IMPACT OF IMPROVED FALLOWS ON ON-FARM MAIZE PRODUCTIVITY

A Research Report presented to the Depart of Agricultural Economics and Extension Studies of the University of Zambia.

By

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In Partial Fulfillment of the Requirements for the Degree of Bachelor of Agricultural Sciences

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<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICRAF</td>
<td>International Center for Research in Agroforestry</td>
</tr>
<tr>
<td>IAPRI</td>
<td>Indaba Agricultural Policy Research Institute</td>
</tr>
<tr>
<td>IF</td>
<td>Improved Falls</td>
</tr>
<tr>
<td>PScore</td>
<td>Propensity score</td>
</tr>
<tr>
<td>KM</td>
<td>Kernel matching method</td>
</tr>
<tr>
<td>NNM</td>
<td>Nearest Neighbor matching method</td>
</tr>
<tr>
<td>ATT</td>
<td>Average Effect of the Treatment on the Treated</td>
</tr>
</tbody>
</table>
ABSTRACT

IMPACT OF IMPROVED FALLEWS ON ON-FARM MAIZE PRODUCTIVITY

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MR KUNTASHULA

Adoption rates of the improved fallows, an agroforestry technology, still remains low among small holder farmers in Zambia. Understanding the impact of improved fallows on on-farm maize productivity would provide a basis for not only understanding why the adoption is low but also for an effective adoption program by providing important information for policy formulation. The main objective of this study was to assess the impact of improved fallows on on-farm maize productivity among smallholder farmers in Eastern Zambia.

The study relied upon secondary data which was collected by IAPRI in 2012/2013 season. The data was composed of 597 smallholder farmers from the two districts of eastern Zambia, namely Nyimba and Petauke. This study first used probit regression to estimate propensity scores for adopters and non-adopters then used propensity score matching methods namely the kernel matching method (KM) and the nearest neighbor matching (NNM) method to estimate the average effect of the treatment (adoption) on the treated (adopters) (ATT).

The study considered factors such as sex of the household head, age of the household head, level of education, marital status, household size, farm size, scarcity of pasture on the farms, household head’s awareness of climate change issues and consequences, membership to an agricultural group, productivity and others in the estimation of the propensity scores. The sex of the household head, household size, awareness of climate change issues and consequences and scarcity of pasture on the farms were significant in estimating the propensity scores. The ATT found was 0.437 and 0.429 for the KM and the NNM methods respectively, this means that adoption of improved fallows had raised the productivity of adopters by 42.90% (NNM) and 43.70% (KM) on average compared to the non-adopters. Adoption rate was found to be 13%, this rate is lower than the one estimated in 2009 which was 20.6%.

Based on the finding, if adoption rate is to be enhanced, more effort should be made through extension programs in facilitating seminars and training to continuously educate farmers on the benefits of IF. The Government and other stakeholders should increase awareness of climate change issues and consequences as this was found to be significant. It is important that future studies should also consider assessing the adoption and impact of this technology on other crops such as high value crops (tobacco) and to incorporate other welfare indicators such as income and number of months in year a farm household goes with enough food in assessment.
CHAPTER ONE-INTRODUCTION

1.1.BACKGROUND

Due to a mix of agro-ecological factors such as; incessant drought, low soil fertility, environmental degradation and other man-made problems such as; illiteracy and unfavorable development policies. Zambia faces several challenges including worsening poverty, food insecurity and low income base. Low soil fertility is identified as one of the greatest biophysical constraints to increasing agricultural productivity (Bekundaet al., 1997, Sanchez, 1999). The degradation of soils is caused by a breakdown of the traditional production systems resulting from shortening of fallow periods due to population pressure (Kwesigaet al.1999). With the reduction in the amount of inputs farmers are receiving from the government under Farmers Inputs Support Program (FISP) most smallholder farmers are unable to purchase sufficient amounts of mineral fertilizers. In addition, Zambia is a landlocked country thus the cost of transporting fertilizer from the ports are high.

There has been a rapid degradation of the miombo woodland, shortage of fodder and decreasing access to fuel wood supplies (Kwesiga and Beniest, 1998). For example, Chidumayo (1997) estimated that Zambia alone loses about 200,000 ha of forests per year, this is leading to high food insecurity and rural poverty. Some of the key avenues for overcoming food insecurity and rural poverty in Zambia include reversing soil fertility depletion, intensifying and diversifying land use with introduction of high value products, and facilitating an appropriate policy environment for the smallholder farming sector. While mineral fertilizer is still one of the best options for overcoming land depletion and increasing food production, the majority of the smallholder farmers are unable to afford and apply the fertilizers at the recommended rates and at the appropriate time because of high cost and delivery delays (Kwesigaet al., 2003; Akinnifesiet al., 2006). Therefore, there is need for low-cost technologies that could improve soil fertility and thus ensure an improvement in the livelihood of smallholder farmers. Agro-forestry has proven to be one of such approaches. For the past fifteen years, farmers and researchers from different national and international institutions led by the International Centre for Research in Agro-forestry (ICRAF), otherwise known as the World Agro-forestry Centre have been combining their expertise and resources to develop agro-forestry technologies and options to
address some of these challenges facing smallholder agricultural production and the environment in the sub-region.

Agroforestry is a collective name for land-use systems in which: woody perennials are grown in association with herbaceous plants and/or with livestock, in a spacial arrangement, a rotation or both and where there are ecological and economic interactions between the tree and non-tree components (Anthony: 1989). It is an integrated approach of using the interactive benefits from combining trees and shrubs with crops and/or livestock. It combines agricultural and forestry technologies to create more diverse, productive, profitable, healthy, and sustainable land-use systems. A narrow definition of agro-forestry is "trees on farms. The different types of agro-forestry technologies address specific human and environmental needs. This study focused on fertilizer tree systems also known as improved fallows (Sesbaniasesban, Tephrosia spp., Gliricidiasepium and Cajanuscajan). The study looked at the impact of these improved fallows on on-farm maize crop productivity.

But in addition Agroforestry-based land use practices provide ecosystem services such as carbon sequestration and storage, biodiversity conservation and protection of watershed among other services that help to adapt to and mitigate climate change effects. The climate is changing and reacting to these changes is crucial for the future of farming. Climate change is linked to internal variability of the climatic system and external natural factors but much more to human activities. The potential fallouts of this phenomenon have been identified to include rise in temperature, much more erratic rainfall regimes, increased frequency and intensity of extreme events, and general unpredictability of agricultural operations among other effects. These have grave economic, social, and ecological consequences for agriculture and food security in many countries, particularly, in sub-Saharan Africa where agriculture is largely rain-fed. Given that over two thirds of the populations in African countries work within the agricultural sector, the environmental and social consequences of climate change, especially for the poor, endangers their livelihoods. In the quest to provide food and fibre to an expanding human population, the provision of agriculture-based ecosystem services that help to moderate climate change is increasingly under threat (FAO, 2007).
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1.2. PROBLEM STATEMENT

In Zambia, agro-forestry technologies have been trialed at research stations since 1988 and also on farms since 1992 in collaboration with farmers (Franzelet et al., 2002). In particular improved fallows and biomass transfer technologies have been developed (Kwesiga & Coe, 1994; Kwesiga et al., 1999; Kwesiga et al., 2003). These technologies have since been extensively introduced to smallholder farmers.

The biophysical performance and the relevance of the Agro-forestry technologies in Zambia have also been well demonstrated (Kwesiga and Coe, 1994; Mafongoyae et al., 2003; Kwesiga et al., 2003; Nyadziet et al., 2003; Mithoefer and Waibel, 2003; Kuntashula et al., 2004). Gradually the focus of agro-forestry research had changed from purely biophysical and field trials to the incorporation of socio-economic and on-farm research to allow for studies of profitability and acceptability of the different agro-forestry technologies to be carried out in a much more real-life context. Research and development activities on agro-forestry had therefore expanded to include questions on farmer uptake, adoption and impact of the technologies. But despite the good things from this technology and how extensively they had been researched on and demonstrated very few farmers are adopting the technology (Akinnifes et al., 2006; Ajayi et al., 2007). Recent adoption studies indicate that both trialing and adoption of these technologies are low. One study conducted in Eastern province estimated adoption of improved fallows in eastern Zambia at 20.6 percent and that of biomass transfer at 10.7 percent (Bigsby et al., 2009).

Most of the research and extension effort over this period has been directed at determining the adoption of these technologies and examining factors that influence their adoption. For example the study on the adoption of improved fallow technology for soil fertility management in Zambia (Ajayi, et al., 2003) and the study on agro-forestry adoption decisions, structural adjustment and gender in Africa (Gladwin, et al., 2002). There has been insufficient research directed fully at finding out the impact of these improved fallows on smallholder farmers’ maize productivity. Is the technology really improving the livelihood of farmers? This has been made worse by the fact that most research & development of improved fallows have been scaled down since mid-2000’s due to the exit of ICRAF. This therefore has further affected the already low level adoption rates.

As stated earlier improved fallows have been found to improve farmer welfare (Ajayi et al., 2007; Franzel, 2004) with indicative parameters between adopters and non-adopters being;
increased maize yields, household incomes and number of months with enough food in a year. Studies reviewed do not incorporate confounding factors such as education and experience differences between adopters and non-adopters that could equally have an influence on outcome variables. Over time adopters & non-adopters may differ in outcome parameters even without adopting improved fallows if there is selection bias. To attribute a technology as causing impact, selection bias has to be overcome. A good example is the study done in Eastern Zambia by (Ajayi et al. 2007) which used two indicators: farmer perceptions of yields and number of months per year when the household had enough food to feed family members, to measure impact. The findings were that the technology had positive impacts on the welfare of farmers measured using crop yields and income from the sale of the crop. When analyzing the number of months per year when households have enough food, the study only controlled for household size. However, including the number of months the household has enough food without necessarily controlling for other variables may produce misleading estimates about causality. Both biophysical variables as well as socioeconomic characteristics of farmers could be important in so far as increasing the availability of food on-farm is concerned. This project used propensity score matching method which matched an adopter to a non-adopter with the same or similar score in order to overcome the selection bias and attribute the difference between adopters and non-adopter to be as a result of the adoption of improved fallows.

1.3.OBJECTIVES

- To ascertain the levels of involvement by farmers in Improved Fallows as a climate change adaptation strategy.

- To determine the impact of Improved Fallows on farmers’ maize crop productivity.

1.4 RATIONALE

A study on the impact of Improved Fallows on on-farm maize crop productivity might among others things help understand the reasons why there has been low adoption of improved fallows despite it having many benefits and being readily available. It has been observed that even though the awareness has been high recent adoption studies indicate that both trialing and adoption of these technologies are low (Ajayi, 2007). Ajayi estimates adoption of improved fallows in eastern Zambia at 20.6 percent and that of biomass transfer at 10.7 percent (Ajayi, 2007). Lack of knowledge and lack of seed have been found as the main factors hindering the
adoption of agro-forestry practices. This research will contribute to the knowledge that policy formulators can use to encourage farmer participation in agro-forestry and will therefore contribute to the attainment of Zambia’s Sixth National Development Plan agriculture sector goal of increasing and diversifying agriculture production and productivity so as to raise the share of its contribution to 20% GDP.

1.5. ORGANIZATION OF THE REPORT

This report opens with Chapter one that highlights the background information about improved fallows and there benefits. It covers the problem statement, objectives and rationale of the study. Chapter two gives an overview of the literature and conceptual framework used in this study. Chapter three looks at the methods and procedures employed in this study. Chapter discusses the findings and lastly chapter five concludes and provides some recommendations on policy formulation and future research on related subjects.
CHAPTER TWO—LITERATURE REVIEW

2.1. INTRODUCTION.

For the past few years, there has been an increase in the number of studies on the impact of improved fallows on small scale farmers’ productivity. A review of literature of impact of improved fallows indicate that several studies have been done which have showed that this technology has various benefits with the main one being improving farmer’s productivity. This chapter reviews the major literature on improved fallows and related concepts. The chapter will discuss first the meaning of productivity, it then goes on to describe what improved fallows are followed by their benefits and lastly the past studies that have been conducted on them and the conceptual framework that have been used.

2.2. DEFINITION OF PRODUCTIVITY

Agricultural productivity refers to the output produced by a given level of input(s) in the agricultural sector of a given economy (Fulghiniti and Perrin 1998). More formally, it can be defined as “the ratio of the value of total farm outputs to the value of total inputs used in farm production” (Olayide and Heady 1982). Agricultural productivity is measured as the ratio of final output, in appropriate units, to some measure of inputs. However, measures of productivity can be divided into partial or total measures depending on the number of inputs under consideration. Single factor productivity (SFP) or partial measure is defined as the ratio of a measure of output quantity to the quantity of a single input used (Diewert and Nakamura 2005). Total factor productivity (TFP) is defined as the ratio of a measure of total output quantity to a measure of the quantity of total input (Wiebe et al. 2003; Zepeda 2001).

2.3. DESCRIPTION OF IMPROVED FALLOWS

This option involves planting fast growing plant species that are (usually) nitrogen-fixing, produce easily decomposable biomass, compatible with cereal crops in rotation and are adapted to the climatic and soil conditions of the miombo woodland ecology of southern Africa (Kwesiga and Coe 1994). The strategy uses leguminous trees to accumulate nitrogen (N) in the biomass and recycle it into the soil, to act as a break crop to smother weeds, and to improve soil physical and chemical properties (Kwesiga et al. 1999). The trees increase the availability of nitrogen (N) through atmospheric fixation of N2. It must be noted that the notion ‘fertilizer trees’ does not
imply that the trees provide all the major nutrients: they are capable of fixing only N which is the most limiting. The two other macro nutrients phosphorus (P) and potassium (K), which are required by crops, can be recycled by the trees, but the two nutrients must be sourced externally if they are depleted from the soil. The cycle of fertilizer trees begins when tree species are established as a pure stand or intercropped with food crops and they are allowed later to grow for one or two more years. The tree fallows are cut between 12 and 36 months after planting and the foliar biomass is incorporated into the soil during land preparation. The complete cycle of fertilizer tree fallows is a fallow phase of one or two years followed by a cropping phase (mainly maize) of 2-3 years. The major plant species used are Sesbaniasesban, Tephrosiavogelli, Tephrosia candida and Cajanuscajan. To avoid the potential risks of developing a technology based on a narrow plant genetic base, a range of other species, some that can re-sprout ("coppice") after they are cut, has been introduced. Technical details on fertilizer tree fallows have been described elsewhere (Chirwa et al. 2003; Kwesiga et al. 1999; Kwesiga and Coe 1994 and Mafongoya et al. 2003).

2.4. BENEFITS OF IMPROVED FALLOWs

The main benefit from Improved Fallows is the increased yields of crops that follow. In addition to increasing crop yields, fertilizer trees provide benefits to farmers in terms of reduced risk from drought, increased fuel wood and other by products, such as insecticides made from Tephrosiavogellii leaves. The main environmental benefits are improved soil physical properties, such as better infiltration and aggregate soil stability, which reduce soil erosion and enhance the ability of the soil to store water. Sesbania fallows were also found to greatly reduce the occurrence of striga weeds, which generally thrive under conditions of low soil fertility (Kwesiga et al. 1999). Tree fallows may also help reduce pressure on woodlands for fuel wood energy. However, rigorous field studies are needed to test this hypothesized linkage between planting trees on farms and deforestation reduction.

The positive productivity effects on smallholders and their yields will have the effect of shifting the supply curve for maize. The shape of the supply curve has not been empirically estimated, but there is likely to be an inelastic portion reflecting the fact that maize is the main staple food and much of it is grown for subsistence purposes. At the initial level of demand, a shift in supply will move the equilibrium. Such a shift is predicted to bring about a fall in the price of maize
yielding consumer surplus. However, there is no evidence to suggest this has happened in eastern Zambia. That may be because demand is highly elastic: there have been almost annual food distribution programs somewhere in the region. Thus, from the supply shift, we have increased private benefits accruing to farmers (mainly for self-consumption), but we do not have an indication of consumer surplus resulting from lower prices. The contribution of fertilizer tree fallows to environmental services such as carbon sequestration may one day increase the demand for the maize production system that includes carbon storing fallows. In such a scenario, society would articulate its demand through environmental service payments.

2.5. PAST STUDIES

Research results from on-station and on-farm trials of fertilizer tree fallows consistently show significant increases in maize yields following SesbaniasesbananTephrosia vogelii fallows compared with common farmers’ practice of continuous maize production without fertilizer. The very first trial results were from 1988-1993 and many others have been conducted on different soils and with different management treatments (Kwesiga et al. 2003). One example of these results is given in Table below.

<table>
<thead>
<tr>
<th>Fallow species</th>
<th>Land use system</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sesbaniasesban fallows</td>
<td>Sesbania fallow</td>
<td>3.6</td>
<td>2.0</td>
<td>1.6</td>
</tr>
<tr>
<td></td>
<td>Fertilized maize</td>
<td>4.0</td>
<td>4.0</td>
<td>2.2</td>
</tr>
<tr>
<td></td>
<td>Unfertilized maize</td>
<td>0.8</td>
<td>1.2</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>LSD (0.05)</td>
<td>0.7</td>
<td>0.6</td>
<td>1.1</td>
</tr>
<tr>
<td>Tephrosiavogelii fallows</td>
<td>Tephrosia fallow</td>
<td>3.1</td>
<td>2.4</td>
<td>1.3</td>
</tr>
<tr>
<td></td>
<td>Fertilized maize</td>
<td>4.2</td>
<td>3.0</td>
<td>2.8</td>
</tr>
<tr>
<td></td>
<td>Unfertilized maize</td>
<td>0.8</td>
<td>0.1</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>LSD (0.05)</td>
<td>0.5</td>
<td>0.6</td>
<td>0.9</td>
</tr>
</tbody>
</table>

*LSD least significant difference. Source: Ayuk and Mafongoya (2002)
To summarize this research, the yield increases from fertilizer tree fallows range between two and four times those from continuous maize without nutrient inputs. In addition to maize yield increases, 10, 15 and 21 tons per hectare of fuel wood was harvested after 1, 2 and 3 years of Sesbania sesban fallow respectively (Kwesiga and Coe 1994). Financial analysis showed that fertilizer tree fallows systems were profitable with positive net benefits per unit land cultivated and favourable financial ratios, hence increasing productivity (Place et al. 2002; Franzel et al. 2002; Ajayi et al. 2004; Franzel 2004).

2.6. CONCEPTUAL FRAMEWORK.

Our outcome variable is the change in expected maize yield. The goal is to construct a proper counterfactual. In particular, interest is in the average treatment effect on the treated (ATT), which is what an adopters’ change in yield would have been had he not adopted. If adoption is allocated randomly across species, we can estimate the counterfactual simply by using the status of the non-adopters because the expected yield in the absence of adoption is identical for adopters and non-adopters. The potential outcome framework for causal inference discussed by Rubin (1974) estimates the average treatment effect on the treated (ATT) or adopters of improved fallows as:

$$\tau = E (Y_1 - Y_0 / G_i = 1),$$

Where E is the expectation in the difference in the outcome ($Y_1 - Y_0$) between adopting, $G_i = 1$ and the counterfactual outcome if the technology had not been received $G_i = 0$.

However, decisions to adopt are determined by observable characteristics of the adopters and their circumstances. Thus adopters and non-adopters, on average, differ in characteristics that may also affect yield changes after adoption (i.e., propensity to adopt or not). In the presence of such potential bias, the methods of matching provide one way to assess the effect of adoption of improved fallows on maize yields.

Matching works by, ex post, identifying a comparison group that is “very similar” to the treatment group with only one key difference: the comparison group did not participate in the program of interest. In this case the comparison group did not adopt improved fallows. Matching mimics random assignment through the ex post construction of a control group. If observable characteristics are selected so that any two species with the same value for these characteristics
display homogenous responses to adoption, then the adoption effect can be measured without bias.

One possible identification strategy is to impose the conditional independent assumption (CIA) that states that, given a set of observable covariates X, the potential outcome in case of not adopting is independent of treatment or technology assignment:

\[ Y_0 \perp \!\!\!\!\perp T \setminus (X) \]

Besides the CIA, a further requirement for identification is the overlap condition, which ensures that for each treated or adopting unit there are control or non-adopting units with the same observables.

\[ Pr (P=1 | X) < 1. \]

With the above two assumptions, within each cell defined by X, technology assignment is random, and the outcome of control units can be used to estimate the counter factual outcome of the adopting in the case of not adopting (Nannicini 2007).

Matching on every covariate is difficult to implement when the set of covariates is large. To overcome the curse of dimensionality, Rosenbaum and Rubin (1983) show that matching on a single index, the propensity score, rather than on a multidimensional covariate vector is possible. According to Heckman et al. (1998), the propensity score is defined as the conditional probability of receiving treatment or in this case of adopting the improved fallow technology. Mathematically, the propensity score can be expressed as:

\[ P(X) = P(G_i = 1 | X_i = X) = E(G_i | X_i = X) \]

Where Gi = 1, for treated farmers, and Gi = 0, for untreated farmers; a = improved fallow technology; and Xi is the vector of treatment covariates. The Propensity Score is estimated through a probit regression in which the dependent variable equaled one if the household adopted improved fallows and zero otherwise. The balancing properties of the propensity scores are checked to test whether or not adopter and non-adopter observations have the same distribution of propensity scores. Various specifications of the probit model are to be tempted until the most complete and robust specification that satisfied the balancing tests and establishment of the common support region are obtained.
Matching is implemented using nearest neighbor with replacement and Epanechnikov kernel (bandwidth 0.06) matching techniques. With nearest neighbor matching, the individual from the comparison group is chosen as a matching partner for a treated individual that is closest in terms of propensity score. With replacement meant that an untreated individual could be used more than once as a match. Matching with replacement increases the average quality of matching and decreases bias (Caliendo and Kopeinig, 2005). Unlike the nearest neighbor matching algorithm that ensures only a few observations from the comparison group are used to construct the counterfactual outcome of a treated individual, Kernel matching (KM) is a non-parametric matching estimator that uses weighted averages of all individuals in the control group to construct the counterfactual outcome. KM is therefore associated with lower variance because more information is used. One drawback of this approach is the possibility of using bad matches. It is for this reason that the proper imposition of the overlap condition is of major importance for KM (Caliendo and Kopeinig, 2005).
CHAPTER THREE-METHODOLOGY

3.1. INTRODUCTION
This chapter describes the methods and procedures that were used in achieving stated objectives. It outlines the study area, data collection method and data analysis tools that were used in this research.

3.2. STUDY SITE
This study was conducted in Eastern Province. This area was selected because it comprises not only village farmers but also smallholder farmers who have settled there from various urban areas. Therefore, it represents both the village farmers and smallholder farmers. This is a true representative of various household characteristics such as education and levels of knowledge, which are some of the variables this study measured.

3.3. DATA COLLECTION METHODS
Secondary data was used in this study. This data was collected from IAPRI and from various relevant publications such journals.

3.4. DATA ANALYSIS
To estimate the impact of improved fallows we get the difference in the yields of adopters after adopting and their yields had they not adopted. \[ \tau = E(\text{Y}1 - \text{Y}0 / \text{Gi}=1) \]. But since the situation had they not adopted doesn’t exist a control group is chosen, this is called matching.

In order to overcome the selection bias individuals with similar characteristics as adopters were chosen as matching partners. With zero selection bias the difference between the yields of adopters and non-adopters was attributed to the technology, i.e., \( E(\text{Y}1 ) - E(\text{Y}0 ) \) respectively.

Propensity score matching was used as matching on every covariate is difficult with a large set of covariates. Propensity scores were estimated using a probit model. The variables that were used to estimate in this study were sex of the household head, age of the household head, level of education, marital status, household size, farm size, scarcity of pasture on the farms, household head’s awareness of climate change issues and consequences, membership to an agricultural group, productivity etc.
CHAPTER FOUR-STUDY FINDING AND DISCUSSION

4.1. INTRODUCTION

This chapter presents and discusses the study findings. It begins with a presentation and discussion of the demographic characteristics. The extent of adoption of tree planting for fertility (improved fallows) will then be presented followed by a presentation of factors which determines the farmers’ likelihood of adopting the technology. Lastly the chapter will present and discuss the finding of the probit model on the average effect of the treatment on the treated called the ATT.

4.2. DEMOGRAPHIC CHARACTERISTICS

Table 2: distribution of farmers by age and sex

<table>
<thead>
<tr>
<th>AGE GROUPS (years)</th>
<th>SEX</th>
<th>TOTAL</th>
<th>PERCENTAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MALE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 to 30</td>
<td>76</td>
<td>9</td>
<td>85</td>
</tr>
<tr>
<td>31 to 40</td>
<td>138</td>
<td>20</td>
<td>158</td>
</tr>
<tr>
<td>41 to 59</td>
<td>195</td>
<td>52</td>
<td>247</td>
</tr>
<tr>
<td>60 and over</td>
<td>70</td>
<td>32</td>
<td>102</td>
</tr>
<tr>
<td>TOTAL</td>
<td>479</td>
<td>113</td>
<td>592</td>
</tr>
</tbody>
</table>

PERCENTAGE 80.9% 19.1% 100%

Most of the respondents in the study (80.9%) were male as compared to (19.1%) females that constituted the sample. This means, therefore, that there were more male headed farm households than female headed farm households. The majority of the farmers (41.72%) had ages between 41 and 59 years. About 26.69% constituted those that were between 31 and 40 years while 17.23% were between 60 years and above. Lastly 14.36% constituted those that were between 15 and 30 years. (See Table 2 above).

In terms of education, only 1.3% of the farmers had reached formal school upto college level. 19.9% had reached up to secondary level and 22.1% of these farmers had never been to school. Since the majority (56.6%) of the farmers had only reached primary level the implication is that they may not be able to comprehend new technologies and practices easily (see Table 3 below).
Table 3: distribution of farmers by education levels

<table>
<thead>
<tr>
<th>Education</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>132</td>
<td>22.10%</td>
</tr>
<tr>
<td>Primary</td>
<td>338</td>
<td>56.60%</td>
</tr>
<tr>
<td>Secondary</td>
<td>119</td>
<td>19.90%</td>
</tr>
<tr>
<td>Post-secondary</td>
<td>8</td>
<td>1.30%</td>
</tr>
<tr>
<td>Total</td>
<td>597</td>
<td>100%</td>
</tr>
</tbody>
</table>

Distribution of farmers by marital status

Figure 1 Distribution of Farmers by Marital Status

The majority of the farmers (76.88%) were monogamously married, as shown in the table above followed by those that widowed constituting 11.22%. From here comes those are divorced (5.03%) and those that are polygamously married (4.69%). The remaining farmers were; separated (1.17%), cohabiting (0.17%) and only 0.84% of farmers were never married. (see figure1 above).
Table 4: summary of average characteristics between adopters and non-adopters

<table>
<thead>
<tr>
<th>CHARACTERISTICS</th>
<th>ADOPTERS</th>
<th>NON-ADOPTERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>64</td>
<td>417</td>
</tr>
<tr>
<td>Female</td>
<td>15</td>
<td>101</td>
</tr>
<tr>
<td>Average age of household head</td>
<td>46.05</td>
<td>45.73</td>
</tr>
<tr>
<td>Average education</td>
<td>9.89</td>
<td>9.44</td>
</tr>
<tr>
<td>Average household size</td>
<td>5.37</td>
<td>5.86</td>
</tr>
<tr>
<td>Average farm size</td>
<td>3.81</td>
<td>3.09</td>
</tr>
<tr>
<td>Average distance from boma</td>
<td>23.47</td>
<td>21.92</td>
</tr>
<tr>
<td>Average hectare planted</td>
<td>2.54</td>
<td>1.87</td>
</tr>
<tr>
<td>Average Productivity</td>
<td>2.92</td>
<td>1.93</td>
</tr>
</tbody>
</table>

From the table above, the number of males that adopted the technology is 64 compared to 417 that did not adopt. For the female only 15 adopted compared to 101 that did not. Therefore, more males had adopted the technology as compared to females. The average age of adopters’ household head was 46.05 years as compared to 45.73 years for non-adopters, this shows that there isn’t a big difference between adopters and non-adopters in terms of their age. This is also the case for their education because average level of education for both adopters and non-adopters is secondary school. There is only a one person difference between adopters and non-adopters average household size since the adopters’ average household was approximately 5 while for non-adopters it was 6. In terms of farm size average farm size for adopters was slightly higher at 3.81ha than that of non-adopter which was 3.09ha. The other significant differences can be seen from the average hectare planted and average productivity. For average hectare planted, adopters had an average of 2.54ha as compared to 1.87 ha for non-adopters. And for productivity, adopters had an average of 2.92ton/ha while that of non-adopters was 1.93ton/ha, which is a huge difference (0.99) approximately 1ton/per difference in productivity.
4.3 EXTENT OF ADOPTION OF IMPROVED FALLOWS

Figure 2 Adoption of Improved Fallows per district

From the figure above 31 farmers had adopted improved fallows out of the total 285 farmers that were sampled in Nyimba district, this represents 10.88% adoption rate in the district. While 48 farmers had adopted improved fallows in Petauke district from a total of 312 farmers that were sampled, this represents 15.38% adoption rate in the district.

OVERALL ADOPTION OF IMPROVED FALLOWS IN EASTERN PROVINCE

From the 597 farmers that were interviewed in the province only 79 farmers had adopted tree planting (improved fallows) technology, this value represents 13% adoption rate of improved fallows in Eastern Zambia. It is therefore still the case that even though these technologies had been extensively introduced to smallholder farmers and there benefits demonstrated the adoption rate is still low. One contributing factor had been the exist of International Centre for Research in Agroforestry (ICRAF) in 2006, a proof of this can be seen by the difference between the adoption rate calculated in this study (13%) and the one reported in 2009 which was 20.6% in Eastern Zambia (Bigsby, H., Cullen, R., Kabwe G. 2009) (see figure below)
4.4. **PSCORE PROBIT REGRESSION RESULTS**

The table below shows the results on variables which were obtained after a probit regression was run to estimate the propensity scores of adopters and non-adopters of IF.

**Table 5: pscoreprobit regression results**

<p>| Adoption of IF          | Coeff   | Std err  | Z       | p&gt;|z| |
|-------------------------|---------|----------|---------|-----|
| Sex                     | -.5285191 | .3168991 | -1.67   | 0.095 |
| Mstatus                 | .0904099 | .1102328 | 0.82    | 0.412 |
| Age                     | -.001298  | .0048092 | -0.27   | 0.787 |
| Hsize                   | -.0639653 | .0318176 | -2.01   | 0.044 |
| Farmsize                | .0307771  | .0246596 | 1.25    | 0.212 |
| CFadvice                | .0188531  | .1534522 | 0.12    | 0.902 |
| Educ                    | .0199273  | .0182803 | 1.09    | 0.276 |
| Bomadist                | .0025026  | .0053593 | 0.47    | 0.641 |
| Mgroup                  | -.094222  | .1520022 | -0.62   | 0.535 |
| Awareness of climate change issues | -.4936122 | .1989189 | -2.08   | 0.013 |
| Labhire                 | -.1349095 | .2249644 | -0.60   | 0.549 |</p>
<table>
<thead>
<tr>
<th>Animlab</th>
<th>-0.1176798</th>
<th>0.1503821</th>
<th>-0.78</th>
<th>0.434</th>
</tr>
</thead>
<tbody>
<tr>
<td>AccessC</td>
<td>0.1162919</td>
<td>0.1663044</td>
<td>0.70</td>
<td>0.484</td>
</tr>
<tr>
<td>ScarPas</td>
<td>-0.2553637</td>
<td>0.1495676</td>
<td>-1.71</td>
<td>0.088</td>
</tr>
<tr>
<td>Oxplough</td>
<td>-0.0100536</td>
<td>0.1558068</td>
<td>-0.06</td>
<td>0.949</td>
</tr>
<tr>
<td>Solarpan</td>
<td>0.2403463</td>
<td>0.2050273</td>
<td>1.17</td>
<td>0.241</td>
</tr>
<tr>
<td>DecSQ</td>
<td>-0.2124743</td>
<td>0.1517963</td>
<td>-0.140</td>
<td>0.162</td>
</tr>
<tr>
<td>Radio</td>
<td>-0.2247229</td>
<td>0.1525861</td>
<td>-1.47</td>
<td>0.141</td>
</tr>
<tr>
<td>TV</td>
<td>-0.2692188</td>
<td>0.2052734</td>
<td>-1.31</td>
<td>0.190</td>
</tr>
</tbody>
</table>

Household characteristics that were found to be significant in estimating the propensity scores (Pscores) for non-adopter and adopters in order for them to be matched and the average effect of the treatment on the treated (ATT) to be estimated include; sex of household head, number of household members (household size), awareness of climate change issues and consequences (PC07), and scarcity of pasture on the farms.

The sex of the household head was found to be significant in estimating the Pscores. This may be due to the amount of work that is involved in managing the fallows, i.e. from planting to cutting down of the trees at the end of fallow period. The males have the muscle needed to do this work and will easily find the appropriate labor to help in cutting down the trees. Therefore the sex of the household head would significantly affect the household’s decision in adopting improved fallows and consequently it makes sense that sex should be significant in estimating the Pscores.

Number of family members (household size) with regards to those providing farm labor was found to significant in estimating the Pscores. This may be because an additional household member providing farm labor increased the probability of the household adopting the technology has this meant labor will be enough for performing farm duties and the need to hire extra labor will be minimized.

Awareness of climate change issues and consequences was found to have a significant influence in the estimation of Pscores. This is due to the fact that improved fallows in addition to increasing farm yields have been found to reduce the consequences of climate as a result of their environmental benefits which among other things include improvement of soil physical
properties, such as better infiltration and aggregate soil stability, which reduce soil erosion and enhance the ability of the soil to store water. Therefore, if a farmer has this knowledge the chances of him/her adopting the technology are increased, it therefore makes sense that this variable be used in estimating the Pscores.

Lastly scarcity of pasture on the farms was found to be significant in estimating Pscores. This may be due to the fact that improved fallows have been found to reduce soil erosion and runoff due to their canopy and biomass in addition to fixing nitrogen in the soil, as a result the fertility of soils and the soil biomass are improved which revitalizes the soil back to its productive state. A farmer whose land or farm has scarce pasture will likely adopt the technology in order to regenerate the soil’s vegetative state and have higher yields once maize or any other crop is planted. It is therefore likely that this variable should have an influence in estimating Pscores to use when matching the non-adopters to adopters to estimate ATT.

4.5. ESTIMATION OF AVERAGE EFFECT OF THE TREATMENT ON THE TREATED (ATT)

Table 6 and Table 7 below report the estimation results for the average treatment effect on the treated (ATT) of the outcome variable using PSM techniques. In our application of PSM, we first estimate a probit regression in which the dependent variable equals one if the household adopted at least one improved technology, zero otherwise. We then check the balancing properties of the propensity scores. The balancing procedure tests whether or not adopters and non-adopters observations have the same distribution of propensity scores. The estimated results based on the two matching algorithms, the Kernel method (KM) and nearest neighborhood (NNM), are reported in Table 4 and Table 5 respectively.

Table 6: ATT estimation using kernel matching method

<table>
<thead>
<tr>
<th>No. Treat</th>
<th>No. Control</th>
<th>ATT</th>
<th>Std. Err.</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>79</td>
<td>434</td>
<td>0.437</td>
<td>0.107</td>
<td>4.092</td>
</tr>
</tbody>
</table>

Table 7: ATT estimation using nearest neighbor matching method

<table>
<thead>
<tr>
<th>No. Treat</th>
<th>No. Control</th>
<th>ATT</th>
<th>Std. Err.</th>
<th>T</th>
</tr>
</thead>
<tbody>
<tr>
<td>79</td>
<td>69</td>
<td>0.429</td>
<td>0.223</td>
<td>1.924</td>
</tr>
</tbody>
</table>
The study reveals that the adoption of improved fallows has a significant positive impact on on-farm maize productivity. The overall average gain of adopting improved fallows in Eastern Zambia was found to be 0.437 for KM method and 0.429 for NNM method. These estimates show a positive and statistically significant impact of adoption of improved fallow on smallholder farmer's productivity. Adoption of improved fallows had raised the productivity by about 42.90% for NNM and 43.70% for KM on average compared to the non-adopters. It is the average difference between productivity of similar pairs of the households belonging to the non-adopters. This indicates that (assuming there is no selection bias due to unobservable factors) productivity for farmers who adopted improved fallows is significantly higher than the non-adopters.

The difference between the results from the KM method and the NNM method is that nearest neighbor strategy used only household from the control units that were very similar or close to the households from the adopting unit. That is 69 households among the control units to match against 79 adopting households. While the kernel matching method used the average of all non-adopters (434) to match against the 79 adopting
CHAPTER FIVE—CONCLUSION AND RECOMMENDATIONS

5.1. INTRODUCTION

This chapter presents the conclusion and recommendations of the study based on the findings and interpretations of the study.

5.2. CONCLUSION

This paper evaluates the potential impact of adoption of improved fallows on rural household on-farm maize productivity in Eastern Zambia. The study utilizes cross-sectional farm household level data collected in 2012 from a randomly selected sample of 597 farm household in Easter Province from two districts; Nyimba and Petauke.

The propensity score matching methods namely the Kernel matching method and the Nearest Neighbor matching method were used to estimate the average effect of the treatment on the treated. These estimated the true impact of the technology adoption by controlling for the role of selection problem on adoption decisions. The causal impact estimation from both the KM method and the NNM method suggest that improved fallow adopters have significantly higher productivity than non-adopters even after controlling for all confounding factors.

The results from this paper generally confirms the potential direct role of agricultural technology adoption on improving rural household on-farm maize productivity leading to improved welfare, as higher productivity from improved technology translate into higher incomes and consequently lower poverty among the smallholder farmers. Maize being the staple food in Zambia and most parts of sub Saharan Africa, the contribution of the improved fallows in ensuring food security and hence alleviating food poverty cannot be over emphasized.

5.3. RECOMMENDATIONS

This study has revealed that the adoption rate of improved fallows has dropped from 20.6% in 2009 to 13% in the Eastern part of the country, as already stated one reason has been the exit of ICRAF. This is despite the technology’s contribution in ensuring increased productivity. In order to encourage the adoption of this technology the policy makers (government) in their extension program should include continuous seminars and training on improved agricultural technologies.
These should be coupled with increase in research and demonstrations so that farmers can have knowledge of the available technologies. Therefore for the farmers to get optimum yields there is need to continuously train them in management of new improved agricultural technologies such as improved fallows.

This study like many other studies focused on the impact of improved fallows on maize productivity, but since many smallholder farmers grow maize just for substance purposes and grow other crops such cash crops which they sell in the case of tobacco in Eastern province further studies should be conducted to assess the impact of this technology on the productivity of other crops. This may encourage farmers that grow high value crops to also take up the technology.

This study only looked at the impact of improved fallows on on-farm maize productivity. Therefore, further research should be conducted on the impact of this technology on other welfare indicators such as farm incomes and number of months in a year with enough food. This is important in that it may assist policy makers know exactly where to target in the promotion of profitable and high yielding technologies for agricultural development and reduction of poverty among the disadvantaged rural society.
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