



# Potential for Agroforestry Adoption in Southern Africa: A comparative study of improved fallow and green manure adoption in Malawi, Zambia and Zimbabwe

## Research

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## Abstract

This paper summarizes the findings of three ex-ante studies, from Malawi, Zimbabwe and Zambia, that examined the potential for adoption of agroforestry technologies should they be extended to farmers. Ethnographic linear programme modelling of households in all three locations shows that the potential adoption of these technologies depends on household composition, farm size, and availability of draft power. Results show that both male and female headed households can adopt the technology. A seed selling incentive enhanced adoption through augmenting household income and benefited farmers by increasing funds available for discretionary use. In Zimbabwe there was a greater increase in discretionary cash for draft animal owners than non-owners. It is concluded that in Southern Africa, improved fallows are a viable alternative to chemical fertilizer use for small farmers.

## Introduction

The major challenges facing most governments in Southern Africa today are to improve food security, income levels, and the standard of living of their population, particularly smallholder farmers. The smallholder sector is characterized by limited resources and limited income within a framework of declining soil fertility, which has resulted in increasingly poor agricultural productivity. Continuous cropping has depleted the soil of nutrients and made it harder for farmers to produce enough to sustain themselves for an entire year. Most of these smallholder households operate complex systems in which farming is supplemented with non-farming activities.

Due to the problems faced by most people in the region for the past two decades, the focus of development workers in Southern Africa, and internationally, has been on economic development, with a particular emphasis on

food security. A person is considered food secure if he or she has the "physical and economic access to an adequate food supply without undue risk of losing such access" (Thomson & Metz 1997).

Trees and shrubs play a vital role in maintaining ecological balance in farming systems and improving the livelihood of people in sub-Saharan Africa. For example, the **miombo** woodlands of the southern Africa eco-region have been used for time immemorial by people living in them or in proximity to them. The woodlands serve as the main reservoir for medicinal plants and yield many non-timber forest products (NTFPs) that contribute to the livelihoods of the majority of rural families and communities. Other benefits that **miombo** woodlands have provided for a long time to local communities include food (in the form of leaves, fruits, roots and honey), and wood energy. Importantly, the **miombo** have been a major watershed in the southern Africa region. However due to population increase and the accompanying agricultural expansion, many **miombo** woodlands have been converted into ar-

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able lands. Today, traditional practices of maintaining soil fertility, e.g., shifting cultivation, are no longer practiced in many parts of the eco-region and hence the challenge to increased agricultural productivity and achievement of food security in the region.

In order to combat food insecurity, one research focus has been on improving present farm management and soil fertility practices in order to increase agricultural yields. Farmers' ability to use chemical fertilizer has declined since governments liberalized the marketing of agricultural inputs: in 1991 in Zimbabwe (Mudhara 2002); 1994 in Malawi and in Zambia (Zeller *et al.* 1998). One of the best alternatives for combating food insecurity is by improving maize yields, which is the major food crop and, in some cases, also a cash crop. To achieve this, research suggests the use of improved fallows in Southern Africa as a means to return nutrients to the soil in a short period of time, as is done with natural fallows (Franzel 1999, Kwesiga & Beniast 1998, Kwesiga *et al.* 1999, Sanchez 1995).

Short duration rotations of managed fallows make use of fast growing, nitrogen fixing trees. *Sesbania sesban* (L) Merr. (*Sesbania*), *Tephrosia vogelii* Hook.f. (*Tephrosia*), *Gliricidia sepium* (Jacq.) Kunth ex Walp. (*Gliricidia*), and *Cajanus cajan* (L.) Millsp. (pigeon pea) are some of the nitrogen-fixing species that have the biological potential to replenish soil fertility and thereby increase crop yields of subsequent crops. The improved fallow technology is being introduced to smallholder farmers in Malawi, Zambia, and Zimbabwe as a viable alternative to chemical fertilizer use. Specifically, farmers in Malawi have been testing *Sesbania* and *Tephrosia*, and of late *Gliricidia*. In addition to *Sesbania*, *Tephrosia* and *Gliricidia*, farmers in Zambia are testing pigeon peas. In Zimbabwe, *Sesbania* and pigeon pea fallows are being tested together with cowpea green manure. Each species has its own planting and maintenance requirements, and soil improving qualities. The likely differential adoption of these technologies among diverse households in the target areas in these countries however, is not known.

This paper summarizes the findings of studies conducted in 1) Kasungu in central Malawi, 2) the Eastern Province of Zambia, and 3) the Mangwende communal area of Zimbabwe to investigate the potential for improved fallow adoption by smallholder farmers. Specifically, these ex-ante studies examined the potential adoption of the technologies by different kinds of households when eventually extended to a large number of farmers and how outside factors, such as economic policies, may affect farmers' decisions to adopt improved fallow technologies. Presented here is a description about the similarities and differences of the three countries, the data and model methodology, adoption potential results and policy implications with recommendations.

### Country Comparison

In Zambia, more than 60% of the population derive their livelihood from agriculture and approximately 51% of those are rural, small-scale farmers cultivating, on average, five hectares or less (Saasa *et al.* 1999). In Malawi, about 85% of the population is rural and is dependent on agriculture. Agriculture represents over 35% of the GDP in Malawi, generates about 90% of export revenues, and employs more than 80% of the population. Generally, land holdings in Malawi are smaller than in Zambia and Zimbabwe, although Central Malawi, where the study was conducted, has relatively larger landholdings than the southern region. In 1987, average land holdings in Malawi were reported to be 0.5, 0.7 and 1.1 ha per farming family, respectively for the southern, central and northern regions (National Statistical Office (NSO), Malawi Government 1989).

In Zimbabwe, agriculture also plays an important role and provides employment and livelihood to approximately 70% of the population and raw materials for the majority of the country's manufactured goods. The sector is grouped into four major production sectors: the large scale commercial farming sector (LSCF), small-scale commercial sector (SSCF), communal areas (CAs) and resettlement areas (RAs). Before the land reform that began in 2000, most of the farmers in CAs, where the Zimbabwe study was conducted, had small land holdings and were located mainly in agro-ecological regions III to V (Vincent & Thomas (1965), where annual rainfall ranges from 450 mm to 800 mm. Production in these areas is mostly for subsistence. Table 1 shows significant differences and similarities in land resource endowment and other characteristics across the countries. Malawi is comparatively small, with 9.4 million hectares of available land, yet it has the highest population of 12 million. Zimbabwe has 38.7 million hectares of land with a population of 11.9 million. By contrast, Zambia, with 74.1 million hectares of land, has the largest land area with the smallest population of 9.8 million.

The main food crop in all three countries is rainfed maize. In Zambia, maize accounts for 80% of the area cultivated (Franzel 1999). Although there are differences in the contribution of agriculture to GDP in these countries, livelihood systems in the three countries are generally based upon rainfed agriculture. Total arable land in the Eastern Province of Zambia is about 3.8 million hectares with approximately 35% of this being utilized for agriculture (Jha & Hojjati 1993, Peterson 1999).

A common aspect of the smallholder farming systems is that the source of most labour comes directly from the household. In many cases, labour is the most limiting factor to increased crop production. In Zimbabwe, unlike Malawi and Zambia, many farmers own oxen and are capable of cultivating a larger field than is possible for hand cultivators. For activities when extra labor is required,

**Table 1.** Land and other comparisons in Malawi, Zambia and Zimbabwe.

Item	Malawi	Zambia	Zimbabwe
Total area (million ha)	11.8	75.3	39.1
Total water area (million ha)	2.4	1.2	0.4
Land (million ha)	9.4	74.1	38.7
Cultivable (million ha)	4.6	9.0	3.2*
Soil types	Sandy loams	Sandy loams	Sandy loams
Agriculture as % of GDP	35.0	16.0	16.0
Population (million)	12.0	9.8	11.9
Annual population increase (%)	2.0	3.5	3.1
Main food crops	Maize	Maize	Maize
Production system	Rainfed	Rainfed	Rainfed
Smallholders below poverty line (%)	>60.0	76.0	80.0

\* Note: The figures used are those before the fast track land reform in Zimbabwe.

such as weeding and harvesting, labor is hired or bartered for maize when household maize stocks are depleted. In some cases, farmer clubs and associations are another valuable source of labor.

## Methodology

### Study sites

The studies were conducted at one site in each country: Kasungu in Malawi, Chipata in the Eastern Province of Zambia, and Mangwende CA in Zimbabwe. The three sites have similar environmental and demographic characteristics (Table 2). Apart from the similarities of the Kasungu and Chipata sites, the areas have a common his-

tory in the introduction of improved fallows. In 1997, due to similarities in culture and land characteristics, the World Agroforestry Centre (ICRAF) facilitated an exchange program between Kasungu and Chipata farmers (Moyo 1999, Thangata 2002). Eighteen farmers from Malawi went to Zambia for hands-on training on the planting and management of improved fallows to benefit from the advanced stage in the testing of improved fallows in Chipata. Later, the Zambian farmers visited their counterparts as part of the ongoing collaboration.

In the areas of Eastern Zambia that were studied, Chipata South, Chipata North, and Katete, soil types are predominately loamy sands to "sandy Alfisols," clays and "loam luvisols," respectively (Franzel 1999). Loam luvisols are a

**Table 2.** Environmental, demographic and other characteristics of Kasungu (Malawi), Eastern Zambia, and Mangwende Communal Area (Zimbabwe).

Characteristic	Kasungu	Eastern Zambia	Mangwende Communal Area
Altitude (m)	1000–1400	900-1200	1000
Soils	Sandy ferrallitic	Loam sandy alfisols (ferrix lixisols)	Alfisols
Annual rainfall (mm)	700-1000	1000	800-1000
Wet season	Nov-Apr	Nov-Apr	Nov-Mar
Temperature (°C)	19-22	15-26	12-25
Growing period (days)	150-180	140-155	120-150
Dambos/Dimbas+	Yes	Yes	Yes
Persons/km <sup>2</sup> #	25	25-40	50

+Wetlands for winter cropping and vegetable production.

Sources: Kasungu data (Minae & Msuku 1988; Eastern Zambia data (ICRAF Annul Report, 1996); Mangwende Communal Area data (Mudhara 2002).

#The population density for Malawi in 1998 was 105 persons/km<sup>2</sup>. At the regional level, the Northern Region (46 persons/km<sup>2</sup>) was the least densely populated whereas the Southern Region (146 persons/km<sup>2</sup>) was the most densely populated followed by the Central Region with 113 persons/km<sup>2</sup> (National Statistical Office (NSO), Malawi Government 2000). The Kasungu population density is low compared to that of the whole country due to the fact that the area has many tobacco farms and the Kasungu National Park.

subgroup of sandy loam soils and are the dominant soils in Malawi as well. In Zimbabwe, the smallholder farming areas are located on sandy soil of low inherent fertility.

### ***Climate and temperature***

The general climate in Zambia is classified as tropical, modified by altitude with a rainy season from October to April. The Malawi climate is sub-tropical with a rainy season from November to May and a dry season from May to November. Zimbabwe has a sub-tropical climate, moderated by altitude; the rainy season is from November to March followed by a long dry season between April and October. Additional detail regarding the study sites, demographics, socioeconomic characteristics, and production activities are reported by Grier (2002), Mudhara (2002), and Thangata (2002).

The Eastern Province of Zambia is located between 10-15°S and 30-33°E. The climate is sub-tropical to tropical with a unimodal rainfall distribution. There are three seasons: the warm wet season from November to April, the cool dry season from April to July, and the hot dry season from August to October. Temperatures during the hot season range from 18-31°C and vary from 9-23°C in the cool dry season. During the rainy season, rainfall exceeds evapotranspiration and averages 800-1000 mm per year with about 85% of this amount falling from December to March. The length of the growing season is typically 140-155 days depending upon the amount of rain.

Kasungu District (Malawi) is located at 13°02'S and 33°38'E, lying at an altitude of 1342 m. The climate is tropical with a mean annual temperature of 19-22.5°C. Kasungu has a unimodal rainfall pattern similar to Chipata with the wet season running from November/December to March/April with erratic rains ranging from 700 to 1000 mm per year, and a prolonged dry season. There are no showers or drizzles during the cold months of June and July (Minae & Msuku 1988).

The Mangwende communal area (CA) is located about 80 kilometers northeast of Harare, the capital city of Zimbabwe. The CA lies between 17° and 18° S and between 31.5° and 32° E. The climate is sub-tropical characterized by a unimodal rainfall distribution. There are three dominant seasons: the warm wet season from November to March; the cool dry season from April to August; and the hot dry season from August to November. Temperatures during the hot season range from 12-25° C and vary from 9-23° C in the cool dry season.

### ***Data collection***

All three studies followed data collection methodology reported in Grier (2002), Mudhara (2002), and Thangata (2002). Data were gathered from farmers via personal interviews in order to understand the livelihood system of

the area and to be able to create a representative mathematical linear programming (LP) model of the system. With a model that adequately simulates the diverse livelihood strategies of individual households, it is possible to predict how improved fallows and other activities may affect the sustainability of the different households (over a five-year period for Zambia and Zimbabwe, and a 10 year period for Malawi). The question asked of the model is what combination of activities (the livelihood strategies of the diverse households) is best for improved food security and livelihood sustainability.

Data were collected in Zambia from May to August of 2000. A total of 36 farmers were interviewed. Out of the 36 households interviewed, 35 were analyzed representing 35 LP models. In Malawi 40 households were interviewed between September and December 1999 and again between June and August of 2001 representing 40 models. In Zimbabwe, data were collected between January and July 2001 through multiple-visit interviews from 99 randomly selected households, representing 99 models.

### ***Description of the ethnographic linear program models***

An ethnographic linear program (ELP) model attempts to simulate the livelihood system(s) of the communities being modelled. With the goal of maximizing or minimizing a particular objective, the model reflects the livelihood strategies of the individual households. Note that the livelihood system encompasses all the activities realistically available to the households to contribute to their livelihoods. The livelihood strategies encompass those activities selected by individual households. The solution is the best available alternative given the resource and other constraints along with the composition of the household. The ELP models in each of the studies were developed to simulate actual livelihoods and to evaluate the potential adoption of improved fallow and green manure technologies within the bounds of individual households. The objective of all the models was to maximize end of year cash available for discretionary spending after satisfying household consumption requirements and minimum cash needs and without exceeding any household constraints.

In the Malawi case, the model maximized the sum of ten years' end cash available for discretionary spending from a combination of activities after satisfying consumption and other necessary cash requirements. The Zambian and Zimbabwe models were for a five-year period. For the Malawi and Zambia data, ELP models were run with and without an improved fallow option to see how planting improved fallows affected year-end discretionary cash. Each country model included an improved fallow seed selling activity. In Zimbabwe, the selling activity was for pigeon pea. In Malawi, the option was to sell *Sesbania* and *Tephrosia* seeds, while in Zambia, on top of selling *Sesbania* and *Tephrosia* seeds, *Gliricidia* and pigeon pea seed sell-



ing were included as options. In addition to the improved fallows, the Zimbabwe models also evaluated the green manure technology. In all cases, maize could be produced either fertilized or non-fertilized, or following improved fallows.

Additionally, in the Malawi models, a borrowing activity was included such that, when needed, a household could borrow tobacco inputs and repay with interest at the end of the season. In the 2000/2001 season, the interest rate for loans was 55% on the principal.

The models were also constructed to allow cash to be transferred from one year to the next to be used for purchasing agricultural inputs after satisfying household requirements. An option to hire labour was also included. All the models from the three sites compared the differences in decision-making and adoption in female-headed households (FHH) to male-headed households (MHH).

## Results

### Potential adoption of improved fallows-Malawi

Results from the Malawi ELP models showed that without improved fallows, more land is planted to fertilized maize, and then groundnuts followed by tobacco. On average, the total land used per farm is less than a hectare in all years. Since all the maize produced is for home consumption, only tobacco and groundnuts are sold. A loan is taken in each year.

When improved fallows were introduced into the model, without the option to sell seed, all the maize came from

land previously planted to improved fallows, less land was planted to tobacco and there was no groundnut. Less tobacco sold resulted in no end of year discretionary income. Since cash from tobacco sales was used to pay back the loan, the household took a smaller loan compared to the no improved fallow scenario. This was due to the fact that cash was transferred for use in subsequent years and also because no fertilized maize was planted. Approximately one-half hectare more land was used than in the previous scenario without improved fallow.

When an option to sell improved fallow seed was introduced into the model, the model predicted more tobacco growing and there was an increase in the total land used. More land was planted to improved fallows than in the no seed selling option. Apart from selling improved fallow seeds, surplus maize, groundnuts, cassava and sweet potatoes were also marketed. These selling activities resulted in more discretionary cash at the end of each season. The marketing of more crops and products also resulted in no loan being taken. Using cash from the seed selling, some fertilized maize was produced and tobacco production increased to more than a half hectare.

When the option to sell seed from fallow species was introduced into the model, more tobacco growing was predicted and there was an increase in land planted to *Sesbania* and *Tephrosia* fallows (Table 3). Of the two improved fallows, more *Sesbania* was planted than *Tephrosia*. This was because *Sesbania* is a prolific seed producer. The higher price paid by ICRAF for *Sesbania* than *Tephrosia* seeds made adopting *Sesbania* a more attractive option due to the additional benefit from selling seed. Apart from selling improved fallow seeds, surplus maize, groundnuts,

**Table 3.** Importance of improved fallows and green manure (GM) studies in Zambia, Zimbabwe and Malawi farming systems.

With no seed selling			
Fallow Species	Country		
	Malawi	Zambia	Zimbabwe
<i>Sesbania</i>	Chosen	Not chosen	Preferred species
Pigeon pea	NA	Not chosen	Chosen if no <i>Sesbania</i> available
<i>Tephrosia</i>	Chosen	Not chosen	NA
<i>Gliricidia</i>	NA	Only species chosen	NA
With seed selling			
<i>Sesbania</i>	Preferred over <i>Tephrosia</i> ,	Preferred if farmer has <b>dimba</b>	Chosen
Pigeon pea	NA	Chosen if no <b>dimba</b>	Chosen
<i>Tephrosia</i>	Planted, but less than <b>Sesbania</b>	Chosen if no <b>dimba</b>	NA
<i>Gliricidia</i>	NA	Not chosen	NA
Cowpea GM	NA	NA	Preferred over any improved fallows

cassava and sweet potatoes were also marketed. Selling surplus produce resulted in more discretionary cash at the end of each season and no loan being taken.

#### **Potential adoption of improved fallows-Zambia**

As in the case of Malawi, a seed selling activity from the improved fallows was included. The ELP model was run on randomly selected households to see how a decrease in seed prices from improved fallow species would affect the decision to plant a particular species. In most cases, at full seed price and half of the seed price, *Tephrosia*, pigeon peas, or *Sesbania* were chosen as the best activity for year-end cash optimization. However, when the seed selling activity was removed, *Gliricidia* was then chosen as the best species to plant. This was due to the fact that *Gliricidia* has less labour requirements than the other fallows species (Table 3) though it does not yield as much seed as the other species and does not produce seed until the third year as opposed to the second year for the other species. In every case, an improved fallow activity was chosen, indicating that improved fallows can be a practical alternative to fertilizer use for small farmers in Eastern Zambia.

#### **Potential adoption of improved fallows-Zimbabwe**

In Zimbabwe the potential adoption of *Sesbania* and pigeon pea improved fallows depended on the composition of the household, farm size, and draft power (farmers with draft power also had access to cattle manure). Adoption of improved fallows increased household income for discretionary spending. The percentage increase in the incomes of households with more limited resources was greater than the better-endowed households.

When pigeon pea seed was not marketed, only *Sesbania* improved fallows were adopted. The adoption of *Sesbania* fallows was highest in the first year, declining in later years. In the first year, 81% of the households adopted one-year fallows. On average, households planted an aggregate of 1.2 ha to *Sesbania* fallows in the first four years of the model. From the second to the fifth year, maize on improved fallow occupied 0.6 ha, which was 60% of the maize area. Adoption of *Sesbania* improved fallows resulted in an increase in annual income for discretionary spending for owners and non-owners of draft power of 10% and 2%, respectively. Increased amounts of labour on the farm had a positive impact on income for discretionary spending. The income for households with one member working full time on the farm increased significantly following the introduction of *Sesbania* fallows.

When pigeon pea and *Sesbania* fallows were modelled together, pigeon peas were adopted only when there was potential to sell the pigeon pea seed. However, when modelled alone, without other fallows species, pigeon peas were adopted even without a market for the seed. In this

case, three quarters of the households adopted pigeon pea fallow. Households relied on one-year fallow and on average, planted 0.53 ha in the first year and 0.46 ha in the third year. Fallows of other durations were planted on 0.1 ha or less and the three-year fallow was not adopted.

#### **Potential adoption of cowpea green manure-Zimbabwe**

This was evaluated in the Zimbabwe study only. When cowpea green manure, *Sesbania* and pigeon pea fallows were available to farmers, only cowpea green manure was adopted in all years. Even when the price of pigeon pea seeds was increased to the equivalent of US\$90/ton, farmers only adopted cowpea green manure. The composition of the household, as reflected in the number of members working full time on the farm, determined the adoption and impact of green manure. Households with more members working full time on the farm and those with larger farms adopted more cowpea green manure. Non-owners of draft power planted more green manure than owners.

Even though the income for better-endowed households was higher than that of the less endowed households, the income of the less resource-endowed households increased by a higher percentage (28%) than that of the better-endowed households (22%).

#### **Gender difference in the adoption of improved fallows**

The gender of the household head plays an important role in the productivity of smallholder farming systems. Differences in the household's access to financial and commodity markets significantly influence cultivated land area, type of crops planted, and farm income. Females and males often face different cash, labour, and access to input constraints so it was important to see what species might be the most appropriate for particular household types. The ELP models therefore simulated two different types of household: female-headed (FHH) and male-headed (MHH). Table 4 summarizes the results from the three countries from this perspective.

In Malawi, without a seed selling activity FHHs adopted similar amounts of improved fallows as the MHHs. The MHH and the FHH planted similar amounts of tobacco and groundnuts. However, since tobacco requires male as well as female labour, the FHH hired male labour that must be fed daily, as well as paid at the end of the season. The hired labour resulted in the need to plant more maize. The need for cash for home use dictated that the FHH grew tobacco, which required a loan, and hired labour, which increased maize consumption requirements. Both the male and female households planted tobacco since it is their main source of cash income.

Table 4. Importance of improved fallow studies in Malawi, Zambia and Zimbabwe farming systems by gender

Country	Fallow Species	Results summary	
		Without seed selling	With seed selling
Malawi	<i>Sesbania</i> <i>Tephrosia</i>	<ul style="list-style-type: none"> <li>FHHs adopted similar amounts of improved fallows as the MHHs</li> <li>Like the MHH, the FHH planted similar amounts of tobacco and groundnuts.</li> </ul>	<ul style="list-style-type: none"> <li>MHH grew more tobacco, but without taking a loan.</li> <li>Increase in total land used, but a decrease in the total land planted to improved fallows.</li> <li>FHH planted more improved fallows</li> <li>FHH plant more <i>Sesbania</i> and <i>Tephrosia</i></li> </ul>
Zambia	<i>Sesbania</i> <i>Tephrosia</i> Pigeon pea <i>Gliricidia</i>	<ul style="list-style-type: none"> <li><i>Gliricidia</i> was chosen as the species to plant for cash optimization</li> <li><i>Sesbania</i> not chosen for FHHs</li> </ul>	<ul style="list-style-type: none"> <li><i>Tephrosia</i> or pigeon peas were chosen as the best species for FHHs</li> </ul>
Zimbabwe	<i>Sesbania</i> Pigeon pea	<ul style="list-style-type: none"> <li>No major differences between MHHs and FHHs in area planted to <i>Sesbania</i> fallows</li> <li>De facto FHHs received more income than de jure or MHHs</li> <li>MHHs planted more pigeon pea than FHHs</li> </ul>	<ul style="list-style-type: none"> <li>When both pigeon pea and <i>Sesbania</i> fallows were included at varying prices of pigeon pea seed, the area planted to pigeon pea fallows increased</li> </ul>

When an improved fallow seed-selling activity was introduced as an incentive to adopt the fallows, the MHH grew more tobacco, but without taking a loan. The cash from selling *Sesbania* and *Tephrosia* seeds resulted in the households having enough cash without the cost of the loans for their tobacco. There was an increase in the total land used, but a decrease in the total land planted to improved fallows. The MHH did not need to pay for hired labour costs, and therefore, produced maize, groundnuts, cassava, and sweet potato for sale to cover cash needs. The FHH put more land to improved fallows (0.85 ha in year 3). The FHH also planted more improved fallows than the MHH. The FHH, however, gradually reduced the total land planted to improved fallows from 0.85 ha in year 3 to 0.69 ha and 0.80 ha respectively in years 4 and 5. In years 7 and 8, the total improved fallow land was further reduced to 0.47 ha and 0.52 ha respectively. When an improved fallow seed-selling activity was introduced as an incentive to adopt the fallows, the MHH grew more tobacco, but without taking a loan. The cash from selling *Sesbania* and *Tephrosia* seeds resulted in the households having enough cash as they did not incur the cost of a loan for the tobacco. There was an increase in the total land used, but a decrease in the total land planted to improved fallows. The MHH did not need to pay for hired labour costs and, therefore, produced maize, groundnuts, cassava, and sweet potato for sale to cover cash needs. The FHH put more land to improved fallows (0.85 ha in year 3). The FHH also planted more improved fallows than the MHH. The FHH, however, gradually reduced the total land planted to improved fallows from 0.85 ha in year 3 to 0.69 ha and 0.80 ha respectively in years 4 and 5. In years 7

and 8, the total improved fallow land was further reduced to 0.47 ha and 0.52 ha respectively.

In the Zambia case, results showed that in most cases, *Tephrosia* or pigeon peas were chosen as the best species for FHHs. When the seed selling option was removed, *Gliricidia* was chosen as the species to plant. *Sesbania* was most likely not chosen for FHHs because the seedlings must be planted in a nursery before they can be planted in the field. Nurseries are usually located in the “*dimba*” area, and most women in the Eastern Province do not have “*dimba*” land. The seedlings also require greater care than the seedlings of the other improved fallow species.

In Zimbabwe, the area planted to *Sesbania* fallows across households with different gender of head of household was not significantly different. De facto FHHs received US\$64 more income for discretionary spending than de jure or MHHs. De facto female headed households are where the male head of household stays away from the home, but visits regularly, while in de jure female headed households the female is the only head. With pigeon pea fallows, there were no major differences between de facto and de jure FHHs in the area planted to pigeon pea fallows. MHHs planted 0.1 ha more pigeon pea improved fallows than either de facto or de jure FHHs. When both pigeon pea and *Sesbania* fallows were included in the ELP model at varying prices of pigeon pea seed, the area planted to pigeon pea fallows increased with the price of seed.

## Conclusions and Recommendations

This paper presented results from three studies conducted in southern Africa on the potential for adoption of soil fertility enhancement technologies. These studies sought to determine how the adoption of improved fallows or green manure technology as a livelihood strategy of different kinds of households may enhance maize cultivation of smallholder farmers. The improved fallows build on the traditional practice of leaving land with infertile soils uncultivated for a period of ten to twenty years allowing the natural vegetation to grow and to restore lost soil nutrients. The improved fallows were introduced to small farmers in Malawi, Zambia, and Zimbabwe to improve the soil fertility on their farms. The green manure technology was tested only in Zimbabwe.

Results from all three countries showed that when benefits from the improved fallows included seed selling, adoption was enhanced. A market for pigeon pea seed was needed for farmers to adopt pigeon pea improved fallow when both *Sesbania* and pigeon pea improved fallows were offered to farmers at the same time. However, in the case of Malawi, even with incentives the technology might not be adopted in areas like the southern region where land sizes are generally smaller.

The studies showed that in Malawi, adoption of improved fallows can happen in both male-headed households (MHHs) and female-headed households (FHHs), as long as land and labour are available. However, in Zambia, *Tephrosia* or pigeon peas were chosen as the best species for FHHs when there was an incentive to sell seed. Without the seed selling option, *Gliricidia* was chosen as the species to plant. Generally, *Sesbania* was the most unlikely to be chosen for FHHs because of greater labour and care requirements of the species. This was attributed to the fact that women in the area do not own "dimba" land where *Sesbania* nurseries are made and later the seedlings are transplanted to the field. This is different in Malawi as women do own "dimba" land where they are expected to plant vegetables or in some case take care of tobacco nurseries.

In Zimbabwe, adoption of the technologies was influenced by household size, farm size, and ownership of draft power. A one-year cowpea fallow gave the same yield as a two-year fallow when maize was planted in the subsequent year. One-year improved fallows were not modeled in the Malawi and Zambia studies where, unlike the Zimbabwe study, farmers were testing tree species and no farmers were observed planting one-year green manures. However, the coefficients used in the Zimbabwe study were from on-station trials and therefore might not be reproducible on farms.

Under current economic and social circumstances facing smallholder farm households in southern Africa, there is potential for improved fallow and green manure technologies to be adopted. From the results of these studies, it is therefore recommended that the improved fallow technology be extended to all smallholder farmers in the region. Before mass extension of these technologies organizations and field personnel should take into consideration household composition and other characteristics such as available labour, land, and cash.

The models presented in these studies have the potential of evaluating other technologies and policies intended for smallholder farmers with appropriate minor modifications.

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