Do input subsidies crowd *in* or crowd *out* other soil fertility management practices?
Evidence from Zambia

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Abstract

It is recognized that inorganic fertilizer, as is commonly distributed in large-scale input subsidy programs, must be used along with soil fertility management (SFM) practices in order to maximize its efficacy. We use nationally representative data with 8,839 household observations to assess the impact of the Zambian input subsidy program on the use of five SFM practices: (i) manure and/or compost application, (ii) soil erosion preventative measures, (iii) minimum tillage, (iv) rotations between cereals and legumes, and (v) leaving land fallow. We estimate at the household level the effect of subsidized fertilizer on probability of adoption of each practice using a maximum likelihood probit model and the effect on number of hectares under each practice with a maximum likelihood Tobit model. The endogeneity of fertilizer distribution is tested and controlled for using the control function approach. We find a small but positive statistically significant crowding *in* effect of receiving subsidized fertilizer on all SFM practices except for fallow land, where we report a statistically significant crowding *out* effect of larger magnitude than estimated for the other practices (a decrease in hectares equal to 11.3% of the unconditional mean hectares of fallow land per household).

1. Introduction

In an effort to catalyze an African Green Revolution, many of the region's governments currently devote a large share of their agricultural sector budgets to input subsidy programs (ISPs). Despite this heavy spending, program impacts on crop yields have been smaller than anticipated in several countries (Jayne and Rashid 2013). Inorganic fertilizer is one of the main inputs included in ISPs. In order to raise yields, inorganic fertilizer must be used in soils that have at least a minimum quality level, but severe soil degradation throughout the region is rendering inorganic fertilizers inefficient and, at times, almost completely ineffective (Marenya and Barrett 2009; Tittonell and Giller 2013). Despite the call for increased use of complementary soil fertility management practices to improve crop yield response to inorganic fertilizer (Jayne and Rashid 2013), there is little empirical evidence on ISPs' effects on the use of such practices.[1] One might expect receipt of subsidized inorganic fertilizer to "crowd in", or encourage, the use of such practices if farmers are aware of their complementarity. On the other hand, it is possible that fertilizer subsidies "crowd out", or discourage, the use of such practices due, *inter alia,* to increased labor required for fertilizer application or misconceptions that using inorganic fertilizer is sufficient to enhance soil fertility. Ultimately, whether ISPs crowd in or crowd out these practices is an empirical question, the answer to which has important implications for agricultural policy, national budgets, regional food supply, household income, and soil health for generations to come. If ISPs crowd out complementary soil fertility management (SFM) practices, it not only means these programs will themselves be less effective, but that the soils they are meant to bolster could in fact become less productive or non-responsive to future fertility management efforts as populations and demand for food rise (Tittonell and Giller 2013).

The study's main research question is does subsidized fertilizer crowd in or crowd out the use of SFM

[1] Two key exceptions are Holden and Lunduka (2012) and Vondolia, Eggert, and Stage (2012), both of which are discussed further below. Numerous studies examine the crowding in/out effects of ISPs on commercial input purchases (Xu et al. 2009; Ricker-Gilbert, Jayne and Chirwa 2011; Liverpool-Tasie 2014; Mason and Ricker-Gilbert 2013; Jayne et al. 2013; Mason and Jayne 2013; Takeshima, Nkonya and Deb 2012).

practices that have been shown to increase soil fertility and have the potential to increase crop yield response to inorganic fertilizer: (i) manure and/or compost application, (ii) soil erosion preventative measures, (iii) minimum tillage, (iv) rotations between cereals and legumes, and (v) leaving land fallow (Place et al. 2003; Bationo et al. 2007; Whalen et al. 2000; Vanlauwe et al. 2001). To answer this question, we use nationally representative cross sectional data from Zambia from the 2010/2011 agricultural year to estimate the effect of receiving subsidized fertilizer on a household's decision to use a given SFM practice on at least one of its fields (a binary decision). We also estimate the effect of the subsidized fertilizer on the number of hectares under that practice. These effects are estimated using probit and Tobit models, respectively. Given the non-random distribution of subsidized fertilizer, the kilograms received by a given household may be endogenous to its use of SFM practices. To test and control for this endogeneity in the context of non-linear models, we use the control function approach and the results of the last presidential election in the household's constituency as instrumental variables for subsidized fertilizer (following Mason and Jayne 2013). Zambia is an appropriate case study for the research question at hand due to the extensive history and reach of its input subsidy programs, the low maize yield response to inorganic fertilizer in the country (Burke 2012), and the wide promotion of soil fertility management practices, detailed below.

The study builds on previous work in a number of ways. First, it provides a useful comparison case to Holden and Lunduka (2012), who estimate the effects of Malawi's input subsidy program on farmers' use of organic manure. Their results suggest that access to subsidized fertilizer crowds in organic manure but that the effects are small in magnitude and statistically insignificant.[2] Moreover, Holden and Lunduka use data covering only six districts and 450 households in Malawi, whereas our data are nationally representative and cover 8,839 households. Second, our study is also a useful comparison case to Vondolia, Eggert and Stage (2012) who estimate the effects of fertilizer subsidies on farmers' investment in soil and water conservation in Ghana, but find no statistically significant effects thereon. Vondolia, Eggert, and Stage also rely on a small

[2] Kamau, Smale and Mutua (2013) find inorganic fertilizer and manure to be complements but do not explicitly estimate the effects of fertilizer subsidies on farmers' use of manure.

sample size of 460 households. Third, the current study goes beyond Holden and Lunduka (2012) and Vondolia, Eggert, and Stage (2012) by estimating the effects of fertilizer subsidies on a number of additional practices not previously examined (i.e., soil erosion preventative measures, minimum tillage, crop rotation, and leaving land fallow). Fourth and finally, to our knowledge, the current study is the first to estimate the effects of ISPs on the use of these soil fertility management practices in Zambia.

The remainder of the paper is organized as follows. Section 2 provides background information on the history of Zambia's input subsidy programs, and on SFM practices and their use in Zambia. Section 3 and 4 describe the methods and data, respectively, that we use to estimate the effect of subsidized fertilizer on SFM practices. In section 5 we report the results; section 6 summarizes the conclusions and policy implications of the results; and we end with section 7, indicating the next steps for this research.

2. Background

2.1 Agricultural Input Subsidies in Zambia

Since gaining independence, an input subsidy program has been integral to agricultural policy in Zambia. Initially, the government offered subsidized maize inputs to producers on credit, purchased maize from farmers at a pan-territorial and pan-seasonal price, and sold the maize to consumers at subsidized prices (Smale and Jayne 2003). Because the government lost money at each stage, the costly system was shut down during structural adjustment in the 1990s. Soon after, however, another country wide agricultural support program was established in 1997, and in 2002 a large-scale subsidy program was enacted, the Fertilizer Support Program (FSP). The program ran through 2007 and gave a uniform package of 400 kg of fertilizer and 20 kg of hybrid maize seed to farm households at 20-50% of the market price. In 2008, FSP was replaced with the present day Farmer Input Support Program (FISP). FISP aimed to serve twice as many households as FSP by reducing the package size by 50%, with each beneficiary farmer receiving 200 kg of fertilizer and 10 kg of hybrid maize seed. FISP's stated goals are "improving household and national food security, incomes, [and] accessibility to agricultural inputs by small-scale farmers through a subsidy" (MACO, 2008, p. 3).

In the 2010 budget year, the government of Zambia spent $117 million on the intended delivery of 178,000 MT of fertilizer to smallholder farmers at a subsidized rate of 76% under FISP (Mason, Jayne and Mofya-Mukuka 2013).[3] The program aimed to reach 891,500 farmers. In practice, during the 2010/2011 agricultural season, the program reached 30.0% of smallholder farmers, with each farmer receiving on average 259 kilograms of fertilizer (Mason, Jayne and Mofya-Mukuka 2013)). As shown in Table 1, households cultivating larger areas are both more likely to receive FISP fertilizer and get more kilograms of it, on average, than households cultivating smaller areas (columns D and E). Households cultivating larger areas are also less likely to fall below the poverty line (column C). Together, these results suggest that FISP fertilizer goes disproportionately to wealthier households. For further information on Zambian input subsidy programs, please see Mason, Jayne and Mofya-Mukuka (2013).

2.2 SFM Practices and Their Use in Zambia

As evidenced by the ISPs, the focus of agriculture in post-independence Zambia has been on promoting high input maize production. To increase the area under cultivation, there were additional credit and subsidy programs for tractors and plows (Haggblade and Tembo 2003). Consequently, soils in the early 1990s in Zambia were more acidic (due to the acidifying effects of inorganic fertilizer) and were compacted due to constant plowing, creating hard pans that make root and water filtration more difficult and soil erosion more likely (Haggblade and Tembo 2003). Many organizations, government institutions, and NGOs became concerned with finding sustainable production technologies (Haggblade and Tembo 2003). In the remainder of section 2.2, we begin by describing various SFM practices and programs to promote them in Zambia. We then present descriptive results on the extent to which smallholder farmers used the practices in the year of our analysis, 2010/2011, and how use of the practices varied between FISP fertilizer recipients and non-recipients that year.

[3] FISP accounted for 29.9% of total agricultural sector spending and 32.6% of agricultural sector Poverty Reduction Program spending in 2010. (Mason, Jayne and Mofya-Mukuka 2013)

Animal Manure and Plant Compost

Integrated Soil Fertility Management (ISFM) has been accepted by the science and development community as a set of principals to guide agricultural intensification (Vanlauwe and Giller 2006; Vanlauwe et al. 2012). It is defined as "a set of soil fertility management practices that necessarily include the use of fertilizer, organic inputs, and improved germplasm combined with the knowledge on how to adapt these practices to local conditions, aiming at maximizing agronomic use efficiency of the applied nutrients and improving crop productivity" (Vanlauwe et al. 2012). Using both inorganic and organic fertilizers, such as animal manure and plant compost, is advocated especially in the Sub-Saharan African context where both are scarce and inorganic fertilizer is expensive. Further advocacy for their combined use, however, lies in evidence that the two many be synergistic. Lab tests have shown that soil pH levels increased when cattle manure is applied, significantly increasing the availability of phosphorus and potassium by three to four times after an eight week incubation period (Whalen et al. 2000). In Zimbabwe, sandy soils responded to inorganic fertilizer with manure present when there was previously no response to inorganic fertilizer, suggesting that targeted application of organic and inorganic fertilizers together is "imperative for improving crop yields and nutrient use efficiencies" (Zingore et al. 2007). Incorporating residues from the leaves of leguminous trees in Nigeria have been found to reduce acidification resulting from chemical fertilizer. (Vanlauwe et al. 2005).

Soil Erosion Prevention

Land where slopes are steep or where there is little vegetation (which can be exacerbated when there is little or excessive rainfall, or caused by deforestation) are especially susceptible to soil erosion. 80% of Zambia has low soil erosion hazard, however it can be of concern in agro-ecological zone I (MTENR 2002). Various practices can prevent soil erosion, including bunding (i.e., low walls), terraces, drainage ditches, grass barriers, and contour farming.

Conservation Farming: Minimum Tillage, Crop Rotation, Crop Residues

In the mid-1980s, commercial and medium scale farmers in the Zambia National Farmers Union (ZNFU) brought the technology of minimum tillage back to Zambia after trips to Australia and the US. They used specially designed plows, known locally as Magoye rippers, to dig deep, thin furrows. This broke through the hard pan that was created from years of plowing to the same depth, but disturbed only 15% of the soil so that water that fell on the untilled ground would run off into the furrow where the plants would be growing. This type of minimal plowing, whether animal powered or mechanized, is known as "ripping". The ZNFU later established the Conservation Farming Unit (CFU) in 1995 to promote hand hoe minimum tillage for small-scale farmers, which consisted of digging deep basins in precise grids and placing fertilizer and seeds within those basins. This would ensure that, again, the pan was broken by the deeper digging and rainwater would run from the hard ground into the basins, but also that water, fertilizer, and seeds would be together in the concentrated basins, allowing the seeds to have easier access to the nutrients it requires than if all were scattered across the plot, as was common smallholder practice.

Crop rotation and leaving crop residue on the field were also both promoted. Crop rotation is the alternation of the crops cultivated on a field between a main crop (most often maize) and a nitrogen-fixing crop (i.e., legumes) from season to season or every few seasons. Residue retention involves leaving the remaining plant matter after harvest on the field, as opposed to burning it or feeding it to livestock, so that it can decompose and add to the organic matter in the soil. Minimum tillage, crop rotation, and residue retention are the three most common practices promoted under Conservation Farming (CF) in Zambia (also known as Conservation Agriculture in other countries)[4] (Haggblade and Tembo 2003; Kassam and Friedrich 2009).

CFU started conducting farmer trials in 1996 and has been promoting CF since, also holding trainings for government extension agents, the private sector (e.g., cotton growers) and NGOs. (Haggblade and Tembo 2003). CF has been promoted in seven provinces in Zambia: Eastern, Central, Lusaka and Southern Provinces

[4] CFU defines a farmer as a CF adopter if 20% of their fields converted to minimum tillage are occupied by legumes (personal communication, Peter Aagaard, May 2014).

in agro-ecological regions I and IIa; Northern, Luapula and Copperbelt Provinces in agro-ecological region III. (Baudron et al. 2007). See Figure I for a map of Zambia's agro-ecological regions.

Fallows

There are two types of fallow practices: "natural" and "improved". Planting a crop on land that is meant to add nitrogen and organic matter to the soil is an improved fallow whereas leaving land completely uncultivated to permit natural vegetation to grow is known as natural fallow. While leaving land under natural fallow does not add to soil nutrition, nutrients are not extracted from the soil as is the case when land is cultivated. In 1996, ICRAF and their partners began providing extension support and distributing seed for improved fallows in Eastern Province (Haggblade and Tembo 2003).

Government Programs

There have been two main government programs that have promoted CF practices: The Food Security Pack Program and the Agricultural Support Program.

The Food Security Pack Program is an additional input support program that has been in place since the 2000/2001 agricultural season. Unlike FISP or FSP, it is 100% a grant, as opposed to a subsidy, and the program is of much smaller size (aiming to reach 15,400 beneficiaries, or 1.7% of Food Security Pack and FISP intended beneficiaries combined in the 2010/2011 season (Mason, Jayne and Mofya-Mukuka 2013)) . The Food Security Pack Program provides inputs and extension services tailored to agro-ecological conditions. Included in the extension training is the promotion of CF and liming. Due to drastic funding cuts the Food Security Pack Program reached just 0.2% of smallholder households with subsidized fertilizer in 2010/2011 compared to 4.5% in 2002/2003 (Mason, Jayne and Mofya-Mukuka 2013).

From 2003-2008, the Swedish International Development Cooperation Agency (SIDA) funded the Agricultural Support Program (ASP), a program through the Ministry of Agriculture and Co-operatives (MACO). The overall goal of the program was to "contribute to poverty reduction by improving livelihoods of small-scale farmer households by improved food and nutrition security and increased income through the sale of agricultural-related products and services" (Sida 2010). One of the five areas of intervention was Land, Seed, Crops and Livestock Development, which included the promotion of CF (Tembo et al. 2007). The program was carried out in 20 districts, reaching a total of 44,000 beneficiaries.

Descriptive Results

As a prelude to the econometric results, Table 2 shows the percentage of smallholder households using each SFM practice studied here, as well as the mean area under the practice at household level. The results are further broken down by FISP fertilizer recipients vs. non-recipients. As shown, the number of households using the different SFM practices varies greatly across practices. In 2010/2011, crop rotation and soil erosion prevention methods were used by 40.7% and 20.0% of smallholder households, respectively. In contrast, despite the promotion of Conservation Farming in Zambia, only 1.8% of household have adopted[5] either ripping or basins to prepare their land in 2010/2011.[6] In all cases except for leaving land fallow, households that receive FISP fertilizer are statistically significantly more likely to use each SFM practice and use it on more hectares of their land than FISP non-recipients ($p<0.01$).

3. Methods

Conceptual model

To understand the impact of FISP on the use of these SFM practices, we use a household model to account for smallholder households' being both producers and consumers of goods. Due to labor, credit, and other market failures in Zambia, we assume that households' production and consumption decisions are made concurrently, and base our factor demand functions for households' use of SFM practices on a non-separable household model. Per Sadoulet and De Janvry (1995), a reduced form factor demand function derived from a

[5] We define *adoption* of a practice as *use* of practice (as opposed to *first time use* of a practice).

[6] These adoption rates, which are based on the nationally-representative Rural Agricultural Livelihoods Survey (RALS, discussed further in section 4), are lower than those reported in previous studies such as Haggblade and Tembo (2003) and CFU (2013). Two likely reasons are that: (i) the latter two studies are not based on nationally-representative samples (but reflect adoption rates for areas with higher levels of adoption), and (ii) high levels of ripping and basins adoption tend to be found in concentrated areas, and sampling for RALS was not explicitly designed to capture such patterns of adoption (thus the RALS results may underestimate adoption rates at national level).

non-separable household model is a function of production side variables such as the prices of inputs (e.g., seed, fertilizer, and labor), the expected prices of outputs (e.g., the expected producer price of maize), and exogenous factors and household characteristics that affect production (e.g., agro-ecological characteristics and quasi-fixed factors of production such as farm assets). In the non-separable case, factor demand functions are also a function of consumer side variables such as household characteristics that affect consumption. In the case of credit market failures, variables proxying for the credit constraint also appear as arguments in the factor demand function (Sadoulet and De Janvry 1995).

Applying this general conceptual framework to the case of SFM practices, we specify use of (demand for) a given SFM practice (y) as:

$$y = y(fisp, \boldsymbol{p\_outputs}, \boldsymbol{p\_inputs}, \boldsymbol{aez}, \boldsymbol{assets}, \boldsymbol{hh}, \boldsymbol{z}) \quad (1)$$

where $fisp$ is the kilograms of subsidized fertilizer received by the household, $\boldsymbol{p\_outputs}$ is a vector of expected crop prices at the next harvest, $\boldsymbol{p\_inputs}$ is a vector of input prices including the price of agricultural labor, $\boldsymbol{aez}$ is a vector of agro-ecological and physical conditions, $\boldsymbol{assets}$ is a vector of farm assets, $\boldsymbol{hh}$ is a vector of other household socioeconomic characteristics affecting production and/or consumption decisions, and $\boldsymbol{z}$ are all other factors that may shift use of the SFM practice. Previous studies indicate that agro-ecological factors, asset ownership, and household socioeconomic characteristics (among other factors) affect technology adoption in general and several of the practices examined in this paper in particular (Feder and Umali 1993; Feder, Just and Zilberman 1985). For example, minimum tillage is commonly promoted and may be more likely to be adopted in low rainfall areas due to its enhanced water infiltration and retention effects (Haggblade and Tembo 2003). Livestock ownership has been found to positively affect manure usage (Holden and Lunduka 2012). Educational attainment and household composition have also been shown to be significant factors affecting adoption of technologies, as they can affect the household's understanding of the benefits to the practices and the labor supply, respectively (Arslan et al. 2013; Feder and Umali 1993)

Empirical Model

Kilograms of FISP fertilizer received by the household ($fisp$) is the key explanatory variable of interest in this study. We estimate the effect of FISP on adoption of SFM practices in two ways for each practice. First, we estimate adoption as a binary variable, indicating the choice of the household to adopt the practice at all (=1 if at least one of the household's fields is under the SFM practice, =0 if none of household's fields are under the practice). Second, following Feder and Umali (1993), we estimate adoption intensity as a continuous variable of the area (ha) of land under the practice.

To estimate these effects, we use the following general model specification:

$$y_i = \beta_0 + \beta_1 fisp_i + \beta_2 pmaize_i + \boldsymbol{p\_inputs_i \beta_3} + \boldsymbol{aez_j \beta_4} + \boldsymbol{assets_i \beta_5} + \boldsymbol{hh_i \beta_6} + \boldsymbol{z_i \beta_7} + u_i \quad (2)$$

where i indexes the household, j indexes areas that the household falls within (i.e., agro-ecological zones), u_i is the error term (discussed further below), the $\beta's$ are parameters to be estimated. We consider five soil fertility management practices, or y variables: 1. Manure and/or compost (combined into one question in the survey), 2. Soil erosion and/or flash flooding prevention measures (also combined in the survey), 3. Minimum tillage (use of planting basins and/or ripping), 4. Crop rotation (which we define as rotating between a cereal and legume at least once between the 2009/2010 and 2010/2011 seasons and/or between the 2010/2011 and 2011/2012 seasons), and 5. Leaving land fallow (pooling natural and improved fallows, which were combined in the survey).

The explanatory variables are defined as follows: $fisp_i$, as mentioned above, is the kilograms of subisidized fertilizer the household received through FISP. (We use this, rather than an indicator variable of having received FISP fertilizer or not, due to many households receiving more or less than the intended 200 kilograms. See Table 1.) $pmaize_i$ are the district level maize producer prices from the 2010 harvest (which we are using as a proxy for a farmer's expected output prices at the 2011 harvest).[7] $\boldsymbol{p\_inputs_i}$ is a vector of

[7] In future analyses, we plan to control for other expected crop prices such as bean, groundnuts, and sweet potato – the commonly marketed crops in Zambia.

input price variables: district median for manual hired labor wages for both land preparation and weeding and farm gate prices of basal and top dress fertilizer. $\boldsymbol{aez_j}$ is a vector of variables inclusive of the agro-ecological zone and three rainfall variables using data at the standard enumeration area (SEA)[8] level for the growing season months of November to March for years 1983/1984 through 2009/2010: mean growing season rainfall (mm), mean moisture stress (number of 20 day periods with less than 40 mm of rain), and coefficients of variation (CV) of growing season rainfall*100. $\boldsymbol{assets_i}$ is a vector of the household's farm assets including total land holding size (ha), share of tenured hectares of total land, number of cattle owned, and the household's Tropical Livestock Unit (TLU) score for pigs, sheep, goats, and donkeys.[9] $\boldsymbol{hh_i}$ is a vector of the following socioeconomic characteristics affecting household production and/or consumption decisions: female headed household (an indicator variable), age of head of household, education level of household head, number of household members in specified age brackets, and share of households in the SEA that received advice on conservation farming. Lastly, $\boldsymbol{z_i}$ incorporates other factors that may affect adoption, including: household distances in kilometers from a market, agrodealer, commercial fertilizer retailer, and a tarmac road; cellphone ownership (an indicator variable); village's access to credit (percent of households in the SEA who reported that village members could access a loan); district level participation in the Agricultural Support Program (ASP), and indicator variables for each province to control for provincial variation. See Table A1 in the appendix for summary statistics of explanatory variables.

Estimation Strategy

Our goal is to estimate the average partial effect (APE) of kilograms of FISP fertilizer on the various SFM practices. If the APE of FISP fertilizer is positive (negative) and statistically significant in the equation for a given SFM practice, then this suggests that FISP fertilizer crowds in (out) the SFM practice. We estimate the binary choice to use a given practice or not by using a maximum likelihood probit model of the form $P(y_i =$

[8] SEAs typically contain 150-200 households or two to four villages.

[9] The household's animals are weighted and then summed to create the TLU score. Sheep, goats, pigs, and donkeys are included and receive the following weights: sheep and goats=0.1, pigs=0.2, donkeys=0.5.

$1|\boldsymbol{x_i}) = \Phi(\boldsymbol{x_i}\boldsymbol{\beta})$, where $\boldsymbol{x_i}$ are all the explanatory variables on the right hand side of equation 2. For all of the practices, the majority of the households do not adopt the practice on any of their fields; therefore the continuous variable of hectares under each practice will be corner solutions (i.e., there are a large proportion of zeros). We therefore use a Tobit model $y_i = \max(0, \boldsymbol{x_i}\boldsymbol{\beta} + u_i)$ with the assumption $u_i|\, \boldsymbol{x_i} \sim Normal\ (0, \sigma^2)$ and maximum likelihood to estimate these effects.

Given the non-random distribution of subsidized fertilizer, the kilograms received by a given household may be endogenous to its use of other soil fertility management practices. To test and control for this endogeneity in the context of non-linear models, we follow Mason and Jayne (2013) and use the control function approach (CFA) (Wooldridge 2010) and the results of the last presidential election in the household's constituency to construct three instrumental variables (IVs) for subsidized fertilizer: 1. an indicator variable =1 if the ruling party won the household's constituency during the last election, 2. a variable for the percentage point spread between the winner and closest rival in the constituency, and 3. the interaction term of the previous two variables. To be valid IVs, the variables must be (i) significantly correlated with the endogenous variable (kilograms of FISP received by the household) and (ii) not be correlated with the error term in the structural equation (equation 2).

To use the CFA, we estimate the reduced form Tobit equation for kilograms of FISP with the explanatory variables from the structural model equation (2) and the three IVs mentioned above. The generalized residuals are predicted and then inserted back into the structural model as an additional explanatory variable (Wooldridge 2010; Wooldridge 2013). If the residuals are statistically significant at the 10% level or lower, we reject the null hypothesis that FISP is exogenous and at the same time are able to control for the endogeneity of FISP by the inclusion of the generalized residuals. The residuals are generated from a first stage regression, therefore the standard errors for the structural models are obtained via bootstrapping to account for the first stage estimation (Woodridge 2010). If the residuals are not statistically significant at the 10% level or lower, then we fail to reject the exogeneity of FISP and the residuals can subsequently be excluded.

Like Mason and Jayne (2013), we find households in constituencies won by the ruling party receive significantly more FISP fertilizer, other factors constant. Moreover, households in constituencies won by the ruling party by a larger margin receive more FISP fertilizer than households in constituencies won by the ruling party by a smaller margin. These results are statistically significant in the reduced form Tobit model at a 5% and 1% level, respectively (see Table 3). Because they are below the 10% significance level, they satisfy condition (i) of a valid IV. (The correlation could be due to the current party using FISP as a reward for the constituencies that voted them into office.[10]) Regarding condition (ii), we do not expect the results of the presidential elections to affect a household's decision to adopt the soil fertility management practices, so we maintain that the IVs should be uncorrelated with the error term, u_i.

4. Data

We draw on data from the Rural Agricultural Livelihoods Survey (RALS), a nationally representative survey of smallholder farm households, with 8,839 observations across the country's 74 districts. The survey was conducted in June of 2012, by the Zambian Central Statistical Office (CSO), the Zambian Ministry of Agriculture and Livestock (MAL), and the Indaba Agricultural Policy Research Institute (IAPRI). The survey gathered information on the 2010/2011 agricultural year (October 2010-September 2011) and the 2011/2012 crop marketing year (May 2011-April 2012).

To supplement the RALS data, we obtain maize prices and wages for land preparation and weeding from the 2010/2011 Zambian CSO/MACO Crop Forecast Survey. Rainfall data comes Tropical Applications of Meteorology using SATellite data (TAMSAT) (Tarnavsky et al. 2013; Maidment et al. 2013; Grimes, Pardo-Igúzquiza, and Bonifacio 1999; Milford and Dugdale 1990). Only rainfall data up to the season prior to the agricultural season captured in the survey could affect decisions made by the farmer during that agricultural season, 2010/2011. Therefore, we use rainfall data from the 1983/1984 season through to the 2009/2010

[10] See Mason, Jayne, and van de Walle (2013) for a more detailed discussion of the political economy of FISP.

seasons. Lastly, we use constituency-level data from the Electoral Commission of Zambia on the percentage of votes won by the Movement for Multiparty Democracy (MMD) and opposition parties during the presidential election in 2008, the last presidential election before the 2010/2011 agricultural season.

5. Results

To begin this section, we describe the determinants of kilograms of FISP fertilizer received, and then discuss the estimated effect of subsidized fertilizer on the adoption of each SFM practice. Table 3 shows the results of the reduced form Tobit, regressing kilograms of FISP received on our other exogenous explanatory variables. We find similar results to Mason, Jayne and Mofya-Mukuka (2013) in that although FISP purportedly aims to reduce poverty, the quantity of subsidized fertilizer received is positively and significantly affected by factors such as land holding size, education level, and livestock ownership. For example, compared with households whose heads have completed no formal education, those with household heads that have completed some post-secondary education receive 86.3 kg more FISP fertilizer on average, other factors constant. Essentially, wealthier and more educated households receive significantly more FISP fertilizer on average, *ceteris paribus.*

Manure/Compost

We find a small, positively statistically significant FISP fertilizer effect on farmers' use of manure and/or compost on their land (Table 4). When testing for endogeneity of kilograms of FISP for both the probit and Tobit estimators, the reduced form Tobit residuals proved to be significant before standard errors were adjusted for the residuals being generated regressors. When bootstrapping was used, the residuals were no longer significant (the residuals for the probit had a p-value of 0.382 and those for the Tobit had a p-value of 0.322), therefore we report the standard probit and Tobit results. In both cases, FISP has a positive, significant effect on manure/compost use, albeit very small (100 more kg of FISP increases the probability of applying manure/compost by 0.3 percentage points (at a 5% significance level) and the hectares with manure/compost by 0.0053 hectares (at a 5% significance level)). As reported in section 2, the unconditional probability of all households using manure/compost is 7.1%. An increase in the probability of adoption of 0.363% is a 5.1% increase from that unconditional probability.

In comparison, Holden and Lunduka (2010) find that a 1% increase in fertilizer use intensity is associated with a 0.62% increase in manure use on all crop plots with the Malawian subsidy program, but find that it is not statistically significant.

Soil Erosion Prevention

An increase in the kilogram of FISP fertilizer received has a positive and statistically significant effect on both the decision to use soil erosion prevention measures and the area of land on which the measures were employed (See Table 5. When testing for endogeneity for both the probit and Tobit models, the residuals were not significant, with p-values of 0.843 and 0.639, respectively. Therefore we report the standard probit and Tobit results). The effect is small in magnitude for both: on average and holding other factors constant, a 100 kg increase in FISP fertilizer raises the probability of adoption by 0.4 percentage points (at a 10% significance level) and increases the amount of land with the measures by 0.01 hectares (at a 5% significance level). Recall that 20.0% of smallholder households use soil prevention methods, so a 0.418 percentage point increase from the mean represents a 2.1% increase in the unconditional probability of using soil erosion prevention measures (Table 2).

Minimum Tillage

For the minimum tillage practices of planting basins or ripping, an increase in FISP fertilizer again has a statistically significant and positive effect, but the effect is small in magnitude (See Table 6. The residuals were significant when testing for endogeneity, but after bootstrapping they were no longer significant with a p-value for the probit model =0.793 and the p-value for Tobit =0.717. Therefore we include standard probit and Tobit results). The results suggest that 100 more kg of FISP fertilizer increases the probability of using minimum tillage by 0.131 percentage points (at a 5% significance level) and area under the practice by 0.002

hectares (at a 5% significance level) on average, *ceteris paribus*. Recall that only 1.8% of the smallholder households in our sample use minimum tillage so although a 0.131 percentage point increase in the probability of adoption of minimum tillage is small in absolute terms, it is a 7.3% increase over the current unconditional probability of using minimum tillage (1.8%).

Crop Rotation

An increase in the kilogram of FISP fertilizer received does not have a statistically significant effect on a household's probability of practicing cereal-legume crop rotation but it does have a positive and statistically significant effect on the area of fields under cereal-legume crop rotation. (See Table 7. The residuals were significant when testing for endogeneity in the probit model therefore bootstrapped results are reported. Standard results are reported for the Tobit model, as the test for endogeneity estimated the residuals to be insignificant with a p-value of 0.563.) The number of hectares farmers rotate increases by 0.016 hectares per 100 kg of subsidized fertilizer received (at 5% significance level) on average, other factors constant. This is a 4.9% increase over the unconditional mean hectares currently under cereal-legume rotations (0.325 ha).

Fallow

Similar to the findings of Mason, Jayne and Mofya-Mukuka (2013), FISP fertilizer has a statistically significant, negative effect on farmers leaving land fallow. (See Table 8. We report standard results as the residuals in the test for endogeneity for both probit and Tobit models were insignificant with p-values of 0.484 and 0.408, respectively.) Receiving 100 kg of subsidized fertilizer decreases the probability of the household leaving a field fallow by 1.83 percentage points (at a 1% significance level) and the hectares left fallow decrease by 0.046 (also at a 1% significance level) on average, *ceteris paribus.* This is a 6.2% decrease in probability of leaving land fallow from the unconditional probability of adoption of 29.7% and an 11.2% decrease from the unconditional mean hectares of fallow land in 2010/2011. This is by far the strongest effect found amongst all the SFM practices.

6. Conclusions and Policy Implications

Agricultural input subsidy programs are prolific throughout sub-Saharan Africa. Because this is unlikely to change soon (Jayne and Rashid 2013), it is important to understand the impact of ISPs on practices that are complementary to inorganic fertilizer use and beneficial for farmer's soils. Our results suggest that receiving subsidized fertilizer has a statistically significant crowding in effect on the use of manure/compost, soil erosion prevention, and minimum tillage. The FISP fertilizer effect on the decision to rotate crops on at least one of the household's fields is statistically insignificant, while its effect on the number of hectares under crop rotation is statistically significant and positive. Where the effects are statistically significant, however, they are very small in magnitude, ranging from an effect on probability of adoption of only 2.1% to 7.3% on average given a 100-kg increase in FISP fertilizer. As an exception to the other SFM practices, we find that FISP fertilizer *crowds out* fallow land, at a high significance level and with a larger magnitude than we find in the other practices.

To compare our results to the current literature on the crowding in and out of effects of ISPs on SFM practices, Holden and Lunduka (2011) find a positive but insignificant correlation between increased subsidized fertilizer and manure usage on all crop plots. Vondolia, Eggert, and Stage find the same effects of input subsidies on soil and water conservation in Ghana. Therefore, aside from the crowding out effects on fallow land, our findings that subsidized fertilizer has no statistically significant effect or positive but very small in magnitude effect on smallholders' use of SFM practices are generally consistent with previous findings in the literature.

It is encouraging that ISPs appear to have a neutral to slightly positive impact on most SFM practices, as this suggests that there are not negative externalities to the program's effect on soil health via the retraction of these practices. However, more research is needed to understand the impacts of decreasing fallow lands in Zambia and whether the benefits to the farmer from the subsidized seed and fertilizer outweigh the long-term potential costs of cultivating in previously fallow land. Further research is also needed to understand which type of fallow is being crowded out. Leaving land naturally fallow increases water retention (Sileshi et al. 2005) but improved fallows have a greater effect on increased soil quality and maize yields in Zambia (Sileshi et al. 2005; Barrios et al. 1997). Using the RALS data, we cannot disaggregate the data results to understand which type of fallow is being crowded out. This must be considered when estimating the extent of the impact of decreased fallows on soil quality.

Due to the complementarities between SFM practices and inorganic fertilizer, a crowding in effect of FISP of greater magnitude would increase the impact of FISP on farmer yields and therefore food security and income. Options to be explored could be incorporating SFM practices into the FISP program by way of extension efforts (e.g., trainings and demo plots), a requirement to use SFM practices in order to receive the subsidies, or desired goods distributed to those who incorporated SFM practices as an incentive mechanism.

7. Next Steps for Our Research

Future versions of this study will include the following additions: 1. a panel analysis using data from the nationally representative Supplemental Surveys collected in three waves for the 1999/2000, 2002/2003, and 2006/2007 agricultural seasons in Zambia; 2. analysis using a double hurdle model; 3. analysis of FISP on the share of household's land under each practice; 4. analysis of probability of adoption at plot level (as opposed to household level); 5. results for the effect of FISP on the SFM practice of leaving crop residue in the field; and 6. inclusion of additional explanatory variables, including other major crops' prices, population density, slope of the land, nutrient availability (i.e., soil texture, soil organic carbon, soil pH, total exchangeable bases), nutrient retention capacity (i.e., soil organic carbon, soil texture, base saturation, cation exchange capacity of soil and of clay fraction), and distance from home to the field.

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Tables & Figure

Table 1: Distribution of FISP by Crop Area Cultivated in Agricultural Year 2010/2011

Total area cultivated by HH	# of HHs (A)	% of total HH (B)	% of total smallholders below the poverty line* (C)	Mean kg of FISP fertilizer received per beneficiary HH (D)	% of HHs in category that received FISP fertilizer (E)	% of total FISP fertilizer acquired (F)
0-0.49 ha	241,289	17.0	17.7	161	7.2	2.5
0.5-0.99 ha	334,200	23.6	26.0	190	22.5	13.0
1-1.99 ha	452,364	31.9	34.1	225	32.1	29.7
2-4.99 ha	333,910	23.5	20.5	286	47.2	41.0
5-9.99 ha	47,076	3.3	1.7	458	54.5	10.7
10-20 ha	9,153	0.6	0.1	766	50.0	3.2
Total	1,417,992	100.0	100	259	30.0	100

Notes: *Based on US$1.25/capita/day poverty line, calculated using household income during the 2011–2012 maize marketing year and the 2005 PPP exchange rate (inflated to the 2011–2012 marketing year).

HH= Household

Source: Mason, Jayne and Mofya-Mukuka (2013)

Table 2: Descriptive Statistics: Use of SFM Practices Among FISP Fertilizer Recipients & Non-recipients

Practice	All HH	HHs that received FISP fertilizer	HHs that did not receive FISP fertilizer	P-value (test difference between FISP fertilizer recipients and non-recipients=0
Area cultivated (total ha)	1.609	2.223	1.346	0.000***
Erosion prevention (% of HHs using practice)	20.0%	24.9%	17.8%	0.000***
Erosion prevention (mean ha under practice)	0.311	0.474	0.239	0.000***
Manure/Compost (% of HHs using practice)	7.1%	9.9%	5.9%	0.000***
Manure/Compost (mean ha under practice)	0.099	0.162	0.072	0.000***
Minimum Tillage (% of HHs using practice)	1.8%	2.5%	1.4%	0.005***
Minimum Tillage (mean ha under practice)	0.020	0.036	0.013	0.000***
Crop Rotation (% of HHs using practice)	40.7%	55.0%	34.3%	0.000***
Crop Rotation (mean ha under practice)	0.325	0.512	0.241	0.000***
Fallow Land (% of HHs using practice)	29.7%	29.1%	30.0%	0.535
Fallow Land (mean ha under practice)	0.408	0.455	0.388	0.140

Notes: HH=Household.

***Indicates P-value significance level of 1%

Source: Authors' calculations based on the CSO/MAL/IAPRI 2012 Rural Agricultural Livelihoods Survey.

Table 3. Reduced Form Tobit of Dependent Variable: Factors affecting kg of FISP fertilizer received by the HH

	Dependent variable: Kilograms of FISP fertilizer received by the HH		
Explanatory Variables	APE		P-Value
IV: =1 if ruling party won constituency in last pres. election	23.541	**	0.017
IV: % point margin btwn current pres. & lead opposition	-0.012		0.945
IV: Interaction effect of ruling party indicator x % point margin	1.233	***	0.000
Km from HH to nearest tarred road	0.062		0.458
Km from HH to nearest private fertilizer dealer	-0.110		0.275
Km from HH to nearest market	0.101		0.298
Km from HH to nearest agrodealer	-0.036		0.683
=1 if HH owns cell phone	44.231	***	0.000
CV of growing season rain (%)	-13.207	***	0.007
Mean moisture stress (20-day periods w/ <40 mm rain, Nov-Mar)	184.517	***	0.006
Mean growing season rainfall (Nov-Mar, mm)	-0.022		0.843
Weeding wage per 0.25 ha of maize (ZMK)	-4.36E-04		0.105
Land preparation wage per 0.25 ha of maize (ZMK)	3.05E-04		0.181
Maize price (ZMK/kg, t-1) (district median)	0.089	**	0.050
Farm gate price of top dressing fertilizer (ZMK/kg)	-0.003		0.672
Farm gate price of basal fertilizer (ZMK/kg)	-0.004		0.537
% of HHs in SEA reporting that village members had access to at least one loan	-0.168		0.166
% of HH's land that is tenured	0.054		0.614
Landholding size (cultivated+fallow, ha)	8.588	***	0.000
=1 if female headed HH	4.303		0.352
Age of HH head	0.740	***	0.000
# of HH members age < 5 yrs	0.474		0.825
# of HH members age 5 to 14 yrs	5.469	***	0.000
# of HH members age 15 to 59 yrs	7.328	***	0.000
# of HH members age > 59 yrs	6.390		0.134
% of HHs in the SEA that received advice on conservation farming	1.256	***	0.000
=1 if HH head education lower primary (gr.1-4)	-7.433		0.243
=1 if HH head education upper primary (gr.5-7)	17.408	***	0.006
=1 if HH head education secondary (gr.8-12)	39.163	***	0.000
=1 if HH head education post-secondary	86.254	***	0.000
Tropical Livestock Unit (Sheep, goats, pigs, donkeys)	8.995	***	0.001
# of cattle	0.630	***	0.003
=1 if Agricultural Support Program district	12.888	*	0.085
Observations	8,530		

Notes: Provincial and Agro Ecological Zone dummies are included in the model. APE= Average Partial Effect. CV = coefficient of variation. HH= Household. ZMK = Zambian Kwacha.

* Indicates APE significance level of 10% ** Indicates APE significance level of 5% *** Indicates APE significance level of 1%

Source: Authors' calculations based on the 2012 CSO/MAL/IAPRI Rural Agricultural Livelihoods Survey.

Table 4: Factors Affecting Adoption of Manure/Compost

	(1) Dependent Variable: Indicator =1 if applied manure/compost to least 1 field			(2) Dependent Variable: Ha of fields manure/compost applied		
	Probit (MLE)			Tobit (MLE)		
Explanatory Variables	APE		P-Val	APE		P-Val
Kilograms of subsidized fertilizer acquired	3.63E-05	**	0.017	5.36E-05	**	0.035
Km from HH to nearest tarred road	1.06E-04		0.412	1.58E-04		0.429
Km from HH to nearest private fertilizer dealer	-1.49E-04		0.356	-3.38E-04		0.198
Km from HH to nearest market	-1.16E-04		0.449	-2.15E-04		0.364
Km from HH to nearest agrodealer	6.76E-05		0.634	2.39E-04		0.297
=1 if HH owns cell phone	0.011		0.152	0.017		0.131
CV of growing season rain (%)	0.010	**	0.040	0.014		0.111
Mean moisture stress (20-day periods w/ <40 mm rain, Nov-Mar)	-0.114		0.130	-0.151		0.220
Mean growing season rainfall (Nov-Mar, mm)	3.47E-04	**	0.028	4.22E-04	*	0.098
Weeding wage per 0.25 ha of maize (ZMK)	1.20E-06	***	0.001	1.70E-06	***	0.001
Land preparation wage per 0.25 ha of maize (ZMK)	-6.00E-07	**	0.050	-8.00E-07	*	0.073
Maize price (ZMK/kg, t-1) (district median)	-4.75E-05		0.328	-3.38E-05		0.642
Farm gate price of top dressing fertilizer (ZMK/kg)	-8.70E-06		0.518	-1.57E-05		0.435
Farm gate price of basal fertilizer (ZMK/kg)	6.10E-06		0.653	1.48E-05		0.468
% of HHs in SEA reporting that village members had access to at least one loan	3.44E-05		0.856	6.59E-05		0.822
% of HH's land that is tenured	2.44E-04	*	0.056	4.06E-04	**	0.029
Landholding size (cultivated+fallow, ha)	1.92E-03	**	0.041	9.30E-03	***	0.000
=1 if female headed HH	-0.023	***	0.004	-0.033	***	0.006
Age of HH head	1.32E-04		0.657	3.30E-04		0.469
# of HH members age < 5 yrs	-2.15E-03		0.523	-3.64E-03		0.499
# of HH members age 5 to 14 yrs	4.58E-03	*	0.054	7.55E-03	**	0.037
# of HH members age 15 to 59 yrs	5.88E-03	***	0.005	8.17E-03	***	0.008
# of HH members age > 59 yrs	5.99E-04		0.937	-3.85E-03		0.730
% of HHs in the SEA that received advice on conservation farming	1.88E-04		0.340	2.73E-04		0.382
=1 if HH head education lower primary (gr.1-4)	-7.00E-03		0.531	-0.015		0.368
=1 if HH head education upper primary (gr.5-7)	-0.014		0.194	-0.028	*	0.098
=1 if HH head education secondary (gr.8-12)	7.33E-03		0.557	0.011		0.572
=1 if HH head education post-secondary	-0.005		0.772	-8.23E-03		0.758
Tropical Livestock Unit (Sheep, goats, pigs, donkeys)	0.012	***	0.002	0.025	***	0.000
# of cattle	1.17E-03	**	0.010	2.13E-03	***	0.001
=1 if Agricultural Support Program district	0.032	***	0.005	0.050	***	0.003
Observations	8,478°			8,478°		

Notes: Provincial and Agro Ecological Zone dummies are included it the model. APE= Average Partial Effect. CV = coefficient of variation. HH= Household. ZMK = Zambian Kwacha.

* Indicates APE significance level of 10% ** Indicates APE significance level of 5% *** Indicates APE significance level of 1%

° Total HHs less than 8839 because data was not collected from all HHs.

Source: Authors' calculations based on the 2012 CSO/MAL/IAPRI Rural Agricultural Livelihoods Survey.

Table 5: Factors Affecting Adoption of Soil Erosion Prevention Measures

	(1) Dependent Variable: Indicator =1 if applied erosion prevention measures to at least 1 field			(2) Dependent Variable: Ha of fields with erosion prevention measures applied		
	Probit (MLE)			Tobit (MLE)		
Explanatory Variables	APE		P-Val	APE		P-Val
Kilograms of subsidized fertilizer acquired	4.18E-05	*	0.075	1.10E-04	**	0.028
Km from HH to nearest tarred road	4.21E-04	**	0.020	7.52E-04	**	0.039
Km from HH to nearest private fertilizer dealer	-3.71E-04		0.125	-7.28E-04		0.110
Km from HH to nearest market	-1.50E-04		0.556	-8.12E-05		0.862
Km from HH to nearest agrodealer	1.20E-04		0.628	3.62E-04		0.452
=1 if HH owns cell phone	0.018		0.142	0.033		0.123
CV of growing season rain (%)	-0.002		0.843	-5.98E-03		0.733
Mean moisture stress (20-day periods w/ <40 mm rain, Nov-Mar)	9.04E-03		0.948	0.060		0.816
Mean growing season rainfall (Nov-Mar, mm)	3.87E-05		0.868	4.67E-05		0.918
Weeding wage per 0.25 ha of maize (ZMK)	2.00E-07		0.766	4.00E-07		0.755
Land preparation wage per 0.25 ha of maize (ZMK)	2.00E-07		0.673	4.00E-07		0.705
Maize price (ZMK/kg, t-1) (district median)	-2.93E-04	***	0.004	-6.26E-04	***	0.002
Farm gate price of top dressing fertilizer (ZMK/kg)	4.20E-06		0.841	6.60E-06		0.871
Farm gate price of basal fertilizer (ZMK/kg)	5.40E-06		0.785	4.20E-06		0.914
% of HHs in SEA reporting that village members had access to at least one loan	5.42E-04	*	0.081	1.03E-03	*	0.063
% of HH's land that is tenured	1.77E-04		0.418	4.75E-04		0.244
Landholding size (cultivated+fallow, ha)	2.26E-03		0.219	0.032	***	0.000
=1 if female headed HH	-1.91E-04		0.989	-0.014		0.552
Age of HH head	-1.14E-03	*	0.051	-2.09E-03	**	0.050
# of HH members age < 5 yrs	-2.04E-03		0.764	-4.97E-03		0.682
# of HH members age 5 to 14 yrs	4.04E-03		0.265	8.17E-03		0.214
# of HH members age 15 to 59 yrs	0.016	***	0.000	0.030	***	0.000
# of HH members age > 59 yrs	0.018		0.228	0.035		0.211
% of HHs in the SEA that received advice on conservation farming	-2.52E-05		0.936	2.05E-04		0.728
=1 if HH head education lower primary (gr.1-4)	0.019		0.257	0.022		0.469
=1 if HH head education upper primary (gr.5-7)	-1.38E-03		0.938	3.96E-03		0.902
=1 if HH head education secondary (gr.8-12)	-3.00E-03		0.875	-7.35E-03		0.832
=1 if HH head education post-secondary	0.012		0.718	0.036		0.591
Tropical Livestock Unit (Sheep, goats, pigs, donkeys)	0.021	***	0.002	0.047	***	0.001
# of cattle	-6.87E-04		0.225	6.01E-04		0.561
=1 if Agricultural Support Program district	0.084	***	0.000	0.154	***	0.000
Observations	8482°			8482°		

Notes: Provincial and Agro Ecological Zone dummies are included it the model. APE= Average Partial Effect. CV = coefficient of variation. HH= Household. ZMK = Zambian Kwacha.

* Indicates APE significance level of 10% ** Indicates APE significance level of 5% *** Indicates APE significance level of 1%

° Total HHs less than 8839 because data was not collected from all HHs.

Source: Authors' calculations based on the 2012 CSO/MAL/IAPRI Rural Agricultural Livelihoods Survey.

Table 6: Factors Affecting Adoption of Minimum Tillage

	(1) Dependent Variable: Indicator =1 if at least 1 field under minimum tillage			(2) Dependent Variable: Ha of fields under minimum tillage		
	Probit (MLE)			Tobit (MLE)		
Explanatory Variables	APE		P-Val	APE		P-Val
Kilograms of subsidized fertilizer acquired	1.31E-05	**	0.014	2.17E-05	**	0.019
Km from HH to nearest tarred road	-4.11E-05		0.431	-6.90E-05		0.332
Km from HH to nearest private fertilizer dealer	-8.31E-05		0.281	-1.12E-04		0.262
Km from HH to nearest market	8.24E-05		0.321	1.10E-04		0.287
Km from HH to nearest agrodealer	-1.42E-04	**	0.039	-1.88E-04	**	0.04
=1 if HH owns cell phone	4.76E-03		0.167	0.006		0.151
CV of growing season rain (%)	-3.22E-03		0.157	-0.004		0.146
Mean moisture stress (20-day periods w/ <40 mm rain, Nov-Mar)	0.055	*	0.097	0.074	*	0.087
Mean growing season rainfall (Nov-Mar, mm)	-1.08E-04		0.108	-1.51E-04	*	0.097
Weeding wage per 0.25 ha of maize (ZMK)	2.00E-07		0.234	3.00E-07		0.226
Land preparation wage per 0.25 ha of maize (ZMK)	-2.00E-07		0.139	-3.00E-07		0.16
Maize price (ZMK/kg, t-1) (district median)	-5.01E-05	***	0.004	-7.02E-05	***	0.004
Farm gate price of top dressing fertilizer (ZMK/kg)	-3.40E-06		0.560	-5.00E-06		0.509
Farm gate price of basal fertilizer (ZMK/kg)	-1.60E-06		0.758	-4.00E-07		0.95
% of HHs in SEA reporting that village members had access to at least one loan	3.40E-05		0.731	4.95E-05		0.7
% of HH's land that is tenured	-5.80E-05		0.286	-8.85E-05		0.23
Landholding size (cultivated+fallow, ha)	1.18E-03	**	0.019	0.002	***	0.003
=1 if female headed HH	1.34E-03		0.737	0.001		0.868
Age of HH head	-2.50E-06		0.987	-3.99E-05		0.845
# of HH members age < 5 yrs	4.16E-03	*	0.066	0.004		0.12
# of HH members age 5 to 14 yrs	-6.21E-04		0.621	-0.001		0.642
# of HH members age 15 to 59 yrs	5.44E-04		0.609	0.001		0.574
# of HH members age > 59 yrs	3.95E-03		0.300	0.006		0.245
% of HHs in the SEA that received advice on conservation farming	-4.76E-05		0.553	-5.74E-05		0.583
=1 if HH head education lower primary (gr.1-4)	0.028	**	0.025	0.042	**	0.03
=1 if HH head education upper primary (gr.5-7)	0.018	*	0.057	0.027	**	0.046
=1 if HH head education secondary (gr.8-12)	0.018	*	0.092	0.027	*	0.086
=1 if HH head education post-secondary	0.034		0.179	0.061		0.156
Tropical Livestock Unit (Sheep, goats, pigs, donkeys)	3.29E-03	*	0.050	0.004	**	0.046
# of cattle	-4.03E-04	*	0.080	-4.28E-04		0.168
=1 if Agricultural Support Program district	-7.18E-03		0.167	-0.010		0.155
Observations	8,477°			8477°		

Notes: Provincial and Agro Ecological Zone dummies are included it the model. APE= Average Partial Effect. CV = coefficient of variation. HH= Household. ZMK = Zambian Kwacha.

* Indicates APE significance level of 10% ** Indicates APE significance level of 5% *** Indicates APE significance level of 1%

° Total HHs less than 8839 because data was not collected from all HHs.

Source: Authors' calculations based on the 2012 CSO/MAL/IAPRI Rural Agricultural Livelihoods Survey.

Table 7: Factors Affecting Adoption of Crop Rotation between Cereals and Legumes

	(1) Dependent Variable: Indicator =1 if at least 1 field rotated btwn cereals and legumes '09/10' to '10/'11 seasons or btwn '10/'11 to '11/'12 seasons			(2) Dependent Variable: Ha of fields rotated btwn cereals and legumes '09/10' to '10/'11 seasons or btwn '10/'11 to '11/'12 seasons		
	Probit (MLE)- with CFA Residuals			Tobit (MLE)		
Explanatory Variables	APE		Bootstrapped P-Val	APE		P-Val
Residuals from subsidized fertilizer reduced form Tobit	1.14E-05	**	0.043			
Kilograms of subsidized fertilizer acquired	-1.90E-06		0.963	1.60E-04	**	0.011
Km from HH to nearest tarred road	-9.65E-04	***	0.000	-1.23E-03	***	0.000
Km from HH to nearest private fertilizer dealer	2.89E-04		0.373	5.86E-04		0.123
Km from HH to nearest market	7.62E-04	***	0.001	6.22E-04	*	0.052
Km from HH to nearest agrodealer	1.64E-04		0.609	1.32E-04		0.724
=1 if HH owns cell phone	8.16E-03		0.500	9.06E-04		0.954
CV of growing season rain (%)	-0.034	**	0.015	-0.036	**	0.030
Mean moisture stress (20-day periods w/ <40 mm rain, Nov-Mar)	0.430	**	0.033	0.433	*	0.066
Mean growing season rainfall (Nov-Mar, mm)	-6.22E-04	**	0.012	-0.001	**	0.025
Weeding wage per 0.25 ha of maize (ZMK)	-1.00E-07		0.835	4.00E-07		0.722
Land preparation wage per 0.25 ha of maize (ZMK)	-9.00E-07	*	0.078	-1.40E-06	*	0.093
Maize price (ZMK/kg, t-1) (district median)	2.97E-04	***	0.004	3.38E-04	**	0.016
Farm gate price of top dressing fertilizer (ZMK/kg)	2.26E-05		0.376	7.12E-05	**	0.024
Farm gate price of basal fertilizer (ZMK/kg)	-3.37E-05		0.189	-6.35E-05	**	0.039
% of HHs in SEA reporting that village members had access to at least one loan	1.67E-03	***	0.000	2.16E-03	***	0.000
% of HH's land that is tenured	3.21E-04		0.319	2.18E-04		0.509
Landholding size (cultivated+fallow, ha)	0.037	***	0.000	0.057	***	0.000
=1 if female headed HH	0.084	***	0.000	0.081	***	0.000
Age of HH head	1.80E-03	***	0.004	1.60E-03	**	0.013
# of HH members age < 5 yrs	5.20E-03		0.506	1.21E-04		0.989
# of HH members age 5 to 14 yrs	9.48E-03	**	0.013	0.011	**	0.016
# of HH members age 15 to 59 yrs	2.76E-03		0.519	2.71E-03		0.638
# of HH members age > 59 yrs	5.00E-03		0.782	0.017		0.324
% of HHs in the SEA that received advice on conservation farming	2.79E-03	***	0.000	2.97E-03	***	0.000
=1 if HH head education lower primary (gr.1-4)	0.016		0.372	0.024		0.286
=1 if HH head education upper primary (gr.5-7)	0.050	***	0.003	0.065	***	0.002
=1 if HH head education secondary (gr.8-12)	0.066	***	0.000	0.082	***	0.001
=1 if HH head education post-secondary	0.039		0.281	0.043		0.362
Tropical Livestock Unit (Sheep, goats, pigs, donkeys)	0.038	***	0.002	0.046	***	0.000
# of cattle	9.70E-04		0.284	1.54E-03		0.151
=1 if Agricultural Support Program district	0.035		0.156	0.014		0.621
Observations	8839			8475°		

Notes: 50 of 500 replications could be completed when bootstrapping the probit model.

Provincial and Agro Ecological Zone dummies are included it the model. APE= Average Partial Effect. CV = coefficient of variation. HH= Household. ZMK = Zambian Kwacha.

* Indicates APE significance level of 10% ** Indicates APE significance level of 5% *** Indicates APE significance level of 1%

° Total HHs less than 8839 because data was not collected from all HHs.

Source: Authors' calculations based on the 2012 CSO/MAL/IAPRI Rural Agricultural Livelihoods Survey.

Table 8: Factors Affecting Adoption of Leaving Land Fallow

	(1) Dependent Variable: Indicator =1 if at least 1 fallow field			(2) Dependent Variable: Ha of fields left fallow		
	Probit (MLE)			Tobit (MLE)		
Explanatory Variables	APE		P-Val	APE		P-Val
Kilograms of subsidized fertilizer acquired	-1.83E-04	***	0.000	-4.58E-04	***	0.000
Km from HH to nearest tarred road	5.24E-04	**	0.019	0.001	**	0.013
Km from HH to nearest private fertilizer dealer	4.76E-04	**	0.038	3.20E-04		0.296
Km from HH to nearest market	-3.98E-04		0.156	-6.10E-04		0.131
Km from HH to nearest agrodealer	-4.73E-04	*	0.051	-7.65E-04	**	0.040
=1 if HH owns cell phone	-0.018		0.157	-3.31E-02	*	0.073
CV of growing season rain (%)	-2.29E-03		0.876	6.14E-04		0.977
Mean moisture stress (20-day periods w/ <40 mm rain, Nov-Mar)	0.116		0.574	0.100		0.726
Mean growing season rainfall (Nov-Mar, mm)	3.73E-04		0.181	9.28E-04	**	0.016
Weeding wage per 0.25 ha of maize (ZMK)	3.00E-07		0.654	3.00E-07		0.748
Land preparation wage per 0.25 ha of maize (ZMK)	-3.00E-07		0.651	1.00E-07		0.911
Maize price (ZMK/kg, t-1) (district median)	8.47E-05		0.471	1.14E-04		0.530
Farm gate price of top dressing fertilizer (ZMK/kg)	-1.09E-04	***	0.000	-1.58E-04	***	0.000
Farm gate price of basal fertilizer (ZMK/kg)	6.80E-05	***	0.005	1.05E-04	***	0.004
% of HHs in SEA reporting that village members had access to at least one loan	-8.11E-04	*	0.062	-1.19E-03	*	0.068
% of HH's land that is tenured	4.37E-05		0.864	7.85E-05		0.845
Landholding size (cultivated+fallow, ha)	0.078	***	0.000	0.201	***	0.000
=1 if female headed HH	-8.22E-03		0.554	2.76E-03		0.889
Age of HH head	1.40E-03	**	0.013	2.17E-03	**	0.010
# of HH members age < 5 yrs	0.010		0.188	0.010		0.398
# of HH members age 5 to 14 yrs	3.39E-03		0.377	-6.67E-03		0.258
# of HH members age 15 to 59 yrs	-1.90E-03		0.629	-7.26E-03		0.264
# of HH members age > 59 yrs	0.012		0.394	0.011		0.582
% of HHs in the SEA that received advice on conservation farming	-9.97E-05		0.806	-4.54E-04		0.423
=1 if HH head education lower primary (gr.1-4)	0.010		0.595	6.28E-03		0.828
=1 if HH head education upper primary (gr.5-7)	-1.86E-03		0.920	-0.020		0.437
=1 if HH head education secondary (gr.8-12)	5.54E-04		0.979	-0.026		0.378
=1 if HH head education post-secondary	-0.140	***	0.000	-0.148	***	0.002
Tropical Livestock Unit (Sheep, goats, pigs, donkeys)	-0.029	***	0.005	-0.072	***	0.000
# of cattle	-6.30E-03	***	0.000	-0.016	***	0.000
=1 if Agricultural Support Program district	0.018		0.491	4.09E-03		0.920
Observations	8530°			8530°		

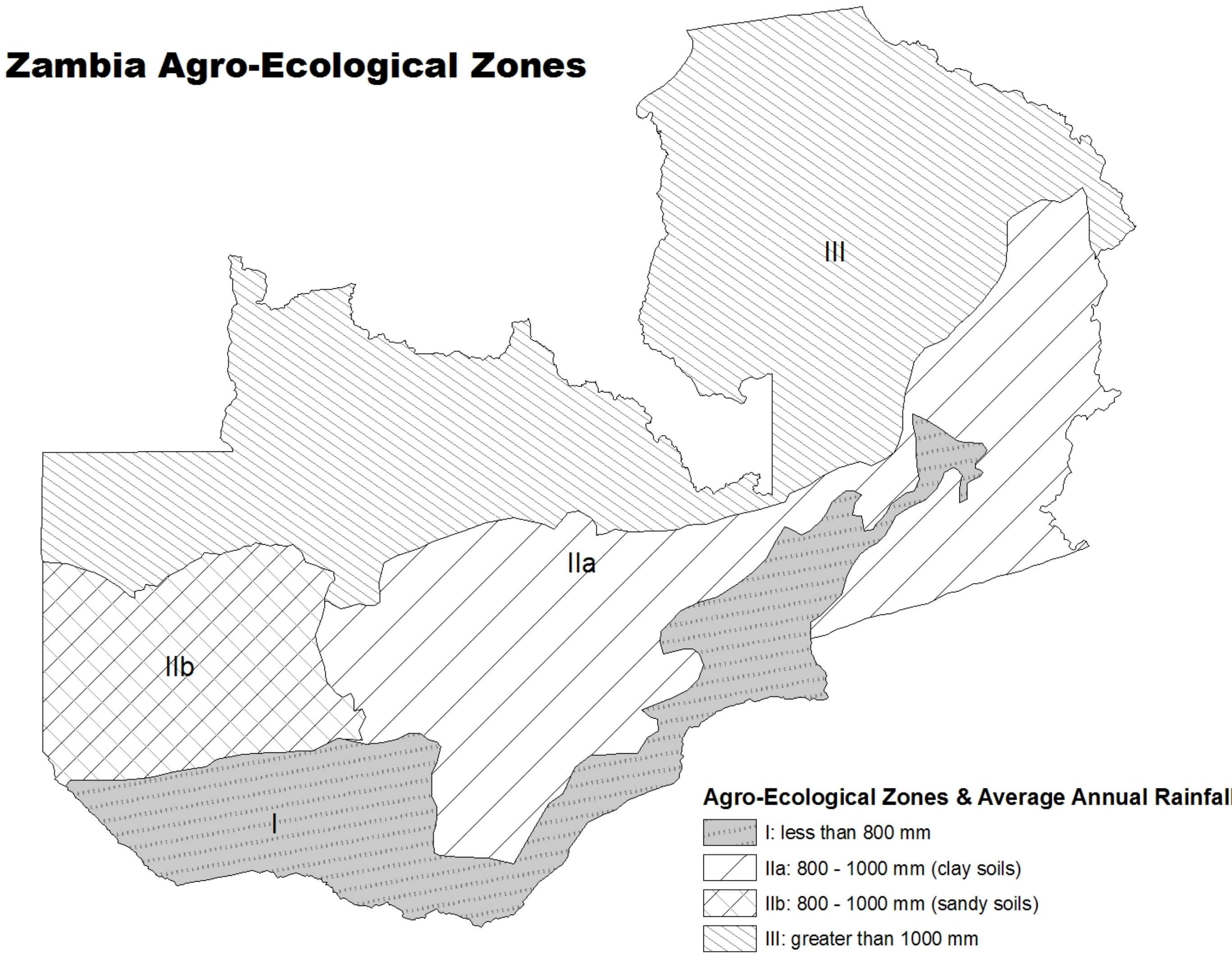
Notes: Provincial and Agro Ecological Zone dummies are included it the model. APE= Average Partial Effect. CV = coefficient of variation. HH= Household. ZMK = Zambian Kwacha.

* Indicates APE significance level of 10% ** Indicates APE significance level of 5% *** Indicates APE significance level of 1%

° Total HHs less than 8839 because data was not collected from all HHs.

Source: Authors' calculations based on the 2012 CSO/MAL/IAPRI Rural Agricultural Livelihoods Survey.

Figure 1.



Source: Map created by Hunter Nielson using data from the Zambia Agriculture Research Institute.

Appendix

Table A1: Summary Statistics of Explanatory Variables

Explanatory Variables	Mean	Std. dev.	Percentile 25th	Percentile 50th	Percentile 75th
Kilograms of subsidized fertilizer acquired	77.667	168.336	0	0	100
Km from HH to nearest tarred road	34.868	42.645	5	20	50
Km from HH to nearest private fertilizer dealer	38.396	37.449	11	27	55
Km from HH to nearest market	27.618	32.095	5	16	40
Km from HH to nearest agrodealer	35.655	36.440	9	25	50
=1 if HH owns cell phone	0.455	0.498	0	0	1
CV of growing season rain (%)	14.355	8.244	7.662	14.648	19.487
Mean moisture stress (20-day periods w/ <40 mm rain, Nov-Mar)	1.070	0.543	0.630	1.148	1.481
Mean growing season rainfall (Nov-Mar, mm)	775.750	68.142	720.335	784.963	825.154
Weeding wage per 0.25 ha of maize (ZMK)	57358.140	24173.120	43243.400	50000.000	61776.290
Land preparation wage per 0.25 ha of maize (ZMK)	78776.240	30493.330	60000	70000	100000
Maize price (ZMK/kg, t-1) (district median)	1086.645	100.490	1111.111	1130.435	1130.435
Farm gate price of top dressing fertilizer (ZMK/kg)	3781.630	474.167	3460	3800	4020
Farm gate price of basal fertilizer (ZMK/kg)	3882.664	486.304	3500	4000	4100
% of HHs in SEA reporting that village members had access to at least one loan	43.909	28.216	21.538	41.966	65.740
% of HH's land that is tenured	7.820	26.491	0	0	0
Landholding size (cultivated+fallow, ha)	2.010	2.309	0.75	1.418	2.5
=1 if female headed HH	0.241	0.428	0	0	0
Age of HH head	44.548	15.521	32	41	54
# of HH members age < 5 yrs	0.790	0.791	0	1	1
# of HH members age 5 to 14 yrs	1.671	1.445	0	1.833	3
# of HH members age 15 to 59 yrs	2.537	1.479	2	2	3
# of HH members age > 59 yrs	0.275	0.572	0	0	0
% of HHs in the SEA that received advice on conservation farming	58.624	26.478	42.284	63.857	79.405
=1 if HH head education lower primary (gr.1-4)	0.216	0.411	0	0	0
=1 if HH head education upper primary (gr.5-7)	0.378	0.485	0	0	1
=1 if HH head education secondary (gr.8-12)	0.245	0.430	0	0	0
=1 if HH head education post-secondary	0.036	0.186	0	0	0
Tropical Livestock Unit (Sheep, goats, pigs, donkeys)	0.245	0.626	0	0	0.3
# of cattle	1.511	6.925	0	0	0
=1 if Agricultural Support Program district	0.429	0.495	0	0	1
=1 if AEZ is IIa	0.404				
=1 if AEZ is IIb	0.082				
=1 if AEZ is III	0.443				
=1 if Copperbelt Province	0.056				
=1 if Eastern Province	0.187				

Table A1: Summary Statistics of Explanatory Variables

Explanatory Variables	Mean	Std. dev.	Percentile 25th	Percentile 50th	Percentile 75th
=1 if Luapula Province	0.106				
=1 if Lusaka Province	0.031				
=1 if Muchinga Province	0.082				
=1 if Northern Province	0.122				
=1 if Northwestern Province	0.071				
=1 if Southern Province	0.131				
=1 if Western Province	0.102				

Notes: CV = coefficient of variation. HH= Household. ZMK = Zambian Kwacha.

Source: Authors' calculations based on the CSO/MAL/IAPRI 2012 Rural Agricultural Livelihoods Survey.