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Improved tree fallows in eastern Zambia: Do initial testers adopt the technology?

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Abstract

In eastern Zambia traditional bush fallows have been shortened by population pressure and are not sufficient for soil fertility restoration any more. Following subsidy removal, the use of mineral fertilizer has sharply declined in the 1990s. Both factors have led to decreasing soil fertility and, hence, low maize yields which threaten food security. Improved Fallows (IF) using leguminous trees are a low cash-input agroforestry practice of soil fertility replenishment. The International Centre for Research in Agroforestry (ICRAF) began on-farm experimentation in 1992/93, and by 1996/97 roughly 3,000 farmers spontaneously tested the technology.

A survey was conducted to assess the adoption of IF by those early testers, and to identify factors which influence the adoption decision and determine the scale of the practice. Furthermore, farmer experiences with the technology and implications on other parts of the farming system were explored.

Seventy-five percent of testers have adopted the technology which shows that IF are a suitable practice under the given conditions. Adopters practice the technology at 42% of its potential scale; land and/or labor availability limit expansion.

Adoption is positively influenced by the availability of land and labor resources. A non-linear relationship was found between adoption and wealth status: Ninety-three percent of farmers in the ‘fairly well-off’ category with ample land resources but limited alternatives of soil fertility restoration adopted IF, as opposed to only 59% of ‘very poor’ and ‘well-off’ farmers. Land scarcity and risk aversion constrain adoption among the very poor stratum, while well-off farmers have more profitable options of soil fertility maintenance, such as mineral fertilizer and manure.

The scale of the practice is larger in a conducive edaphic environment. Furthermore, it depends on per capita land endowment which determines the share of land that can be fallowed.

Increased maize yields are the primary benefit derived from IF, allowing farmers to sell some of the additional maize produced. Thus, apart from enhancing maize consumption, IF also lead to increased cash income.

To facilitate the expansion of the practice, future research should emphasize IF options which reduce land and labor requirements, such as intercropping and species which can be direct-seeded.

1. Introduction

The decline in soil fertility in smallholder farming systems is a major factor inhibiting equitable development in much of sub-Saharan Africa (FRANZEL, 1999: 305). In thinly populated savanna areas farmers traditionally practiced shifting cultivation (RUTHENBERG, 1980: 30; SANCHEZ, 1995: 21). This system involves an alternation between cropping for a few years on selected and cleared plots and a lengthy fallow period which restores soil fertility. As population grows, increasing land scarcity forces farmers to shorten fallow periods, which eventually leads to a loss of soil fertility and, hence, to declining yields (BOSERUP, 1965: 11-14; RUTHENBERG, 1980: 61).
This process has taken place in eastern Zambia where population pressure has led to reduced fallow periods of one to three years (SANCHEZ, 1995: 21). Some farmers even practice continuous cropping because brief natural fallows do not result in an increase in yields (FRANZEL et al., 1999: 4). Fertilizer use was widespread during the 1980s but the removal of subsidies following structural adjustment programs in the early 1990s caused its use to decline by 70% between 1987/88 and 1995/96, hence exacerbating the process of soil degradation (FRANZEL et al., 1999: 4).
Improved Fallows (IF) using leguminous trees are a low cash-input agroforestry practice of supplying nutrients to subsequent crops (KWESIGA & COE, 1994: 206).
IF accumulate N in the biomass and recycle it into the soil (YOUNG, 1989: 99; KWESIGA & COE, 1994: 200), act as a break crop to suppress weeds (DE ROUW, 1995: 31), and also improve soil physical properties by increasing the organic matter content (JUO & LAL, 1977: 567). The other essential nutrients such as P are cycled to some degree through plant biomass and returned to the soil during litter decomposition (SANCHEZ & PALM, 1996: 24).
The International Centre for Research in Agroforestry (ICRAF) selected Eastern Province for their research activities because of its high potential as the breadbasket of the country. In *on-station* trials, established by ICRAF at Msekera Research Station in Chipata in 1988, a maize grain yield of 5.0 t ha^{-1} was obtained following a two-year fallow of the N_2-fixing tree species *Sesbania sesban* (L.) Merr.. This compared to 4.9 t ha^{-1} from continuously cropped maize with fertilizer application[1] and 1.2 t ha^{-1} without fertilizer, whereby the latter is a common practice among the farmers of this area (KWESIGA & COE, 1994: 204-205). *On-farm* experimentation began in 1992/93 with five farmers and involved 158 farmers in 1994/95. Farmer interest is strong as experimentation with the technology spread spontaneously to involve approximately 3,000 farmers in the 1996/97 season (KWESIGA et al., 1999: 60-62).

2. Objective of the Study

The objective of this study is to assess the adoption of Improved Fallows, and experiences made by those farmers who tested the technology in the 1996/97 season or earlier in the Eastern Province of Zambia. These farmers have experienced at least one full IF cycle of two fallow years plus two post-fallow cropping seasons.
The study addresses the following research questions:

I. How many farmers have continued planting IF? At which scale are they now practicing the technology?
II. What are motivations to practice and expand IF, what are constraints?
III. Which farm and household characteristics influence the adoption decision and the scale of the IF practice?

[1] 112 kg N ha^{-1}

An adoption study helps research and extension to be more effective in responding to farmers' needs. A feedback on farmer experiences contributes to a better understanding of constraints to the adoption and farmer adaptation of the technology, and therefore helps to identify issues for further adaptive research to improve its adoptability. An analysis of farm and household characteristics influencing the adoption of IF assesses the relative suitability of the innovation for different groups of farmers. This information can be used to improve the focus of future research and extension activities.

3. Conceptual Framework

Research question III was examined using regression analysis. It was subdivided into two consecutive parts:

1. Which factors influence the decision whether or not to adopt the technology?
   The dichotomous dependent variable 'Adoption of Improved Fallows'(Y) is defined as follows:
   Testers who have planted at least one IF after they have experienced the effect of their initial IF on a subsequent crop are considered adopters.

2. Which factors determine *the scale* at which the technology is practiced?
   IF are generally viewed as a means to increase maize yields. Since the IF system involves a four-year cycle of two fallow years plus two subsequent cropping seasons in which yields are affected, a farmer who practiced the technology to full extent would plant one quarter of his maize area to IF in each year. Hence, the continuous variable 'Intensity of Adoption of Improved Fallows'(IA) is defined as follows:

   $$IA[\%] = \frac{IF}{0.25 \cdot M} \cdot 100$$, where

   IF = Annual area planted to Improved Fallow
   M = Annual area planted to maize

   (Note: Since the use of IF is *not necessarily* restricted to the maize area, the IA can exceed 100%)

A two-step regression procedure was applied, correcting for sample selection bias as proposed by HECKMAN (1979). In the first step, Y is estimated using a PROBIT model. For each observation, the Inverse Mills Ratio (IMR) is derived which can be interpreted as a variable capturing unobserved or unobservable determinants of Y. These could potentially also influence IA. In the second step, IA is estimated *conditional on adoption* using OLS[2]. The IMR is included in the OLS model, thus correcting for sample selection bias. The same procedure was followed for example by KUMAR (1994).

4. Methodology

Description of the study area

The plateau area of eastern Zambia is characterized by a flat to gently rolling landscape and altitudes ranging from 900 to 1200 m above sea level. The main soil types are loamy-sand or sand Alfisols and clay and loam Luvisols, whereby the latter are more suitable for IF species (FRANZEL et al., 1999: 10). Rainfall is unimodal and highly variable, averaging 1,030 mm. Approximately 85% of the total amount is received within four months, December through March. Average air temperature ranges from 18 ^{o}C in June, the coolest month of the dry season, to 27 ^{o}C in October, just prior to the start of the rainy season (AGROMET office, Msekera, Zambia, 2001).
In 2001, Zambia's population is estimated at 10.546 Mio, with an annual growth rate of 3.0% (THE WORLD GAZETTEER, 2001). Average population density in Zambia is 14.2

[2] Ordinary Least Squares

persons km^{-2}, in the study area it ranges from 25 and 40 persons km^{-2} (FRANZEL et al., 1999: 3). Maize (*Zea mays* L.) is the most important crop accounting for about 80% of the total cultivated area (KUMAR, 1994: 34; FRANZEL et al., 1999: 3).

Sampling and data collection

Four sub-districts of contrasting soil types[3] were purposively selected according to logistical criteria. Within these, a random sample of 100 farmers who had tested IF in the 1996/97 season or earlier was selected, stratified by soil type. ICRAF had records of these early testers because they had provided them with planting material for their initial IF. These records served as sampling frame. Structured interviews were conducted in the local language, Nyanja.

Wealth ranking

Households were classified as being 'very poor', 'poor', 'fairly well-off' or 'well-off' based on indicators which had been identified by key informants in four ICRAF target villages in 1999 (PHIRI et al., 1999: 15). These included farm size, number and kind of animals owned, technology used for cultivation, type of housing, ownership of certain assets, sources of off-farm income etc..

5. Results

Adoption rate and determinants of adoption

In six cases adoption could not be assessed yet. Out of the remaining 94 respondents, 71 (75.5%) had adopted the technology. The results of the PROBIT regression concerning determinants of the adoption decision are listed in Table 1.

Table 1. Determinants of the adoption of Improved Fallows, Y (PROBIT estimate)

Explanatory variable	Coefficient	t-value	Mean
ACCESS	0.48794	1.897*	2.585
SOILPROB	2.20605	2.610***	0.947
SOILTYPE	- 0.59916	- 1.420	0.457
SEX	0.48325	0.106	0.266
AGE	0.12129	0.746	48.245
EDUC	0.66684	0.403	3.245
WEALTH1	- 0.44011	- 0.876	0.181
WEALTH3	1.42012	2.104**	0.287
WEALTH4	- 1.42499	- 1.982**	0.128
FARMSIZE	0.13554	1.701*	4.743
LABWEIGH	0.24215	1.675*	3.668
CAMP3	- 2.20088	- 3.216***	0.202
Constant	- 3.99140	- 2.487**	
N = 94			
Chi-squared = 37.66***			
Percentage predicted correctly = 84.04			

Source: Own survey

Notes:

Dependent variable: Adoption of Improved Fallows (Y; 0 = no, 1 = yes)

Definition of independent variables:

ACCESS	= Accessibility of village (1 = poor: quite remote, not accessible by vehicle at the height of the rainy season. 2 = fair: relatively close to major road, accessible by vehicle all year round. 3 = good: in immediate proximity of a major road)
SOILPROB	= Dummy, if low soil fertility is perceived to be a problem (0 = no, 1 = yes)
SOILTYPE	= Predominant soil type (0 = Alfisol, 1 = Luvisol)
SEX	= Sex of household head (0 = male, 1 = female)
AGE	= Age of household head (years)
EDUC	= Level of formal education of the most educated household member (1 = never attended school, 2 = attended primary school, 3 = completed primary school, 4 = attended secondary school, 5 = completed secondary school, 6 = attended higher educational institution)

[3] In two sub-districts Luvisols are the predominant soil type, in the other two this is Alfisols.

WEALTH1	= Dummy, if household belongs to the ‘very poor’ wealth stratum (= 1, else = 0)
WEALTH3	= Dummy, if household belongs to the ‘fairly well-off’ wealth stratum (= 1, else = 0)
WEALTH4	= Dummy, if household belongs to the ‘well-off’ wealth stratum (= 1, else = 0)
FARMSIZE	= Farm size (ha)
LABWEIGH	= Weighted household labor availability during the cropping season (ME[4])
CAMP3	= Dummy, if household resides in Jerusalem camp (= 1, else = 0)

*(**)[***] Significant at the 10% (5%) [1%] level of error probability

Adoption intensity and its determinants

Among adopters, the extent of the IF practice was found to be 42% of its potential scale. Table 2 shows the results of the second-step OLS model regarding the determinants of the scale of the practice.

Table 2. Determinants of the intensity of adoption of Improved Fallows, IA (OLS estimate)

Explanatory variable	Coefficient	t-value	Mean
ACCESS	3.40987	0.472	2.662
SOILTYPE	14.84256	1.689*	0.471
SEX	- 18.45753	- 1.735*	0.265
AGE	- 0.75875	- 1.978**	49.059
EDUC	3.32339	0.846	3.250
WEALTH1	15.54184	0.983	0.147
WEALTH3	23.01194	2.043**	0.353
WEALTH4	- 21.48845	- 1.198	0.088
FARMSIZE	- 1.47713	- 0.979	5.089
FARMMEM	15.97175	1.649*	0.757
LABHAWEI	3.97724	1.099	1.371
IMR	12.82092	0.676	0.264
Constant	35.66648	1.001	

N = 68[5]
R^2 (adjusted) = 0.078
F = 1.47

Source: Own survey

Notes:
Dependent variable: Intensity of Adoption of Improved Fallows, conditional on adoption (IA (%))

Definition of independent variables as in Table 1, apart from:

FARMMEM	= Per capita land availability (ha person^{-1})
LABHAWEI	= Weighted household labor availability during the cropping season (ME), per ha
IMR	= Inverse Mills Ratio

*(**) Significant at the 10% (5%) level of error probability

Benefits derived from Improved Fallows

Ninety-five respondents had derived benefits from their IF, and 22 different benefits were cited altogether. Farmers rated the benefits on a scale from 1 (= very small benefit) to 5 (= very big benefit). Figure 1 shows the benefits which were mentioned by at least five respondents (5%), and their mean rating.

Other benefits mentioned by a smaller number of farmers included for example weed suppression, prevention of soil erosion, and improved physical soil properties.

Increased maize yields allowed 54 respondents to sell some of the additional maize produced, and another six farmers reduced the area devoted to maize due to the yield increase and grew cash crops like groundnuts and sunflower instead. Thus, 60 respondents (60%) had obtained cash income from the IF practice.

[4] Man-equivalents. Weights used are 0.50, 0.75, 1.00 and 0.75 for age groups < 10, 10 to 15, 16 to 60 and > 60 years, respectively. No weight was attached to females since labor bottlenecks were identified mostly for gender-neutral activities like planting and weeding of IF.

[5] Three extreme values were identified using a boxplot and excluded from the analysis.

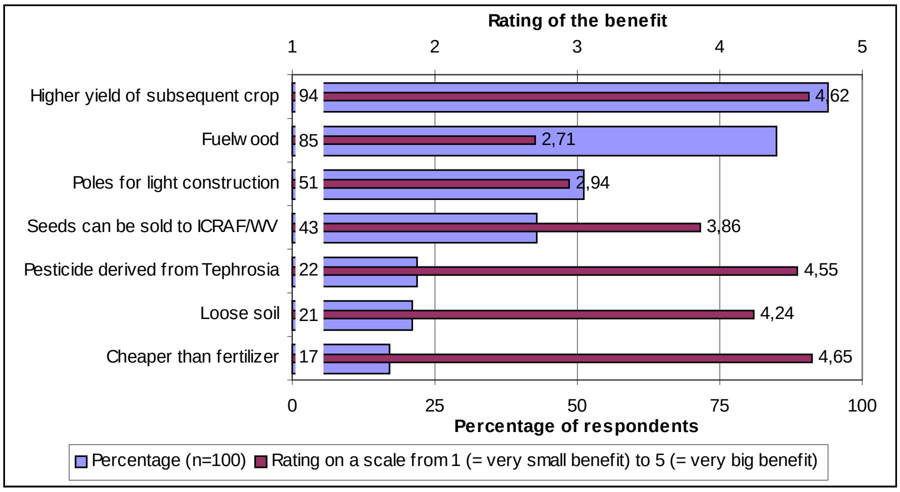

Figure 1. Rated benefits from Improved Fallows, cited by at least 5% of respondents
Source: Own survey

Problems encountered with Improved Fallows
Four farmers had not encountered any problems when practicing IF. The remaining 96 respondents cited 24 different constraints altogether.
Respondents rated the problems perceived on a scale from 1 (= very small problem) to 5 (= very serious problem). Figure 2 shows the problems mentioned by at least five respondents (5%), and their mean rating.

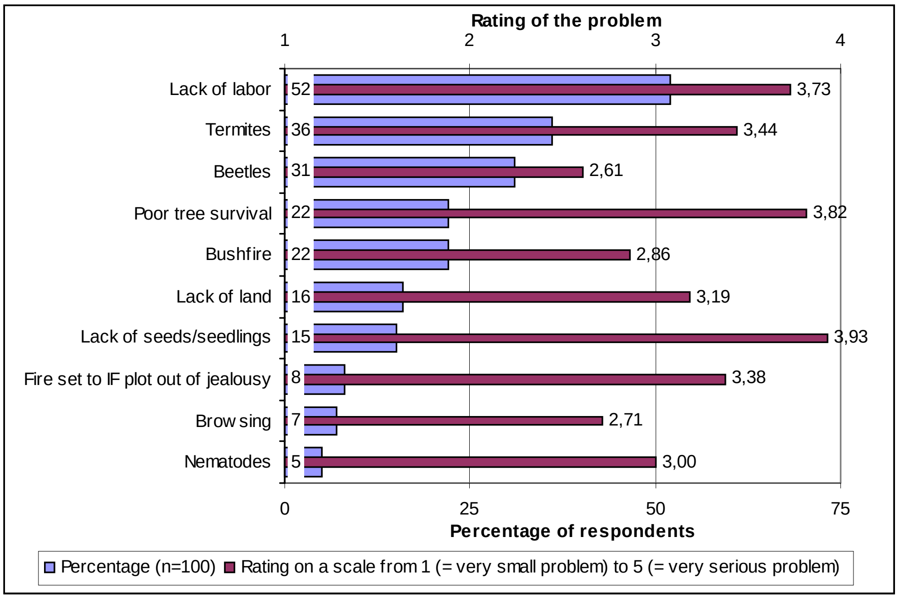

Figure 2. Rated problems regarding Improved Fallows cited by at least 5% of respondents
Source: Own survey

Other constraining factors were for example lack of water for a nursery and poor health which makes the cutting of IF difficult.
Adopters cited lack of land (62%) and labor (61%) as the main constraints to the further expansion of the IF practice on their farms.

6. Discussion and Conclusions

An adoption rate of 75% of testers of the technology confirms that IF are a suitable practice under the given biophysical and socioeconomic boundary conditions in the study area. Hence, the title question whether 'initial testers adopt the technology' can be

answered positively.
An average adoption intensity of 42% is also an encouraging result but land and/or labor availability constrain further expansion of the practice.
The adoption of IF (Y) is positively influenced by good accessibility of the village, and sufficient land and labor resources. A non-linear relationship was found between wealth status and the adoption of IF: Adoption is highest (93%) for 'fairly well-off' farmers with ample land resources but limited alternative options to restore soil fertility.
Only 59% of 'very poor' and 'well-off' farmers adopted IF: Due to their small farms, very poor farmers may not be able to take any land out of production, and the risk of bushfire or pests destroying IF may also deter them from using the technology.
Well-off farmers have more profitable options of soil fertility maintenance, such as the use of mineral fertilizer and kraal manure.
The intensity of adoption (IA) is positively influenced by an edaphic environment which is conducive to the biophysical performance of IF species. Furthermore, the IA depends on per capita land endowment which determines the share of land that can be fallowed whilst still ensuring sufficient production. A similar non-linear relationship as above for Y was also found between wealth status and IA, the only difference being that *if* very poor farmers decide to adopt the technology, they practice it at a considerable scale.
Older farmers and female heads of household practice IF at a smaller scale, which may be due to higher risk aversion or physical constraints to the cutting of large IF plots.
Increased yields of post-fallow crops are viewed as the primary benefit derived from IF, and most farmers also use them as a source of fuelwood.
The sale of tree seed to ICRAF or World Vision was also mentioned as a major benefit derived from the technology, and some farmers seem to view IF as a lucrative cash crop rather than a means of restoring soil fertility on their farms.
Increased maize yields due to the IF practice allow farmers to sell some of the additional maize produced, or enable them to reduce the area dedicated to maize and grow more profitable cash crops instead. Thus, apart from enhancing maize consumption, IF also lead to increased cash income of small-scale farmers.
The following recommendations for research and extension are derived from the above conclusions:

Research

Since lack of labor for planting and weeding of IF is a serious constraint which affects both the adoption and expansion of the technology, further research should emphasize species which can be direct-seeded, or coppicing species. The same can be said for intercropping which reduces both land and labor requirements. Since these labor- and land-saving options lead to a less pronounced impact on subsequent crop yields, an economic analysis is crucial to assess their profitability.

Extension

- 'Well-off' farmers should certainly not be a high priority group regarding extension activities. Other options of soil fertility maintenance such as manure and mineral fertilizer are available to them, therefore both the adoption rate and the adoption intensity of IF are comparatively low among this group.
  The 'fairly well-off' stratum eagerly adopt IF. Hence, extension workers need not invest a lot of time and effort in encouraging this group to test IF.
  The lion's share of extension efforts should thus be directed towards resource-poor farmers. Although their adoption rate is *relatively* low, it still proves that there are no barriers completely preventing this group from using the technology. And, once they have decided to plant IF, they practice the technology at a considerable scale.

- Care should be taken not to neglect the monitoring of IF testers in more remote villages. If their first IF fails and they do not receive any project support and encouragement they easily drop the technology again.
- Extension staff should emphasize the importance of harvesting IF seed for the purpose of *replanting*. Only if farmers obtain their own planting material, the use of IF can be a sustainable means of soil fertility restoration.

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