmers used and modified the technology to suit their needs.

Our approach to on-farm research was first to establish solid relationships with the extension staff, and through them to the farmers. We spent much time exposing the technology to the camp extension officers in their target villages, where each camp extension officer is responsible for about 200 farm families. Camp officers were thus the main facilitators at the grassroots level.

To ensure farmer involvement, we combined the training of camp officers with village discussion groups arranged by extension agents. The approach was initially to select a village near a farmer training center (FTC), which would later be used for demonstration and experimentation. Meetings were then arranged where both the researchers and extension staff interacted with farmers and discussed the causes of low maize yields, farmers' fallowing practices, and the potential of improved fallows. Such a combination of strategies gave us ideas about which farmers could be trained in establishing nurseries and conducting improved fallow experiments on their farms.

We invited farmers from these villages to visit the station and see the results of our trials. Such visits generated much discussion among farmers and confirmed that they were genuinely interested in the technology. At the end of each visit, the camp officers

made a list of farmers who were interested in trying out the technology and initiated contact. The activities culminated in the establishment of on-farm research trials and demonstrations.

We also utilized research 'open days' when farmers, extension staff, and development agencies were invited to the research station or to on-farm trials to see and discuss the progress on research and technologies being developed. We increased the frequency of field days so that they coincided with the major phases of improved fallows: the nursery, the fallow, and crop phases. We also decided to reach out to more farmers by using the 'pilot area' approach, setting up trials at a few farmers' fields and FTCs in villages selected because they were representative of the range of biophysical and socioeconomic features in the area (Franzel et al. 2002). In this way, we were able to increase our contacts with the camp extension staff and the farmers. We established three types of on-farm trials, each with different objectives (Franzel et al. 1999), as discussed below.

Researcher-designed, researcher-managed trials (type 1 trials)

Five researcher-designed, researcher-managed trials were established in the 1992/93 season on farmers' fields. These were designed to measure biological performance under farmers' soil conditions. The example of the trial on Mr. Mphanza's farm shows how the research benefited greatly from early collaboration with farmers. Mr. Mphanza's trial evaluated contrasting techniques of establishing sesbania. After two years of improved fallows, there was no significant difference in biomass production and maize yield between the use of potted and bare-root seedlings, but direct sowing of sesbania was distinctly less productive. Fallows established from bare-root and potted

sesbania seedlings resulted in remarkable maize yield increases compared with yields achieved following continuous unfertilized maize and grass fallows. Maize yields following sesbania were similar to those achieved for the fully fertilized control maize. Mr. Mphanza was very impressed by the results and established his own nursery to produce bare-root seedlings. He was also a pioneer in using sesbania natural regeneration to expand the area under sesbania improved fallow. Mr. Mphanza, along with other farmers participating in these trials, were enthusiastic about the results and later expanded the use of improved fallows on their own.

Researcher-designed, farmer-managed trials (type 2 trials)

We started farmer-managed trials at a small scale by selecting types of farmers that were likely to benefit from improved fallows. Between 1992 and 1994, we were involved with eight farmers testing sesbania improved fallows and methods of establishing these fallows. Establishment and tree growth were satisfactory and bare-rooted seedlings emerged as farmers' preferred establishment method. In 1994, the team decided to greatly expand participatory on-farm research as a follow up to the encouraging on-station results, the positive indications from the financial analysis, and the on-farm trials.

In 1994/95, the team assisted four FTCs and six individual farmers to establish nurseries in various agricultural camps in Chipata, Chadiza, and Katete Districts. Using bare-rooted seedlings from these nurseries and in some cases direct sowing, 158 farmers initiated researcher-designed, farmer-managed trials ('type 2' trials) with 400 m^2 plots of improved fallows (Franzel et al. 2002).

The objectives were to assess the biophysical response of trees and crops under farmers' management, assess costs and returns of the technology, and to obtain farmers'

assessments. We made a distinct effort to involve farmers representing the range of different types found in the area — e.g., high and low income, male and female, and oxen and hoe-users. In the trials, farmers selected one of the six options of improved fallow technologies. The options represented a factorial combination of three species (sesbania, tephrosia, or pigeonpea) and two methods of fallow management (pure stands or intercropped with maize during the first year of establishment and then allowed to grow into a pure stand fallow in the second year). These options were compared with continuous cropping of fertilized and unfertilized maize.

Green manure crops, such as sun hemp (*Crotalaria juncea*) and velvet bean (*Mucuna pruriens*), were not included in the trials because they had been widely tested by researchers and farmers but have not been adopted, except among a very few farmers. Green manure crops can be planted early in the season, left to grow for 6 weeks, and plowed in before planting maize. But this practice is very risky, as late planted maize performs poorly if the rains end early. Green manure crops can also be planted late in the season but the effect in the following year on crop yields is low (Raussen 1997).

Sesbania was planted using bare-root seedlings, while tephrosia and pigeonpea were established by direct sowing. Researchers were involved in laying out about half of the trials; extension staff helped farmers plant the rest. The project supplied sesbania seeds, inoculum, maize seed, and fertilizer for the trials.

Rainfall was low and sporadic during the 1994/95 season. Trees in two-thirds of the trials had to be re-seeded or gapped, one to two times. Many farmers throughout eastern Zambia, with and without improved fallows, shared the experience of reseeding and gapping maize. We estimate that 60 percent survival of the fallow species in the first

three months is required for satisfactory biomass production at the end of two years. In

1994/95, 82 percent of the surveyed farmers for tephrosia, 63 percent for pigeonpea, and

48 percent for sesbania achieved this level of survival. Aside from drought, other

problems affecting survival were weed competition and browsing.

In a survey of farmers one year after planting, the main problems affecting

establishment and growth of improved fallow species were a leaf-defoliating beetle,

Mesoplatys ochroptera Stal. for sesbania, livestock browsing for pigeonpea, and drought

(especially during the long dry season) (Table 1).

**Table 1--Problems cited by farmers as having affected establishment and growth of
species in improved fallows during the first 12 months after establishment
in 1996 in eastern Zambia.**

Problem	Farmers having species who mentioned the problem (% of total)[a]		
	Sesbania sesban	*Tephrosia vogelii*	Pigeonpea
Beetles	80	0	1
Browsing by livestock	16	36	78
Drought	68	80	72
Poor seed	0	20	33
Termites	48	32	50
Other[b]	28	8	12
Number of cases	25	25	18

Source: Franzel et al. 2002
[a] Percentages do not sum to 100 because each farmer could mention more than one problem.
[b] Includes fire, poor soil, waterlogging, late planting, weeds, and competition between trees and crops.

A paired comparison of survival rates at six months and at one year after planting

showed that sesbania ranked highest in ability to withstand the long dry season. Sesbania

survival declined from 81 to 63 percent between 6 and 12 months, whereas tephrosia

survival declined from 91 to 51 percent, and pigeonpea survival dropped from 73 to 21

percent (Kwesiga et al. 1999).

Intercropping trees with maize during the first year appeared to have a negative effect on both maize yields and tree survival. Maize yields when intercropped were 29 to 39 percent lower than when sole-cropped. Tree survival rates 12 months after planting were 14 to 25 percentage points lower than when planted in pure stand, depending on the species. However, many farmers prefer intercropping as a means of economizing on land and labor. By 2000, 49 percent of farmers establishing improved fallows were intercropping them with other crops, primarily maize (Keil 2001).

In summary, farmer experimentation has helped both researchers and farmers to understand the advantages and disadvantages of different improved fallow practices.

Farmer-designed, farmer-managed trials (type 3 trials)

In this type of trial, farmers were given seed or seedlings and advice on available options, such as fallow length, tree density, and planting method. They were left to design their own trials, planting trees where they wished on their own farms. The main purposes of this type of trial are to understand how farmers adapt improved fallows into their existing farm practices and to identify farmer innovations, for feedback to research and extension and for promoting the exchanges of such innovations among farmers. Few biophysical data are collected in these trials. The number of farmers with 'type 3' trials increased from 5 in 1993/94, to 37 in 1994/95, to 797 in 1995/96.

Farmers planted fallows on areas ranging from about 0.04 to 0.09 ha. Many farmers who initially started off as 'type 2' farmers also planted 'type 3' trials after experiencing the benefits of improved fallows or after viewing experiences of others. Usually, they used planting material from their own farms.

Surveys of type 3 trials have allowed researchers to monitor the performance of improved fallows under farmers' own management and to assess how they use and modify the practice. For example, surveys have shown farmers' increasing interest in tephrosia relative to sesbania. In 1995/96, tephrosia was grown by 30 percent of type 3 farmers while 42 percent grew sesbania. By 2000, the ranking of species had changed; in a survey of a different sample of farmers, tephrosia was grown by 49 percent of farmers while 35 percent planted sesbania (Keil 2001).

Farmers' innovations in type 3 trials have been one of the main elements contributing to the success of improved fallows. Two of the main technological options, bare-root seedlings instead of potted seedlings, and intercropping, instead of planting in pure stands, were innovations that farmers introduced in type 3 trials in the early 1990s. In these trials, farmers were given potted seedlings grown at farmer training centers but to reduce the cost of transporting them to her farm, one farmer removed the seedlings from the pots and carried them 'bare-rooted' in basins. When farmers' plantings of these seedlings proved successful, researchers conducted type 1 trials to compare the performance of bare-rooted seedlings, grown in raised seedbeds, with potted seedlings. They found no significant difference in performance and as potted seedlings were much more costly to produce, they were phased out (Kwesiga et al. 1999).

Farmers' second main innovation, intercropping during the year of tree establishment, was also later tested in on-farm trials. The trials found that intercropping reduces maize yields and tree growth during the year of establishment, but many farmers prefer it because it economizes on land and labor use relative to planting in pure tree stands. Intercropping appears to be increasing; the percentage of farmers practicing it

rose from 17 percent during the planting of 1994/95 type 2 trials to 42 percent in the

1995/96 type 3 trials to 49 percent of farmers in a survey conducted in the 2000/01

planting season (Keil 2001).

Several other key farmer innovations include:

- The use of sesbania regenerations as planting material for establishing new fallows. This innovation saves farmers' labor for having to establish nurseries during the dry season.

- Planting seedlings into a bush fallow without preparing the land first.

- Planting sesbania seedlings behind the ox-plow. As the plow moves along an adjacent furrow, it covers the seedling roots with soil.

- Gapping up their sesbania fields with seedlings planted one year after the first planting.

- Planting sesbania at weeding time into parts of fields where maize was performing poorly.

- Testing the effect of improved fallows on crops other than maize, such as sunflower and groundnuts. In fact no research has been conducted on the effect of improved fallows on other crops.

- Removing of sesbania tips to stimulate lateral branching and thus biomass production.

- Using rainfed nurseries as opposed to nurseries in dimba gardens during the dry season. These nurseries are preferred because they reduce the labor required for transporting the seedlings and reducing the labor needed for watering.

- Using sesbania wood for making granaries and tools, such as machete and hoe handles.

Sesbania, tephrosia, and cajanus are non-coppicing trees, that is, when cut at the

end of the fallow they do not resprout or coppice. Research is also being conducted on

coppicing species, because they have several advantages. First, there is no need to replant

them when a new fallow is needed, farmers can simply allow them to resprout, saving

considerable labor and eliminating the need to save or acquire seed and establish nurseries. However, an important disadvantage of coppicing species is that they require strict management, as they need to be cut back when a crop is established; otherwise they may compete with the crop for light, moisture, and nutrients.

The residual effects of Sesbania fallows on subsequent maize yields have been shown to be high for two or three seasons, but they will start to decline rapidly in the third season. This may be related to depletion of soil nutrients and deterioration in soil chemical and physical properties. It can be hypothesized that fallows with coppicing tree species will have longer lasting residual effects than those with non-coppicing species because of the additional organic inputs derived each year from coppice regrowth. Coppicing species include *Gliricidia sepium*, *Leucaena leucocephala*, *Calliandra calothyrsus*, *Senna siamea* and *Flemingia macrophylla*.

> **Box 2: Farmers' experiences with coppicing and non-coppicing fallows**
>
> Several farmers have been shown the differences in long term trials at Msekera station over 8 years of cropping after gliricidia, a coppicing species, and sesbania, which is non-coppicing. Some farmers are also experimenting with the two species. Their main conclusion is "Uyu mtengu wa gliricidia ni wamuyaya" in Nyanja the local language. This translates into English "The gliricidia fallows are for life."
>
> The implications are that once *gliricidia* fallows are established and cut, you need not replant as is the case with *Sesbania.* You maintain maize yields due to application of coppice growth. However with *Sesbania* you have to replant the fallows after every 2-3 years and wait for a similar period before cropping. This will incur labour costs for fallow establishment and foregone maize yields. This will not be the case with coppicing *gliricidia* fallows. Of late seed demand for *gliricidia* has grown very rapidly and demand cannot be met. *Gliricidia* fallows are popular with farmers and many farmers are experimenting with them.

3. HOW DID THE PRACTICES SPREAD (PHASE 3)

FARMERS' INTERESTS AND THE SPREAD OF IMPROVED FALLOWS

Farmers' interest in improved fallows has been overwhelming. The initial results showing that sesbania fallows increased maize yields without fertilizers triggered enthusiastic responses from a large number of farmers, extension staff, NGOs, and development agencies.

During the 1996/97 planting season, the number of farmers testing improved fallows increased from about 1,000 to about 3,000. The nurseries that the farmers had set up could not meet the high demand for seedlings. Some of the farmers resorted to transplanting sesbania regenerating from FTC fallows or a neighbor's field, and a few traveled over 20 km with hired ox carts in search of sesbania seedlings from the research station.

The improved fallow technology was conceived as a natural progression, building and improving upon the traditional approaches to improve soil fertility. Our initial

approach used the diffusion model in which technologies are passed from research scientists via extensionists to farmers (Rogers, 1962). This approach was necessary in order to give extension staff sufficient time and information to develop and enhance their skills in planting, caring, and managing of trees. Tree planting was not part of agricultural extension, and as such most farmers had never planted trees for soil fertility enhancement (Kwesiga and Chisumpa 1992).

Together with extension, we also spent much time in the villages, with farmers, NGOs, and farmer groups to ensure that planting of sesbania was incorporated into the agricultural calendar. These contacts enabled us to learn more about land use and farming problems that farmers faced, including labor shortages.

Box 3: The importance of the level of extension effort in disseminating improved fallows: two contrasting examples.

Improved fallows are knowledge-intensive practice that require considerable training. Furthermore, the training cannot be conducted at a single time; it needs to be done at several different periods in the cycle of the technology. In some instances, the planting of improved fallows has spread largely through the efforts of farmers without much support from researchers or extension staff. For example, during the dry season, 1995, a lorry load of 78 farmers arrived unannounced at Msekera Research Station. The farmers came from Kapinde, a village next to another village where there were on-farm trials. The farmers had hired the truck to come to the research station to learn about improved fallows. The farmers were members of self-help groups and were accompanied by their camp extension officer. Project staff gave them a tour of the station and nearby on-farm trials. The farmers were given sesbania seed and instructions on raised-bed nursery methods to produce bare-rooted seedlings. Several months passed without contact but in December, project staff went to visit the village, arriving unannounced. The camp officer quickly assembled some of the group leaders and accompanied Chipata staff to the nursery. It was well-managed, weed-free, and well-watered, with about 40,000 seedlings ready for planting. Soon afterwards, 71 farmers planted improved fallows using seedlings from the nurseries.

   But in most cases, substantial outside support, that is, training and planting material, is required. In the above case, Kapinde farmers had very low survival rates compared to nearby camps, probably because of less training and experience. One lesson that we learnt was that improved fallows are knowledge-intensive and, to use the practice effectively, farmers need to acquire considerable knowledge and skills compared with technologies such as improved crop varieties.. Farmers in new areas do not have access to seed and private sector institutions may be constrained, and will therefore require considerable support (through external support or community mobilization) to scale up the widespread adoption of these practices. Such support does not need to come solely from outside institutions, it can also come from farmers themselves. In 1997, ICRAF facilitated 18 famers from the Kasungu area of Malawi to visit Zambian farmers practicing improved fallows and spend three nights in their homes. The training was conducted solely by farmers themselves. During the next season, the Malawian visitors and their neighbors planted 135 improved fallows; each visiting farmer thus influenced an average of seven other farmers to plant the fallows (Bohringer et al. 1998)

THE ADAPTIVE RESEARCH AND DISSEMINATION NETWORK

        The Zambia-ICRAF project has helped facilitate the establishment of an informal

network to conduct adaptive research, training, and facilitate dissemination of improved

fallows. The network has two functions: to provide coordinated and analytical

mechanisms for participatory monitoring and evaluation of on-farm research and

dissemination of improved fallows and to act as a catalytic and action-oriented group for

the widespread dissemination of the technology. The network began when the project started supplying planting material, training, and information to extension services, development projects, NGOs and farmer groups that wanted to help their members test improved fallows. In exchange, these organizations provided the project with feedback on the performance of the technology.

The network is based on the principle that adaptive research and extension are really two sides of the same coin; once on-farm research has confirmed that a technology has adoption potential, dissemination is already beginning. Researchers need to be involved to obtain feedback from farmers and extension staff on problems and to identify researchable issues. Moreover, the more extension staff become involved in on-farm research, the more knowledgeable and enthusiastic they will be in extending the practice. Their involvement helps save scarce research resources and improves the feedback to research.

The network thus has had the following impacts (Cooper 1999):

- reduced cost of conducting on-farm research as field-based extension officers and NGOs establish and monitor on-farm trials;

- enhanced breadth of input into and relevance of the research;

- expanded range of sites under experimentation with relatively little additional cost;

- partners increasingly well-informed on key aspects of technology options and better placed to disseminate technologies and respond to farmer feedback; and

- partners have developed a sense of involvement, enthusiasm, and ownership of promising innovations

The extension service in Zambia is a full partner in the on-farm research. In fact, about a half of the type 2 trials were laid out by extension staff in the absence of

researchers. Extension staff also play an important role in supporting the village nurseries and in monitoring the trials. They view the trials as joint research-extension work. Relations are also excellent at higher levels. Throughout the system, the managing of on-farm trials is seen as a normal duty of extension and NGO staff rather than a burden imposed on them from outside. Development projects provide some incentives to extension staff, such as bicycles and lunch allowances, which facilitate institutional linkages and raise the effectiveness of the extension staff. That only one researcher and technician from the Zambia/ICRAF project were involved in the establishment and monitoring of the hundreds of on-farm trials in the mid-1990s attests to the strength of the network.

DISSEMINATING IMPROVED FALLOWS: WORLD VISION INTERNATIONAL'S EXPERIENCES

Project background

The Zambia Integrated Agroforestry Project (ZIAP) was initiated with the goal of improving household food security and incomes through increased agricultural productivity by promoting adoption of low-cost and environmentally sustainable agricultural production techniques. The project is addressing the issue of soil fertility and food security through the promotion of (1) short-term fallows of leguminous trees and shrubs, (2) soil and moisture conservation, and (3) improved crop varieties. Furthermore, the project has developed an elaborate training mechanism for increasing farmers' access to (1) extension services and skills (2) market information and (3) market participation.

The number of farmers targeted to test/adopt the improved agricultural technologies is 12,000 rural households in five districts of Eastern Zambia over a five-

year period. The target districts (Chipata North, Chipata South, Katete, Mambwe and Chadiza) cover a land area of 18,533 square kilometers with a total population of 621,000.

A base line survey indicate that although 66 percent of the respondents were aware of improved fallows, most of the farmers did not possess adequate knowledge to plant their own improved fallows. In order to reduce the knowledge gap on improved fallows, the Project has been facilitating community sensitization meetings and mobile courses. The project works through lead farmers, who are selected by the community together with government and project field officers. They are given basic training in agroforestry. The lead farmers with the help of the Block Development Facilitators, Block Extension Officers[5] and Camp Extension Officers conduct community sensitization meetings and mobile courses. The training conducted by the lead farmers is done in the villages. As improved fallows are a new concept, efforts are made during farmer training sessions to discuss the use of improved fallow technology. In addition farmer visits are arranged to demonstration plots as well as to ICRAF on-farm trials. Farmers who show interest are registered and assist with initial seed on loan basis. Each lead farmer works with 50-100 new households every season.

Seed distribution pathway

In order to meet the large demand for tree seed, eight large seed production stands were established in 1998/99 season with seven contract farmers. The seed that was bought by the project was distributed to farmers on loan basis: farmers were required to pay back twice the amount of seed that they received. These repayments are given to the

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[5] The extension service in a district is organized into blocks, and blocks are divided into camps. The camp extension officer is responsible for assisting roughly 1000 farm households.

area seed management committees. A lead farmer heads the area seed management

committee. The area seed management committees are free to distribute this seed to other

farmers in the village that would like to practice improved fallows (on loan basis). We

find this arrangement to have a number of advantages. Firstly, the level of involvement

of World Vision in supervising the loan repayment scheme is minimal. Second, since

each committee works with large number of farmers (50-100), the seed bulking system

ensures that a wide genetic base is maintained at a local level in planting material. Third

by carrying out repayment and distribution at a local level, World Vision avoids the

difficulties associated with transportation and documentation.

Feedback from farmers

In 2000/2001 season, the Project had a total of 11,000 farmers who planted

14,356 fallows. These numbers are included in the overall Zambia/ICRAF estimate of

over 20,000 farmers noted above). The area covered by these fallows is approximately

3419 hectares or about 0.3 ha per farmer (Table 2).

Table 2--Improved fallows species planted by the farmers facilitated by World Vision Integrated Agroforestry Project during the 2000/2001 cropping season

Species	Men	Women	Group	Total No. of fallows
T. vogelii	7,077	4,360	32	11,469
S. sesban	1,261	294	13	1,698
C. cajan	511	457	4	972
G. sepium	202	48	6	256
Total	9,051	5,159	55	14,395

Source: World Vision Integrated Agroforestry Project

This number includes households planting fallows for the first time and those who

have planted before. It is clear from this data that tephrosia is still the most preferred

species. The preference is for tephrosia even though maize yields are higher in fields following sesbania fallows than tephrosia fallows. The farmers' reason for this preference is that tephrosia fallows require less labor than sesbania fallows, primarily because tephrosia can be established through direct seeding whereas nurseries are required for sesbania. The preference for tephrosia over sesbania appears to be especially strong among women. For example, in the World Vision Integrated Agroforestry Project, 38 percent of the tephrosia improved fallows were planted by females whereas they planted only 17 percent of the Sesbania improved fallows (Table 2).

Most of the farmers did not plant *Gliricidia sepium* fallows because they could not access seed. The farmers who accessed seed from the project have not yet started harvesting seed from the *Gliricidia* in significant amounts.

It is worth noting that the improved fallow species with the highest proportion of female participants was pigeon pea (Table 2). Pigeon peas are edible and because women are responsible for feeding the family, they are very keen in establishing pigeon pea fallows.

One issue emerging from our experiences is the importance of providing options for farmers on the species that they want to plant. This will give farmers the opportunity to make choices on the species to use based on their local agro-climatic conditions as well as their own resource constraints and preferences. The resource constraints may include lack of knowledge about establishing a nursery or competing labor demands from other household activities. Giving the farmers the opportunity to choose between several species further empowers them to take responsibility for the process of soil fertility replenishment on their land. The project will not be able give the farmers a "basket of

choices" if the availability of seed for certain fallow species remains elusive. The time of fallow establishment is very crucial to the performance of the fallow species. From the information gathered, it is apparent that most of the fallows were established in the months of January and February. We noted though, that the best fallows in terms of growth and survival were those that were established in December and January and the worst were those that were established after February. Many farmers plant the fallows late because they need to plant their food crops first. This finding highlights the importance of developing fallow practices with minimal labor requirements.

Constraints encountered during promotion and dissemination of the technology

The problems mentioned by the farmers were both species and site specific. In areas were farmers had planted sesbania, the most common problem was that of beetles. In addition to beetles in areas with very sandy soils, drought at the time of planting was mentioned as the number one problem. We also suspected the problem of root rot nematodes in these light soils. The problem of nematodes appears to be both on sesbania and tephrosia contrary to the earlier view that tephrosia was not susceptible to root-nematodes.

Browsing of the fallow species appeared to be a major problem in eastern Zambia because animals are not herded during the dry season and also the fallows were established late. The farmers in these areas have started approaching the local leadership to try and find ways of dealing with the problem of livestock browsing. An example of an area where this problem has been successfully addressed is Kafunka in Katete district. The animals in this area are herded through out the year. Ajayi et al. (2002) found that local bylaws established by traditional chiefs have helped to limit dry season grazing where improved fallows are grown. Almost half of the farmers indicated that in the

previous five years, their fields had been burnt by fires at least once during the dry season.

Lessons learned

- The project should continue developing and applying better methods for forecasting seed requirements, and to facilitate establishment of sustainable, community-based seed production and distribution systems. In dealing with this issue particular attention should be given to Cajanus cajan and Gliricidia sepium seed, which are currently in short supply.

- Working with farmers concentrated in one geographical area (Clustering approach) appears to be better than working with the same number of farmers scattered over a wider geographical area. Using the former method one is able to use the resources more efficiently and farmers are able to exchange experiences.

- We observed that working through farmer groups is a more efficient way of reaching beneficiaries than working through individual farmers. There are more farmers testing/adopting improved fallows in areas were active farmer groups existed.

- Well-targeted and well-planned farmer field days are an important tool in promoting adoption of improved fallows

- It is important to allow farmers to choose the fallow species that they prefer. Seed needs to be available for a range of species.

- Farmer to farmer transfer of information is very effective.
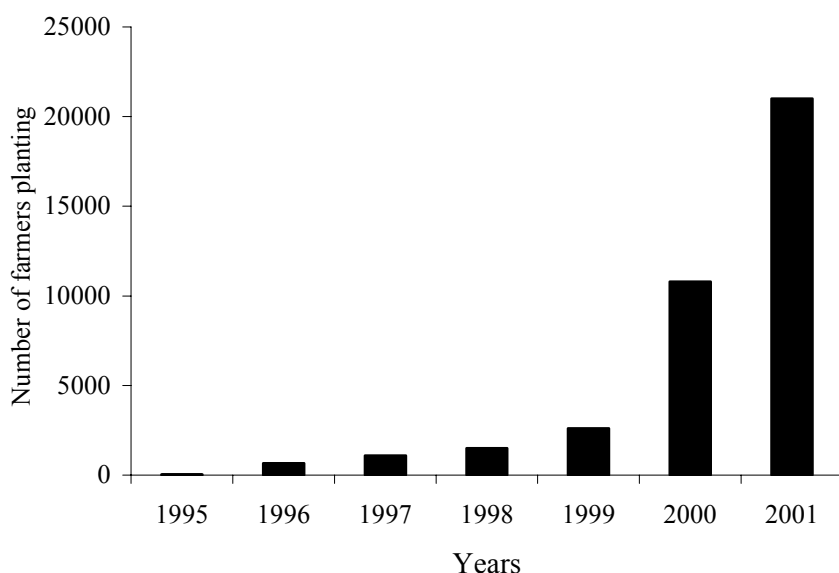
4. IMPACTS

ADOPTION RATE: HOW MANY FARMERS HAVE ADOPTED THIS PRACTICE?

It is important to distinguish between planting an improved fallow, which the farmer may view as an experiment, and adopting the practice. We generally define adopting an improved fallow as the planting of a second improved fallow after a farmer has witnessed the benefits arising from the first fallow.

The number of farmers who have planted improved fallows has increased steadily since the mid-1990s (Figure 3). Before 1997, most of the farmers planting improved fallows could be said to be testing improved fallows. But by the late 1990s, as farmers began to expand their plantings of fallows, most could be said to have adopted.

Figure 3—Farmers planting various agroforestry species 1995-2001

During the 2000/01 season, about 20,000 farmers planted improved fallows in Eastern Province of Zambia. Several hundred farmers across the border in Malawi had also planted, largely as a result of farmer-to-farmer exchange visits between Zambian and Malawian farmers.

CATEGORIES OF FARMERS ADOPTING IMPROVED FALLOW

The decision of farmers to adopt the practice is influenced by a series of factors including the technological characteristics, household characteristics, community level factors, access to information, local institutional arrangements and macro policies on agriculture. Our empirical studies have thus far included three main types of analyses:

- regression models to assess the influence of farm and household characteristics on adoption (Place et al. 2002) and the intensity of adoption (Keil 2001)

- decision tree models to represent the series of sub-decisions farmers make in considering planting and adoption (Peterson 1999; Gladwin, et al. 2002)

- tests of association between planting improved fallows and farm and household characteristics (Franzel et al. 1999; Ajayi et al. 2003; Kuntashula et al. 2002) .

Using an amalgam of results from these three methods, the relationship between planting/adoption of improved fallows and a range of variables are detailed below:

Wealth: As could be expected, there was an association between wealth level and planting improved fallows (Log linear model, p< .08). As wealth status declined, the proportion of farmers planting improved fallows also declined. Whereas 53 percent of the well-off farmers planted fallows, 40 percent of the fairly well off, 22 percent of the poor and 16 percent of the very poor planted fallows (Phiri, et al. in press). Interestingly, though, the proportion of farmers continuing to plant improved fallows after their first planting did not appear to vary by wealth status. The fairly well-off were the most likely to continue, followed by the poor, the very poor, and the well-off (Kiel 2001). The lower likelihood of the well-off to continue planting improved fallows is probably associated with their ability to use a range of soil fertility measures, such as manure and fertilizer that are not available to other farmers.

Labor: Availability of labor does not necessarily prevent farmers from establishing improved fallows because the area planted to improved fallow during the testing phase is very small, but it may pose an important limitation to the area that a farmer allocates to the technology (Place 2002).

Gender: Improved fallows appear to be gender-neutral and there are no significant differences between the proportions of women and men planting improved fallows or between

single women and female heads of households who were married (Franzel et al 1999, Ajayi et al 2001). In certain cases however, some married women may not establish improved fallow without the consent of their husbands (Peterson 1999). Improved fallow plots owned by women were significantly smaller than those of men. The proportion of women claiming that they had access to sufficient seed was similar to that of men, so limited access to seed was not the reason women had smaller plot sizes than men. Rather, their reasons for smaller plot sizes may have been associated with greater land and labor constraints or risk aversion (Franzel et al. 2002).

Farmers' groups: Farmers who belong to cooperatives or clubs have higher probabilities to test improved fallow (Kuntashula et al 2002, Ajayi et al 2001). One of the reasons is that the cooperative groups facilitate the sourcing and dissemination of information to their members.

Land: Availability of land and size of available land holding were positively associated with the establishment of improved fallow plots.

Age: the planting and adoption of improved fallow are age neutral (Franzel et al 1999, Phiri et al (in press), Kuntashula et al 2002, Ajayi et al 2001, Place et al 2002).
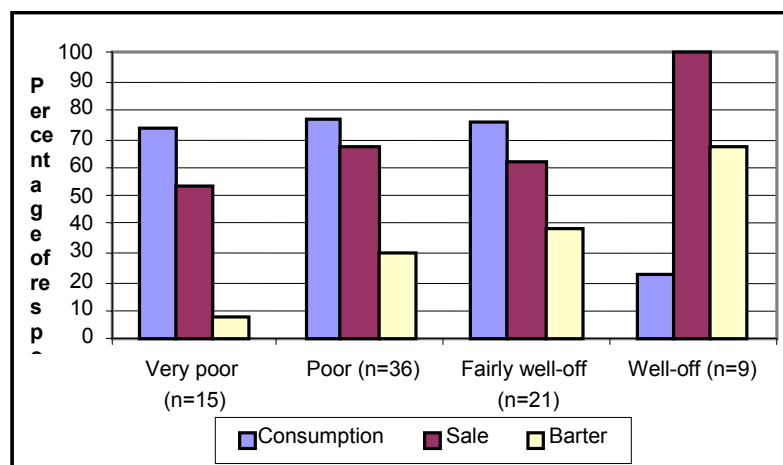
Awareness: Farmers who plant improved fallows generally perceive that they have poor soils, have heard of or witnessed (in their own or in fellow farmers' field) the role of trees to improve soils, have an interest to plant trees to improve the fertility of their soil (Peterson 1999, Ajayi et al 2001).

Affordability of fertilizer: farmers are motivated to plant improved fallows because of the high price of fertilizer and lack of access to cash to purchase it. Even farmers who can afford fertilizer presently still plant improved fallows because they are not sure that they will be able to continue to afford fertilizer in the future given the history of changes in fertilizer policy and prices in Zambia (Peterson 1999, Ajayi et al 2001).

The categories of farmers who do not plant improved fallow are those who lack access to land, or who think that the technology involves too much labor and are unwilling to wait for two years before realizing the benefits of the technology (Peterson 1999).

Farm-level data also shows that once started, most farmers continue to plant improved fallows. Keil (2001) noted that 71 percent of a sample of farmers who planted improved fallows in 1996/97 continued to plant them over the next three seasons (Figure 4).

Figure 4--Adoption of improved fallows, by wealth category

Note: Sample of 94 farmers who had been selected randomly from lists of farmers who had tested the practice. A few had tested the practice in on-farm trials, most had tested it on their own.
Source: Keil (2001)

Interestingly, the proportion of farmers continuing to plant was highest among the fairly well-off (93 percent), followed by the poor (77 percent), the very poor (59 percent) and the well-off (58 percent). That the well-off continued less frequently than the other groups can be explained by their access to other means of improving their soils; some evidently decided that mineral fertilizer or manure were better alternatives.

To assess the proportion of a farmers' area planted to improved fallows, Kiel (2001) computed an index of intensity, that is, the area planted to improved fallows as a proportion of the maximum area a farmer could plant (one-quarter of his/her maize area).[6] The average index of intensity was 52 percent. As with the proportions continuing to plant, the index was highest for the fairly well-off farmers (57 percent) and lowest for the well-off (21 percent). The indices for the poor and very poor were 37 percent and 36 percent, respectively.

ECONOMIC[7] IMPACT OF IMPROVED FALLOW

During 1996-98, data were collected on costs and returns from 12 selected type 2 and type 3 farmers planting sesbania improved fallows; these were supplemented by data from other farmers, local markets, and secondary sources. Agricultural extension staff assisted ICRAF staff to select the farmers, based on their willingness to host the trials (Appendix 1). The twelve were the only ones who had complete sets of yield response data from the improved fallows during 1995/96 and 1996/97. Enterprise costs and returns were drawn up for twelve farms and used to calculate net present values per hectare to assess returns to land (in which household labor is valued) and net returns per workday to assess returns to labor (in which household labor is not valued). The analysis covered a

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[6] The index of adoption is defined as the area planted to a practice as a percentage of the area that a full adopter would plant (adapted from Hildebrand and Poey 1985). Whereas a farmer planting a new maize variety could conceivably plant it on all of his maize area, it would be inconceivable for a farmer to allocate all of his maize area to improved fallows –she/he would harvest no maize during the fallow period! As the improved fallow system usually involves a cycle of four seasons (establishment, fallow, and two post-fallow maize crops), a full-adopter of improved fallows would plant one-quarter of the maize area to improved fallows each season. The area under other crops is not included in the index of adoption because improved fallows have not yet been tested or recommended for them.

[7] The cost and returns analysis in this paper is termed a "financial analysis" in the terminology of the economics profession, because it takes the perspective of the individual farmer and values inputs and outputs at the prices farmers face. By contrast, an "economic analysis" is defined from the perspective of society; market prices of inputs and outputs are corrected if these do not reflect their real values to society. For example, if the fertilizer price was subsidized, economic analysis would use the unsubsidized price whereas financial analysis would use the subsidized price.

period of five years: two years of fallow and the three 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. Since data on maize yields during the second and third years following improved fallows were not available from on-farm trials, data on the percentage decline in the maize yield response following the first post-fallow year from on-station trials, 30 percent for the second year and 60 percent for the third year, were used in the analysis. Where cost was a function of yield, as in the case of harvesting labor, costs 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. A semi-structured survey was conducted following the first post-fallow maize harvest, to assess farmers' experiences and opinions.

Farm models using the Microsoft Excel Program were drawn up to assess the impact of adopting improved fallows on maize income. 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.

During 2001/2002, a second cost and returns study (called the 2002 study below) was conducted, in which farmers were interviewed on their farms once per week during the cropping season, to assess costs and benefits. Farmers were selected based on a multi-stage stratified random sampling technique: first, a sampling frame of all improved

fallow farmers were collected from the World Vision and ICRAF database. The list was stratified according to the year of establishment of field, then by gender and finally by the type of improved fallow species that a farmer planted. From the number a farmers in each strata, a representative sample of farmers was drawn to provide proportional representation of the different phases of the 5-year cycle. In most cases, someone literate (the farmer, the farmers' children, or other relatives) recorded labor use and other data in field notebooks. Crop yields were also measured for individual fields. The survey involved assessing 5 different soil fertility management systems: sesbania, gliricidia, and tephrosia improved fallows and continuous cropping with and without fertilizer. For improved fallows, farmers were selected on a multi-stage stratified random sampling technique so as to provide proportional representation of the different phases of the 5-year cycle. For example, for sesbania, the sample included 10 farmers in the first year of the cycle (establishment), 1 farmer in the second year (fallow maintenance), 8 farmers in the third year (first post-fallow maize harvest), 4 farmers in the fourth year (second post-fallow maize harvest) and 3 farmers in the fifth year (third post-fallow maize harvest). Sample size thus ranged from 1-10 farmers for any single phase (year) of an improved fallow. This method permitted a more accurate and precise estimate of costs and returns than the method used in the 1996-98 study. Moreover labor use was disaggregated by gender, age, and source (household, exchange, or hired labor). Given the small size of farmers' field, a GIS equipment was used to measure the sizes of each field to obtain accurate figures.

In both the 1996-98 and 2001-02 analyses, the main benefits of improved fallows, relative to continuously cropped maize, were labor saved in years one and two because

maize was not planted, fuelwood production in year 2, increase in maize yields in years three through five, 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, maintaining and harvesting the fallow, and harvesting and threshing the increased maize produced.

In the 2001-02 study, adult females provided the greatest share of labor for maize production (36 percent). Adult males provided 29 percent, youths 28 percent, and hired labor 7 percent. Females provided the greatest share of all tasks in maize production and improved fallow management except in nursery operations and land preparation.

In the 1996-98 study, maize yields 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 (Table 3). The post-fallow plot out-yielded the unfertilized plot on all twelve farms and the fertilized plot on four of the twelve farms. Results of the economic analysis of the twelve farms, using average values across farms, are summarized in Table 4; the detailed budgets for improved sesbania fallows and fertilized and unfertilized maize are shown in Appendix 1. Over a five-year period, a hectare of improved fallows required 11 percent less labor than a hectare of unfertilized maize and 32 percent less labor than fertilized maize. The findings of the 2001 survey were somewhat different. A hectare of improved fallow required 13 percent more labor than a hectare of unfertilized maize and 2 percent less labor than fertilized maize (Table 4).

Table 3--Maize yield following two-year *Sesbania sesban* improved fallows, as compared to yields in continuous unfertilized and fertilized maize, type 2 and type 3 trials, 1996 and 1997.

	I. Continuous unfertilized maize	II. Maize following improved. fallow	III. Continuous fertilized maize	Ratio: II/I
Phiri Tikozenji	440	3,000	2,860	6.8

Isaac Phiri	1,310	4,720	3,630	3.6
Whyson Mbewe	2,200	5,010	5,100	2.3
Harrison Chogwe	960	3,790	4,580	3.9
Maine Mwale	700	3,560	4,150	5.1
Lazarus Mwanza	970	2,760	6,570	2.8
Peniyas Tembo	190	1,420	2,820	7.5
T.Phiri[1]	1,300	2,300	5,100	1.8
Z. Mwanza	300	4,400	3,700	14.7
M. Jere	1,100	3,500	4,200	3.2
P. Nthani	800	4,800	4,200	6.0
J. Zulu	1,300	4,400	5,700	3.4
Mean	964	3,638	4,384	3.8
S.D.	548	1,108	1,108	

Source: Franzel et al. 2002

[1] Fallow period was for three years

Table 4--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[8]

Option	Work-days/ha		Tons Maize/ha	Returns to land: net present value (US$/ha)			Returns to labor: Net returns (US$) per workday	
	1996	2002		1996	1998	2002	1996	1998
Continuous unfertilized maize	499	462	4.8	6	6	130	0.47	0.79
Improved 2-year Sesbania fallow	441	521	8.5	170	215	309	1.11	1.64
Continuous fertilized maize	645	532	21.9	229	544	498	1.04	2.18

Source: Data from 1996, 1998, and on tons of maize produced are from Franzel et al. (2002). Data from 2002 are preliminary results from a survey by Olu Ajayi.

In the 1996-98 study, on a per-tonne basis, fertilized maize required only 29

workdays, while improved fallows and unfertilized maize required 52 and 104 days,

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[8] Means of values from individual budgets of the twelve trial farmers were used. Monetary values for 1996 and 1998 are in 1998 constant US dollars adjusted for inflation. All returns are discounted. Details on budgets and coefficients are provided in Appendix 1.

respectively. Relative to unfertilized maize, the improved fallow increases total maize production per hectare over the five-year period by 77 percent, even though it does not produce maize during the first two years of the fallow. But fertilized maize gives the highest five-year maize yield, 2.5 times that of improved fallows. The value of fuelwood produced in the fallow was low, only about 3 percent of the value of maize following the improved fallow.[9]

For financial data in the 1996-98 study, two scenarios are presented, one using prices for a year following a bumper harvest when prices were low (1996) and one following a poor harvest when prices were high (1998). Values in both years are expressed in 1998 US dollars, taking into account inflation between 1996 and 1998. In the analysis of returns to land, net present values (NPVs) per hectare for fertilized maize were over 30 percent higher than those of improved fallows in 1996 and over double those of improved fallows in 1998; NPVs for both fertilized maize and improved fallows were much higher than for unfertilized maize in both years. Using 1996 prices, six of the twelve farmers obtained higher NPVs for improved fallows than for fertilized maize; eleven obtained higher NPVs for improved fallows than for unfertilized maize. Using 1998 prices, NPVs for fertilized maize were over double those for improved fallows, because of the much higher maize prices.

In the 2001 study, the rankings of the different alternatives on NPV were the same as in the 1996-98 study. Net present values for fertilized maize were over 61 percent higher than those of improved fallows. Both were much higher than NPVs for unfertilized maize.

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[9] 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 fuelwood.

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. In the 1996-98 study, the payback period, that is, the period required for improved fallows to yield higher cumulative net present values than unfertilized maize, was three years for ten of the twelve farmers. This indicates that even without residual maize yield increases during the second and third post-fallow maize harvests, improved fallows were still more profitable than unfertilized maize.

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 fertilized maize narrowly, using average values across the twelve farms and 1996 prices (Table 4). Improved fallows gave higher net returns to labor than for unfertilized maize on eleven of the twelve farms and higher net returns to labor than for fertilized maize on eight of the twelve 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. Using 1998 prices, fertilized maize had higher returns to labor than improved fallows. 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 labor, the improved fallows performed better using 1996 prices while fertilized maize was superior using 1998 prices.

The performance of improved fallows relative to continuous, unfertilized maize was fairly stable under a wide range of possible changes in parameters in the 1996-98

study (Table 5). For example, improved fallows have returns to land and labor at least double those of unfertilized maize under most tested changes, including a 500 kg decline in post-fallow maize yields, and 50 percent increases or decreases 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.

Table 5--Sensitivity analysis showing the effects of changes in parameters[10]

	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	6	0.47	170	1.11	229	1.04
Maize price + 50%	114	0.83	330	1.73	718	2.31
Maize price - 50%	-101	0.11	10	0.49	-260	-0.23
Labor price + 50%	-61	0.47	117	1.14	142	1.04
Labor price - 50%	73	0.47	223	1.05	315	1.04
Discount rate 30% instead of 20%	5	0.47	119	1.02	186	1.04
Discount rate 10% instead of 20%	8	0.47	246	1.20	290	1.04
Seedling cost +50%	6	0.47	164	1.06	229	1.04
Seedling cost -50%	6	0.47	176	1.16	229	1.04
Fertilizer price + 50%	6	0.47	170	1.11	-11	0.42
Fertilizer price - 50%	6	0.47	170	1.11	469	1.66
Yield response to improved fallows + 500 kg/ha	6	0.47	209	1.25	229	1.04
Yield response to improved fallows - 500 kg/ha	6	0.47	131	0.96	229	1.04
No response to improved fallow (y4-5)	6	0.47	72	0.89	229	1.04
No response to improved fallow (y5)	6	0.47	138	1.09	229	1.04

Source: Franzel et al. 2002

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[10] Values are based on 1996 prices expressed in 1998 US dollars

In contrast, the performance of improved fallows relative to continuous, fertilized maize is sensitive to changes in key parameters (Table 5). Increases in maize prices (such as between 1996 and 1998) raise the returns to fertilized maize at a much faster rate than they raise the returns to improved fallows. Similarly, the relative profitability of the two practices is highly sensitive to the price of fertilizer; reductions in fertilizer price greatly increase the profitability of fertilized maize relative to improved fallows. 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.

Box 4--Ms. Jennifer Zulu: a pioneer experimenter with improved fallows

Ms Jennifer Zulu is one of the early collaborators in the testing of improved fallow in Eastern Zambia. Aged 40, Ms Zulu is the head of her household of 8 comprising of 5 male and 3 female. She has a modest education, attaining formal education up to grade primary grade four. In addition to the staple food, maize, Ms Zulu also cultivates groundnut, sunflower, cowpea and beans.

Ms Zulu established her first improved fallows when she planted *Sesbania sesban* and *Tephrosia* fields on a trial basis in 1992/93. After seeing the benefits of the technology, Ms Zulu has continued ever since to plant improved fallows on a yearly basis. Apart form the species that she started with, she has ventured into planting other improved fallow species including *Gliricidia sepium* and *Cajanus cajan*. She has conducted her own innovative research exploring weeding frequency in fallow plots, intercropping vs. growing trees in pure stands, and intercropping improved fallow species with other crops including sunflower and groundnuts.

Why does Ms Zulu continue to plant improved fallow after almost a decade? This is due to "the high maize yield I get from improved fallow which helps me achieve food security in my house" and also because improved fallow is "cheap and very sustainable for me".

Over the years, Ms Zulu has benefited from improved fallow in several ways: she has enough food to feed members of her household, she has been able to build a four-bedroom house with iron roof, she is able to sell the surplus produce from her fields which enabled her to send all her children to school. In addition, she obtains abundant firewood from the improved fallow fields and so does not have to walk long distance to collect them.

Making an overall impression of improved fallows, Ms Zulu in her own words said: "Improved fallows are very beneficial, cheap and very sustainable. They are especially useful for rural poor people who are unable to buy fertilizer, to achieve food security". On the basis of these benefits, Ms Zulu recommended that improved fallow should be expanded to locations where the technology has not been introduced.

The above analysis of profitability examines returns per hectare; but how will adoption of improved fallows affect farm income once they have been incorporated into the farming system? A "full-adopter" of improved fallows would divide his/her maize area into five parts and plant one-fifth of the area to improved fallows each year on a rotating basis. The farmer would thus allocate each plot to a different phase of the

practice: one plot planted to improved fallows, a second plot in year two of the practice, and a plot planted to maize following a fallow, and a fourth and fifth plot with maize in its second and third planting, respectively, following the fallow. The analysis assumes that the farm household cultivates manually, and has 1.4 ha and 120 workdays available for cultivating maize. The analysis in Table 6 uses 1996 data and compares the planting of improved fallows with two alternatives, continuous cropping of maize with fertilizer and without fertilizer. The farmer would earn US$ 262 per year using fertilized maize, US$ 173 per year growing improved fallows, and only US$ 95 cultivating continuous maize without fertilizer (Table 6). Even if the improved fallows do not increase maize yields in the third year following improved fallows, earnings are still twice as high as on unfertilized maize.

Table 6--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[11].

Farm practicing improved fallows (Farm has 0.28 ha in each of the 5 phases of improved fallow)					Farm with unfertilized maize (1.2 ha cultivated)				Farm with fertilized maize (0.92 ha cultivated)			
Crop	Area (ha)	Work-days/yr	kg. maize prod./yr	Net returns/yr US$		Work-days/yr	kg. maize prod./yr	Net returns/yr US$		Work-days/yr	kg. maize prod./yr	Net returns/yr US$
Fallow, 1st yr.	0.28	31	0	0	Maize	120	1157	95	Maize	120	4077	262
Fallow, 2nd yr	0.28	1	0	1								
Maize 1st post fallow	0.28	27	1026	97								
Maize 2nd post fallow	0.28	31	800	75								
Maize 3rd post fallow	0.28	30	573	52								
Total	1.4	120	2390	225								
Net returns to labor if maize in the 3rd post fallow season yields the same as on the farm with unfertilized maize			195									

Source: Franzel et al. 2002

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[11] Household is assumed to have 120 workdays available during the cropping season for maize production; the amount needed to manually cultivate 1.2 ha maize without using fertilizer. Labor use is standardized across the three systems; farmers cultivate as much land as they can using 120 workdays. Costs and returns are from Appendix 1. Improved fallows are two years in length and are followed by three years of maize crops.

RISK ASSESSMENT

The risk of drought is critical for farmers in Zambia; unfortunately the effects of drought in the season following an improved fallow could not be assessed using the data collected for the above economic analysis. But there are five reasons why improved fallows are likely to be much less risky than fertilized maize:
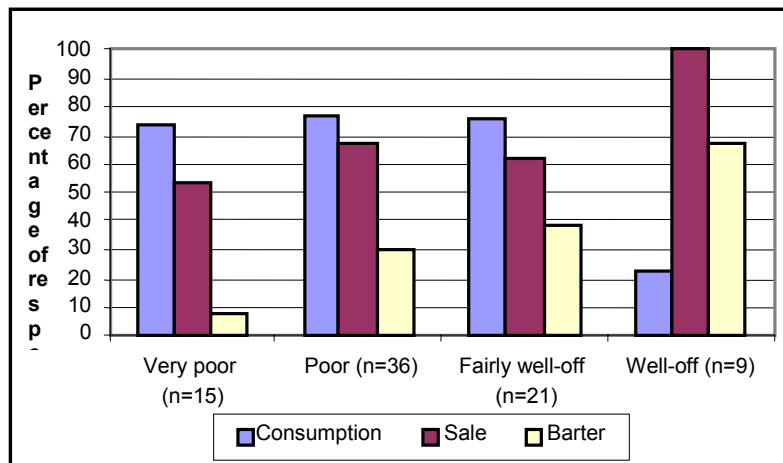
1. In the event of a complete crop failure, a farmer using fertilizer would lose his investment in fertilizer, US$ 154 ha^{-1} whereas a farmer with improved fallow would lose his investment in planting and maintaining the trees, only about US$ 90 ha^{-1} (using 1998 prices). In addition, both farmers would lose their investment in growing maize that year.

2. Whereas nearly all of a farmer's investment in fertilizer is in cash terms, improved fallows require little or no cash input. Seed from the main tree species is plentiful and is rarely sold, rather farmers obtain seed by harvesting it from neighbors' plots or on loan from projects (the are requested to reimburse the projects when their own trees mature). The opportunity cost of cash is extremely high and in case 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. In fact, Peterson (1999) reported that 44 percent would not accept fertilizer on credit under any circumstances.

3. The benefits of improved fallow are likely to be spread over a three-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.

4. 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 (see section below on ecological impact).

5. Farmers relying on fertilizer may not be able to purchase fertilizer even if they have the cash, as it sometimes arrives too late in the season to have any effect.

Box 5--Ms. Tafadi Mbewe's comparison of improved fallows and mineral fertilizer with regard to reduced risk and improved food security

Tafadi Mbewe of Kapita village, in Chipata North district has been planting improved fallows since 1997. Currently she has a first year crop in the Tephrosia field that is doing exceptionally well. She also hosts a "type 2" researcher designed, farmer managed trial where she is comparing mixing Gliricidia and Tephrosia trees with sole plots of Gliricidia and Tephrosia. There is a first crop of maize following the fallow growing in these plots. So far she has not noticed any differences in maize among the three tree plots although she has seen huge differences in maize production between the three tree plots and the plots where no trees were grown or fertilizer was applied. Answering a question from visiting scientists from various Southern Africa nations in January 2002, about her preference between improved fallows and fertilizer, she answers it by giving an implicit benefit in improved fallows over fertilizer that perhaps most scientists have taken for granted: "Fataleza ya loni yambiri yamene himabwela siimafika kuli alimi. Ba agriculture ba maba. Mitengo yathaka ukashanga mumunda siibewa Chaka chasira alimi ambiri sanalandire fataleza chifukwa inabewa. Azanga ambiri alikufa kunjala, koma ine milisi yomwe ndinashanga chaka chasira mumunda wa nyamundoro ndikali nayo." This is translated as: "Unlike fertilizer that is normally stolen by agricultural workers, improved fallow trees cannot be stolen once they are established on farm. For example in 2001 most of the loan fertilizer meant for peasant farmers did not reach the intended beneficiaries because it was stolen. Most of my friends who had hoped to use the same fertilizer are now starving but in my case I have enough maize from my pigeon pea improved fallow field that I harvested last year".

How do farmers use the additional income they earn from improved fallows? Keil (2001) found the well-off farmers tended to sell or barter most of their additional maize whereas the other three income groups consumed most of the additional maize (Figure 5).

Figure 5--Use of additional maize produced, differentiated by wealth category (multiple uses possible)

Source: Keil (2001)

Money earned from sales was used, in order of importance, for consumption goods (e.g., soap, paraffin, and salt), clothing, education, health care, and food. High proportions of the well-off and fairly well-off spent more of the additional money on education and clothing, priorities for the poor and very poor were clothing and health care.

ECOLOGICAL IMPACT

Effects on soil physical properties

Improvements in soil physical properties have a positive impact on plant growth and crop production. Over the years soil physical properties have been measured after two or three years of coppicing and non-coppicing fallows. Several researchers have reported that tree fallows improve soil physical properties by additional of large quantities of litter fall and root biomass decomposition which leave a lot of channels in the soil system. Work done in improved fallows of two years *Sesbania sesban* and *cajanus cajan* have shown that soil properties such as aggregate stability, resistance to penetration, infiltration are greatly improved, which lead to high water storage as compared to continuous cultivated soils (Table 7).

Table 7--Effects of land use system on some soil physical properties after 8 years of improved fallow-crop rotations at Msekera, Chipata-Zambia (November 1998)

Land-use system	Average infiltration rate (mm min^{-1})	Average cumulative water intake after 3 hours (mm)	Average water stored in 70 cm root zone at 8 weeks after planting (mm)	Average penetrometer resistance at 40 cm soil depth (Mpa)	Average water stable aggregates >2.00mm (%)
Sesbania sesban	4.4a	210.6ab	235.4a	2.2c	83.3a
Cajanus cajan	5.2a	235.8a	222.7b	2.9b	80.8a
Natural fallow	5.3a	247.9a	209.5c	2.9b	65.7b
Continuous M+F	3.1b	142.0bc	208.8c	3.9a	65.6b
Continuous M-F	2.1c	103.4c	217.3b	3.2b	61.2a
Mean	4.0	187.9	218.7	3.1	71.5
SED	0.5	36.0	7.9	0.2	3.1

Means in a column followed by the same letter or letters are not significantly different at P≤0.05 based on the Duncan's Multiple Range Test

Torquebiau and Kwesiga (1996) report that soil properties such as bulk density, infiltration, soil resistance to penetration were improved after 2 years of *Sesbania sesban* fallow as compared to maize mono cropping system. Other work on coppicing fallows of *Gliricidia sepium, Leucena Leucocephala* and *Acacia angustisima* at Msekera, have shown that soil physical properties are greatly improved relative to continuous maize cropping system as was evident from lower bulk density, increased soil aggregation and reduced resistance to penetration in the surface soils at the end of three year fallow phase. The improvement in the soil resulted in high infiltration rates and increased water storage under the fallow system. Continuous maize with or without fertilizer causes break down of soil structure, which will eventually lead to poor crop growth. Juo et al. (1995) showed that chemical fertilizer alone on poorly buffered soils cannot sustain crop yield under continuous cropping because of soil acidification, compaction and crusting. High soil aggregation under improved fallow system promotes increased water infiltration and water holding capacity, which reduces water runoff and hence decreased erosion as compared to continuous maize mono cropping system. Increased water storage under improved fallow system will have a positive impact on the supply of water to the crop during periods of prolonged droughts. Increased soil resistance to penetration is due to increased bulk density or decrease in water content in the soil system, which will eventually reduce uptake of nutrients and water by maize root system. Bulk density is one of such indicators for soil degradation that influences crop productivity as observed by many farmers using improved fallow technology.

Effects on soil nutrient balances

Improved fallows with sesbania or tephrosia have been shown to give maize grain yields of 3 to 4 t/ha without adding any organic fertilizer. (Palm 1995) showed that

organic inputs of various tree legumes applied at 4t/ha can supply enough nitrogen (N) for maize grain yields of 4t/ha. However most of these organic inputs could not supply enough phosphorus (P) and potassium (K) to support such maize yields.

The question to be posed for the sustainability debate is: can improved fallows potentially mine P and K over time while maintaining a positive N balance. In order to answer this question we conducted nutrient balances studies in improved fallow trials at Msekera Research Station. These plots were under fallow- crop rotations for 8 years. The objectives of these nutrient balance studies were:

- Can nutrient balances trials be used as land quality indicators?

- Can they be used to assess soil fertility status productivity and sustainability?

- Can they be used as policy instruments for recommending the types of fertilizers to be imported or distributed to farmers?

The nutrient balance was determined by subtracting outputs from inputs. The nutrient inputs included leaves and litter fall and stocks were measured from 0-60 cm soil layer before planting maize. Nutrient outputs included fuel wood taken away at end of the fallow, maize grain harvested, and, maize stover removed. The results of these nutrient balances are shown in Table 8. For all the land use systems there was a positive N balance for two years of cropping after the fallows, which in turn followed eight years of fallow-crop rotation. Fertilized maize had the highest N balance due to annual application of 112 kg N/ha for the past 10 years. However unfertilized maize had lower balances due to low maize grain and stover yields over time. The tree-based fallows had a positive N balance for the two years of cropping after the fallows due to biological nitrogen fixation and deep capture of N from depth. These results are consistent with those of Palm 1995

**Table 8--Nutrient balances of improved fallows at Msekera Research Station,
following eight years of fallow-crop rotation.**
Nitrogen budgets for different options in two-year non-copping fallows (0-40cm)

Options	Nitrogen Balance		Phosphorus Balance		Potassium Balance	
	1998	1999	1998	1999	1998	1999
	(kg/ha)					
Cajanus	27	5	21	8	13	-9
Sesbania	22	5	39	24	-42	-32
Natural fallow	8	11	19	15	-10	-4
Fertilized maize	150	103	57	43	-19	-17
Unfertilized maize	31	11	31	20	19	-1

However in the second year of cropping (1999) the N balance in the improved fallow plots was very small. This is consistent with our earlier results, which show a decline of maize yields in the second year of cropping after two-year fallows. The huge amount of N supplied by fallows could be lost through leaching beyond the rooting depth of maize. Our leaching studies have clearly shown substantial inorganic N at depth under maize after improved fallows. These results imply that if cropping goes beyond two years after fallows there will be a negative N balance. Thus the recommendation of two years of fallows followed by two years of cropping is well supported by N balances and maize grain yield trends.

Most of the land use systems showed a positive P balance. This can be attributed to low uptake of P in maize grain yield and stover. In addition this site had high P status. The trees could also have increased P availability through secretion of organic acids and increased mycorrhizal population in the soil. These issues are under investigation at our site. In general we have observed positive P balances over 8 years. However this result needs to be tested on farm where the soils are inherently lower in P.

Most land use systems showed a negative balance for K. For tree based systems sesbania showed a higher negative K balance compared to cajanus. This is attributed to higher fuelwood yield of sesbania with subsequent higher export of K compared to pigeonpea. The higher negative K balance for fully fertilized maize is due to higher maize and stover yield which export a lot of

K. Maize yields were high with a negative K balance. This implies that the K stocks in the soil are very high and the K mining has not reached a point of negatively affecting maize productivity. However in sites with low stocks of K in the soil maize productivity may be adversely affected.

Overall, the tree based fallows maintained a positive N and P balance. However on soils of low P status a negative P balance would be expected. There was a negative K balance with most land use systems. It can be hypothesized that if we scale up improved fallows on depleted soils on farmer's fields, K and P balances will be reduced to negative levels. This has implications on the fertilizer policy of Zambia. Compound D, which contains N, P, K, is the current. imported base fertilizer for maize. However if farmers adopt improved fallows on a wider scale these fallows will meet the N requirement of maize. Where there are K and P deficits, farmers may not need to buy compound D because N is adequately supplied by; fallows. They only need K and P as nutrients to supplement N in the fallows. This may require a shift in government policy on the type of fertilizer imported, as K and P fertilizers without N are currently not available. There is also urgent need to conduct these nutrient budgets at landscape level under farmer's fields to test their validity.

Effects on conserving woodlands. Another potential ecological impact of improved fallows is that the wood they provide reduces pressure on natural woodlands for fuelwood. In fact, farmers' use of fuelwood from improved fallows appears to vary across locations. In areas where fuelwood is scarce, wood from fallows is carried to the house while in surplus areas it is burned in the field. The role of improved fallows in reducing pressure on the natural woodlands is currently being assessed in an MSc thesis research project.

5. CONCLUSION

Development is a process whereby people learn to participate constructively in the solving of their own problems. The driving force is people's enthusiasm for change (Bunch 1995). Improved fallow practices have important economic and ecological benefits to participating farmers and society as a whole. Moreover, the work of the adaptive research and dissemination network has helped farmers and grassroots organizations to develop problem-solving skills critical for the sustained use of improved fallows. Our current achievements so far can be attributed to:

- Correct diagnosis of farmers' problems from the onset of the program.

- Involvement of farmers and extension in the research process from the inception of the program. The scientists, like the camp extension staff, spent much time interacting with farmers and could respond quickly to the needs of farmers.

- Starting small and using local knowledge in the design of solutions.

- Demonstrating easily recognizable results.

- The strategy of testing a wide range of management options with farmers (e.g., offering three different species with intercropping and pure stand options) and then allowing them the freedom to modify, innovate, and improve the prototypes.

- Establishing a system for nurturing, capturing, and disseminating farmers' innovations.

- The technology appears to be gender neutral, as half of the participating farmers are female. It also appears to be attractive to a range of different types of farmers — e.g., high income and low income, ox- and hoe-cultivators.

- The funding of the research project has been adequate and for a reasonable length of time.

- Ex-ante economic analysis helped identify key features of the technology that make it financially attractive — e.g., bare-root seedlings and the superiority of a 2-year fallow over 1- and 3-year fallows .

- Development of an adaptive research and dissemination network of partners for testing and extending the technology in new areas.

Table A1--Cost benefit analysis of improved fallow and cropping options ($US/ha)

	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
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								0.00	0.00	0.00	142.82	142.82	142.82	142.82	142.82
Fert. transport								0.00	0.00	0.00	6.40	6.40	6.40	6.40	6.40
Total cash costs	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															
Tree nursery						10.52									
Land preparation	12.00	12.00	12.00	12.00	12.00	12.00		9.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00
Ridging	4.00	4.00	4.00	4.00	4.00	4.00		3.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Planting maize	2.00	2.00	2.00	2.00	2.00	0.00		2.00	2.00	2.00	2.80	2.80	2.80	2.80	2.80
Planting trees	0.00	0.00	0.00	0.00	0.00	11.24		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1st weeding	8.00	8.00	8.00	8.00	8.00	8.00		6.00	8.00	8.00	10.00	10.00	10.00	10.00	10.00
2nd weeding	4.00	4.00	4.00	4.00	4.00	4.00		3.00	4.00	4.00	6.00	6.00	6.00	6.00	6.00
Tree cutting	0.00	0.00	0.00	0.00	0.00	0.00	2.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harvesting mz	5.96	5.96	5.96	5.96	5.96	0.00	0.00	8.88	8.00	7.13	9.58	9.58	9.58	9.58	9.58
Mz shelling	3.96	3.96	3.96	3.96	3.96	0.00	0.00	6.88	6.00	5.13	7.58	7.58	7.58	7.58	7.58
total labor costs	39.92	39.92	39.92	39.92	39.92	49.76	2.08	38.76	44.01	42.26	51.96	51.96	51.96	51.96	51.96
total costs	62.16	62.16	62.16	62.16	62.16	52.68	2.08	61.00	66.25	64.50	223.42	223.42	223.42	223.42	223.42
labor workdays	99.8	99.8	99.8	99.8	99.8	124.4	5.2	96.9	110.0	105.6	129.9	129.9	129.9	129.9	129.9
BENEFITS															
Maize	63.74	63.74	63.74	63.74	63.74	0.00	0.00	257.63	199.47	141.30	304.11	304.11	304.11	304.11	304.11
Fuelwood	0.00	0.00	0.00	0.00	0.00	0.00	6.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total benefits	63.74	63.74	63.74	63.74	63.74	0.00	6.40	257.63	199.47	141.30	304.11	304.11	304.11	304.11	304.11
Net ben to labor	41.50	41.50	41.50	41.50	41.50	-2.93	6.40	235.39	177.23	119.06	132.66	132.66	132.66	132.66	132.66

Net ret to lab/day	0.42	0.42	0.42	0.42	0.42	-0.02	1.23	2.43	1.61	1.13	1.02	1.02	1.02	1.02	1.02
Net benefits	1.58	1.58	1.58	1.58	1.58	-52.68	4.32	196.63	133.22	76.80	80.70	80.70	80.70	80.70	80.70
Workdays	499.0					442.2					649.5				
NPV	4.74					168.00					241.33				
discounted days	0.24					0.21					0.31				
disc net ben to lab	124.12					271.54					396.72				
Disc nb/disc days	0.42					1.05					1.02				
Quantity of maize	5 t/5 years					9.0 t/5 yrs.					23 t/5 years				

Source: Franzel et al. 2002.

Notes.

Prices are from local markets for the 1996 cropping season. Exchange rate: US$1.00=1250 Zambian Kwacha (ZK), 1996.

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, is 1.4 ZK, median from cost analysis of eight farmer nurseries. Mean cost was 1.9 ZK, s.d., 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 DOA 1991, Kwesiga *et al*., 1995, and Place *et al*., 1995, 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 seven 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. (s.d. 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, s.d. =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 A1 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 3.4). For the continuously cropped maize fields, yields are assumed to be constant over the five year period (964 kg ha^{-1} without fertilizer and 4,384 kg ha^{-1} with fertilizer). Maize yields following the improved fallows are 3,638 kg ha^{-1} for the first post fallow season (Table 3.4), 2836 kg ha^{-1} for the second, and 2034 kg ha^{-1} for the third season. The latter two figures are based on a 30% and 60% reduction in response, as obtained in on-station trials. The maize prices is 83 ZK/kg, the estimated farm-gate price during the harvest period, 1996. The 1998 price was 167 Kw/kg.

Fuelwood: Fuelwood is not normally sold; yield is estimated at 4 t/ha and price at 2000 ZK/t.

Discount rate: 20%

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