Adoption and crop productivity impacts of sustainable agricultural and land management practices in Zambia

by

Alefa Banda

Submitted in partial fulfilment of the requirements for the degree of MSc Agric (Agricultural Economics)

Department of Agricultural Economics, Extension and Rural Development
Faculty of Natural and Agricultural Sciences

University of Pretoria
South Africa

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DECLARATION

I **Alefa Banda** declare that this thesis, which I hereby submit for the degree of Master of Science in Agricultural Economics at the University of Pretoria, is my own work and has not been previously submitted by me for a degree at this or any other university.

Signature: ______________________________

Date: June, 2017

DEDICATION

To my dear parents, Brown Kamwana and Elina Banda

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ABSTRACT

Agricultural productivity in the Sub Saharan African (SSA) region has been cited to be low (Suttie & Benfica, 2016). As a result, there is a consistent call for evolution in smallholder farming. In addition to improving agricultural productivity, this evolution should factor in adaptation to climate variability and change. To achieve this, the use of sound and sustainable agricultural and land management practices (SALMPs) stands paramount. Among these include: (1) improved agronomic practices such as the use of improved seed varieties (HYV), (2) integrated nutrient management practices (INM), (3) tillage and residue management practices (TRM), (4) water management practices (WM), and (5) agroforestry practices (AF) (Branca *et al*., 2011 and Smith *et al*., 2007). These sets of SALMPs have been argued to be more environmentally friendly and are associated with positive and significant productivity impacts, in isolation and/or combination.

Even though several studies that analyse adoption and impacts of various agricultural practices exist, they are limited to single practices mostly. However, it is seldom that farmers adopt agricultural practices in isolation. Consequently, factors influencing adoption and impact of individual and combined sets of agricultural practices remain elusive. For instance, the influence of location specific and weather covariates with potentially significant effects on adoption decisions have not extensively been investigated. Among these variables include: agro-ecological zones and weather factors — temperature and rainfall. To address this issue, this study includes dummies for the three agro-ecological zones (AEZs) in Zambia and actual historical temperature and rainfall

data as explanatory variables. This is a step farther as opposed to using indicative variables based on farmer perceptions. Crop productivity, gross value of production and net revenue impacts of individual and combined sets of SALMPs are also estimated to achieve the main objective of the study. Unlike most studies, this research project uses panel data. A second panel sample is created for first-time adopters primarily to estimate pure adoption impacts of individual and combined sets of SALMPs.

The study findings show wide-spread distribution of SALMPs adoption sets by AEZs. The widely practiced sets of non-mutually exclusive SALMPs were HYV, TRM and INM practices, whereas AF practices were the least adopted. At household level, extensively practiced sets of SALMPs in combination include: HYV and INM practices, and HYV, INM and TRM practices. Various human and social capital characteristics, wealth status of the household, resource constraint and access to information variables, location and field level characteristics are found to have significant effects on adoption decisions. More interestingly, the influence of agro-ecological zone location dummies and weather factors are mixed. For example, compared to AEZ I a drier zone with the poorest distribution of rainfall, farm households located in AEZ IIa (area with good agricultural potential are significantly less likely to adopt WM practices). Also, higher average temperatures significantly lower the likelihood of adopting most sets of SALMPs, whereas adoption and dis-adoption is more likely with increase in the average rainfall during the growing season. This to some extent, indicates the climate variability and change adaptability potential of several SALMPs.

Lastly, the results from the impact analysis show that combining different sets of SALMPs yields positive and significant crop productivity gains per hectare. On average, the gains in crop productivity for widely practiced sets of SALMPs — HYV, INM and TRM practices and HYV and INM practices, are above 15 percent. This shows that greater productivity gains can be realized by adopting various combinations of different individual sets of SALMPs. In fact, first-time adopters were found to be better-off when specific sets of SALMPs are adopted in bundles. However, the expected net revenue impacts of individual and combined sets of SALMPs are mixed, even though they are negative for the most part.

These study findings support the positive and significant crop productivity impacts of SALMPs. However, the negative net revenue impacts, among maize selling households, suggest that the gains in crop productivity may not be sufficiently large enough to offset variable production costs. This, therefore, calls for simultaneous promotion of agricultural technology uptake and maize commercialization through value addition.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

ACRONYMS

SDGs	Sustainable Development Goals
UN	United Nations
FAO	Food Agricultural Organization of the United Nations
CSA	Climate Smart Agriculture
SA	Sustainable Agriculture
CA	Conservation Agriculture
CF	Conservation Farming
CT	Conservation tillage
SSA	Sub-Saharan Africa
FARA	Forum for Agricultural Research in Africa
US$	United States Dollars
IAPRI	Indaba Agricultural Policy Research Institute
RALS	Rural Agricultural Livelihoods Survey
SALMPs	Sustainable Agricultural and Land Management practices
TFP	Total Factor Productivity
HYV	High Yield Maize Variety
AF	Agroforestry Practices
INM	Integrated Nutrient Management Practices
TRM	Tillage and Residue Management Practices
WM	Water Management Practices
AEZ	Agro-Ecological Zone
CRE	Correlated Random Effects
MVP	Multivariate Probit
FE	Fixed Effects
SEA	Standard Enumeration Area
ZMW	Zambian Kwacha
Ha	Hectares

CHAPTER ONE

1.1 Introduction

Sustainable agriculture continues to be at the forefront of global development agenda due to the potential for climate change adaptation and mitigation. This attention is reinforced and signalled by the recent formulation of Sustainable Development Goals (SDGs) (United Nations (UN), 2016). Among the 17 SDGs formulated, Goal 2 explicitly highlights the need for sustainable agriculture while working towards ending hunger, achieving food security and improved nutrition. To achieve this SDG, sound agricultural practices stand paramount (UN, 2016) especially given that agricultural land in many countries including in Africa has competing needs for mining, urbanization and industrialization. This, therefore, calls for evolution in farming particularly smallholder in Sub-Saharan Africa (SSA) countries where agricultural productivity is low (Suttie & Benfica, 2016).

According to Ruttan (2002), differences in output per hectare and per worker among developed and developing countries have widened. As an example, the Forum for Agricultural Research in Africa (FARA, 2006:9) pointed out that in SSA land productivity is between 0 and 100 US$ output per hectare. This is lower in comparison to other regions that have experienced the green revolution breakthroughs such as developing Asia, Latin America and Caribbean. It is argued that productivity is low in many African countries because green revolution developments observed in other regions have yet to take hold (Africa Progress Panel Policy Brief, 2010:6).

Productivity growth experienced during the green revolution era was a result of various factors including intensive investment in the generation, improvement and use of agricultural technologies — irrigation and utilization of improved inputs; hybrid seed varieties and inorganic fertilizers. Of late, several other cost effective and more environmentally friendly agricultural and natural resource management practices, some of them conventional, are been promoted for adoption. Branca *et al*. (2011) and Smith *et al*. (2007) presented sets of such practices categorized as: (1) improved agronomic practices, (2) integrated nutrient management practices, (3) tillage and residue management practices, (4) water management practices, and (5) agroforestry practices. The first set of improved agronomic practices comprises the use of cover crops, legumes in crop rotation, improved crop varieties, crop and/or fallow rotations. Set two, integrated nutrient management practices — involves organic fertilization and/or nitrogenous inorganic fertilizer meant to improve nitrogen fixation. Set three, tillage and residue management practices — requires the use of minimum/zero tillage methods and/or crop residues etc. Set four, water management practices — through irrigation (drip), bunding, terraces, contour farming, and/or water harvesting. Lastly, agroforestry which entails having crops on tree-land and/or trees on cropland.

1.2 Problem statement and rationale

The fraction of farmers that make land improvements in Zambia irrespective of the land title ownership is very low (Sitko *et al*., 2014). This finding has implications for management and conservation of natural resources (especially land), as well as productivity growth among smallholders in Zambia. It is also indicative of probable deterioration in land quality over time.

Summary statistics from the 2015 Rural Agricultural Livelihoods Survey (RALS) report for Zambia showed that, among the potential tillage methods, only three are popular at national level: ridging, ploughing and conventional hand hoeing. Interestingly, adoption of conservation farming practices, which make use of minimum tillage methods, remains low (Indaba Agricultural Policy Research Institute — IAPRI, 2016). Furthermore, the results show rather remarkable level of utilization for some sustainable agricultural practices. For instance, over 60 percent of the farmers reported using improved seeds for maize, groundnuts, soya beans and cassava at national level. Among the tillage and residue management practices, retention of crop residue was more practiced. In contrast, the implementation of integrated nutrient management practices, such as the use of manure, was found to be limited — 5.4 percent at national level. In addition, farmers intercropping with nitrogen fixing leguminous crops accounted for 3.3 percent. Like other practices, agroforestry adoption is equally low.

A more relatively ready body of literature analysing adoption decisions relating to several agricultural practices and their respective effects on various agricultural outcomes exists (e.g., Dorfman, 1996; D'Souza *et al*., 1993; Ajayi *et al*., 2003; Nkonya *et al*., 2004; Smith, 2004; Pender *et al*., 2004; Pender & Gebremedhin, 2007; Marenya & Barret, 2007; Hall *et al*., 2009; Tey *et al*., 2012; Sitko *et al*., 2014; Teklewold *et al*., 2013; Kuntashula, 2014; Kuntashula *et al*., 2015; Khonje *et al*., 2015; Kassie *et al*., 2015a,b; Manda *et al*., 2015; Arslan *et al*., 2015; Arslan *et al*., 2016). Most of these studies analyse factors affecting the adoption of single agricultural practices, while those that analyse the adoption and impacts of more than one practice and the respective combinations on agricultural outcomes like crop productivity, remain scarce. Among these, Pender *et al*. (2004) for Uganda; Pender and Gebremedhin (2007) for the highlands of Tigray in Ethiopia; Kassie *et al*. (2015a, b) for Malawi and Ethiopia, Arslan *et al*. (2016) for Tanzania, respectively (see section 2.4.3.1 for a detailed review).

Notwithstanding this, the type and number of agricultural practices implemented within and across countries and/or regions by a typical smallholder farmer differ in general. Differences in agro-ecological environments and cropping systems among other factors contribute to this trend. This is one of the justification for this research project. This argument is based on Zhen and Roultry (2003) that stated that sustainability evaluation of specific farming practices should be conducted using site-specific indicators (e.g., economic indicators — crop productivity, social indicators — equality in income and food distribution, and ecological indicators — soil nutrient content, among others) within a specific time frame.

For Zambia, Smith (2004) examined the determinants of crop productivity per unit area and farm labour force in Southern Zambia. However, the fixed investments (aggregate cost) variable used to capture fixed land investments does not include practices whose costs were not reported or derived e.g., soil conservation practices (application of manure and minimum tillage). Kuntashula (2014) analysed welfare and on-farm environmental quality impacts of improved fallows, whereas Khonje *et al*. (2015) evaluated the impact of improved maize varieties only. Manda *et al*. (2015) and Arslan *et al*. (2015) conduct similar work for the Eastern province of Zambia and the entire country, respectively.

Like Kuntashula (2014) and Khonje *et al*. (2015), Manda *et al*. (2015) and Arslan *et al*. (2015) focused on maize, a staple cereal for Zambia. For sustainable agricultural practices, Manda *et al*. (2015) examined three individual practices and the combinations in relation to maize yields and household income. These practices are those which were actively promoted by a project.[1] They include, crop rotation involving maize and legumes, improved seed varieties for maize and retention of crop residues. Likewise, some of the climate smart agricultural practices[2] analysed by Arslan *et al*. (2015) are among those commonly promoted under the Zambia's conservation farming programme. Regarding the impacts of the practices, Manda *et al*. (2015)

[1] Sustainable Intensification of Maize-Legume Systems for the Eastern Province of Zambia (SIMLEZA)
[2] Minimum soil disturbance practices, crop rotation, legume intercropping, inorganic fertilizer and improved seed.

only estimated the average treatment effects on the population associated with individual and combined sustainable practices. Arslan *et al*. (2015) equally determined the effects of climate smart agricultural practices — individual sets only. Also, they did not analyse factors driving the adoption of these same practices. Further, Arslan *et al*. (2015) pointed out that comprehensive empirical evidence assessing the benefits of conservation farming in Zambia is still somewhat small, and that evidence for yield improvements is founded on less than robust research methods and simulated data, rather than observed data (see section 2.4.3.1 and 2.4.3.2 for a detailed review).

Moreover, univariate analysis has shown supremacy in identifying drivers of technology adoption, even though single agricultural practices are seldom adopted among smallholder farmers. Consequently, as Dorfman (1996) contends, the decision to adopt is essentially multivariate — involving interdependent-simultaneous adoption decisions. This implies that the total effect of adopting a combination of Sustainable Agricultural and Land Management Practices (SALMPs) is not the same as the sum of effects derived from adopting single sets of SALMPs (Wu & Babcock, 1998). Therefore, multivariate modelling is vital as it allows for evaluation of individual and combined agricultural practices. This research project is therefore warranted owing to the heterogeneity of SALMPs sets and their selection criteria for data analysis, varying agro-climatic conditions that are likely to influence adoption decisions, differences among the modelling techniques and the overall vagueness of the associated crop productivity impacts in Zambia.

1.3 Study objectives

Overall, this project seeks to determine the crop productivity impacts of individual and combined sets of SALMPs in Zambia.

The research project specifically seeks to:

1. Describe the distribution of SALMPs adoption sets by Agro-ecological zone
2. Identify the optimal individual and combined sets of SALMPs for a typical rural farm household.
3. Identify factors influencing the adoption of different sets of SALMPs.
4. Determine the level of maize productivity per hectare for a rural farm household for different SALMPs practices.

1.4 Research report outline

This thesis report has eight chapters. The first chapter presents the introduction and background. The problem statement and rationale, overall and specific objective(s) are also presented under this chapter. Chapter two presents a literature review. It reviews definitions of key terms, gives an overview of agricultural productivity growth in Zambia and a synthesis of relevant related empirical studies. Methods and procedures applied in the study are presented in Chapter three. Specifically, the chapter highlights the conceptual framework, econometric strategy applied, type of data used and the source. Chapter four presents and discusses the descriptive findings of the research project, whereas Chapters five, six and seven present and discuss the results of the econometric analysis. Lastly, study conclusions and main implications are drawn and made in Chapter eight, respectively.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter presents a review of literature on agricultural crop productivity and sustainable agriculture with the associated practices in four steps. The first section presents the definitions and measures of agricultural productivity. It also emphasises goals and principles of sustainable agriculture. An overview of SALMPs and agricultural productivity growth trends for Zambia is presented in the second section while the third section reviews specific empirical studies on adoption and impacts of SALMPs by focusing on specific themes. The review focuses on the research questions asked, methods and data used, and associated results. Lastly, the section closes with a conclusion highlighting relevant features of the reviewed literature, establishing the niche of this study and contribution to literature.

2.2 Agricultural productivity and sustainable agriculture

2.2.1 Definition and measurement of agricultural productivity

Fulginiti, Perrin and Yu (2004) define productivity as output per unit of input. While this is the case, there are principally two measures of agricultural productivity and these are, partial and total measures (Block, 1995). Partial measures are the amount of output per unit of a particular input. For example, yield and labour productivity — output per economically active person or per adult equivalent. The success of new agricultural production practices and/or technologies is generally evaluated using yield (Block, 1995). Among the total (multifactor) agricultural productivity measures is the Total Factor Productivity (TFP).The TFP index unlike the partial productivity measures, includes all inputs and outputs of a production process (Nkonde *et al*., 2015). Even though the full impact of technical change is not fully revealed in the partial measures, they are intuitively appealing and have welfare and/or policy significance (Block, 1995).

2.2.2 Sustainable agriculture

The definition of sustainable agriculture (SA) is embedded in its goal with Tilman *et al*. (2002) highlighting that the maximization of net benefits received (from agricultural activities and the ecosystem) by society defines SA. Net benefits such as increased agricultural production through increased output yield should be fostered by efficient use of available natural resources using ecologically based management practices. These are argued to improve cropland by minimizing degradation of land and water resources and consequently contributing to climate change adaptation (Branca *et al*., 2011). Lee (2005) underlined that these practices are often site-specific because of the prevailing population requirements, existing natural resources and environmental conditions. Thus, SALMPs cannot be generalized and scaled up with ease. It is also worth pointing out that SALMPs practices are not necessarily new, they emanate from traditional knowledge and practices (Kassie & Zikhali, 2009).

While several benefits of SA practices have been identified, major factors limiting their adoption have also been identified. Kuyvenhoven and Ruben (2002) highlighted that the higher labour intensity of the sustainable agricultural practice, the lower the likelihood of adoption. Figure 1 depicts a typical relationship between the expected yield effects and labour requirements for several practices. Reinforcing the critical role of labour, the figure shows practices requiring a lot of labour are associated with lower yield effects.

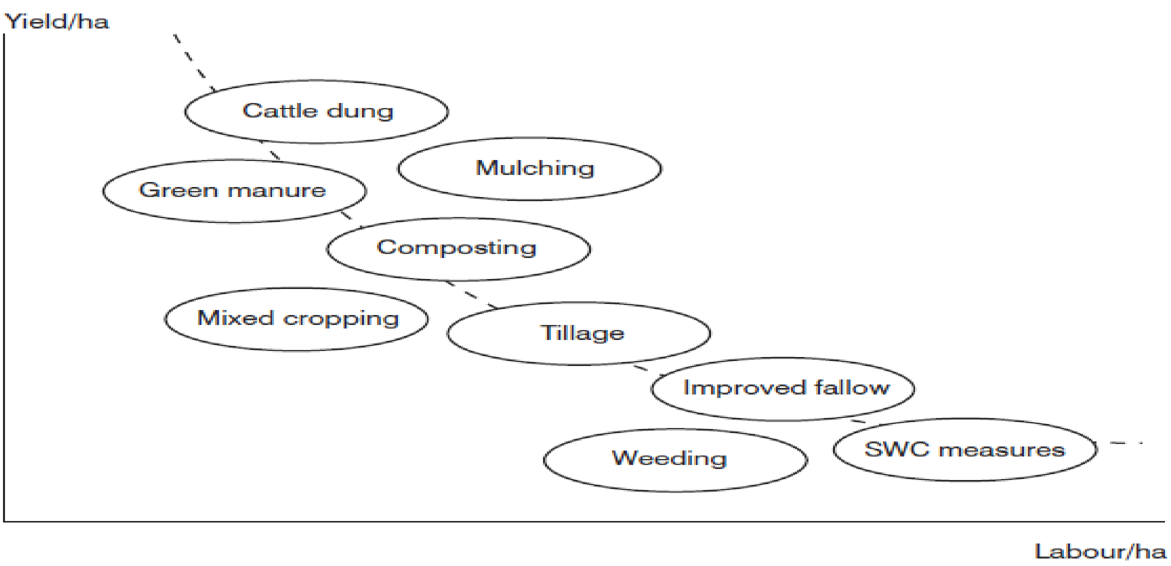

Figure 1: Labour requirements of Conservation Agriculture (CA) techniques versus yield. Source: Kuyvenhoven and Ruben (2002)
***SWC — Soil and Water Management Practices**

2.2.3 Principles of sustainable agriculture

Kassie and Zikhali (2009) illustrate three principles of sustainable agriculture which are not mutually exclusive. The first principle is economic sustainability that highlighted how vital economic profitability, through increased yields, is for agricultural sustainability. Second principle is environmental sustainability that proposes minimal and/or no destructive environmental effects through reduced use of synthetic chemicals, improved natural resource base that is the basis for the agricultural economy. Third, social sustainability identifies more extensive use of available labour, at least for some techniques, thus contributing to cultural cohesion.

2.3 Sustainable agricultural and land management practices and agricultural productivity growth trends for Zambia

2.3.1 SALMPs in Zambia

In Zambia, conservation farming (CF) which employs conservation tillage methods (CT) has principally been the vehicle through which many SALMPs have been promoted (Manda *et al*., 2015). According to the Conservation Farming Unit (CFU) (1997), CT comprises a combination of several practices that facilitate conservation of soil, moisture, improved inputs like inorganic fertilizers and seeds, and resources like time and money. These practices include, crop residue retention, reduced tillage, completion of land preparation in the dry season, digging planting basins, early ripping, application of lime, organic fertilizer (manure) etc. This applies to ox and hand-hoe farmers. Combination of CT practices with others like crop rotation and nitrogen fixing legumes, define CF (CFU, 1997). Some of the benefits associated with CF include, reduced soil erosion and better rainwater infiltration, fixation of atmospheric (free) nitrogen by legumes (CFU, 1997) among others.

In Zambia, rain-fed agriculture is the mainstream especially among smallholder farmers. This makes agricultural production activities subject to weather induced production risks. Based on amount of rainfall received, three Agro-Ecological Regions (AERs) — AER I, II and III define the agro-ecology of Zambia (Siegel, 2008; Famine Early Warning Systems Network (FEWS NET), 2013; Chikowo, n.d). Figure 2 shows the three Agro-ecological zones of Zambia, while some of the associated key characteristics are presented in Table 1.

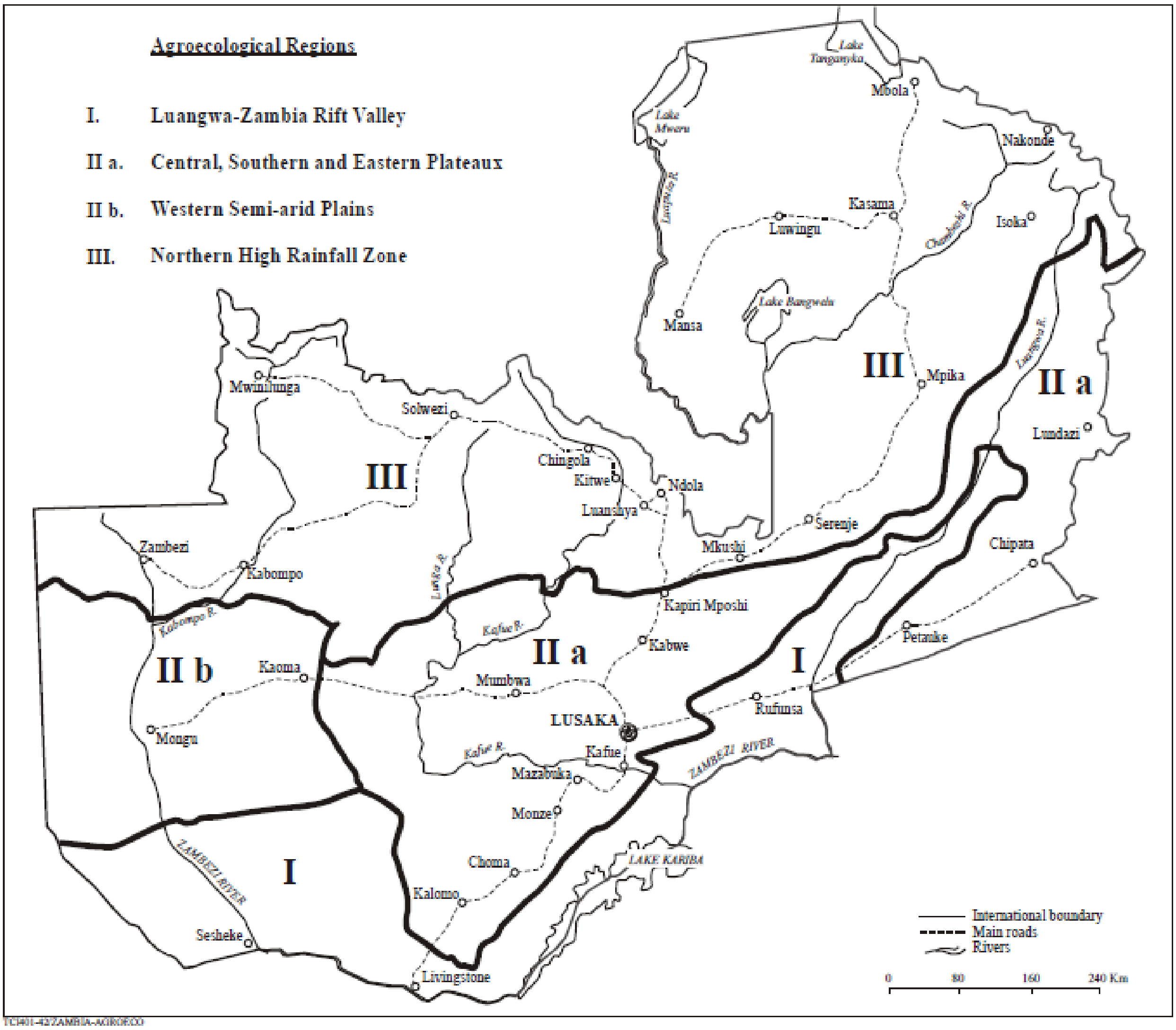

Figure 2: Agro-ecological Zones of Zambia
Source: Siegel (2008) adopted from FAO (2005)

Table 1: Characteristics of Agro-ecological zones of Zambia

Region	Location/Provinces Covered	Rainfall (mm)	Growing season (days)	Soil Quality/types -- Agricultural Potential	Agricultural Potential Crop Potential
AEZ I	Luangwa-Zambezi Rift Valleys — most of Southern Province and parts of Western and Eastern Provinces	600-800mm	80-120 days	Slightly acidic loamy and clayey soils with loam topsoil, and acidic-shallow sandy soils	Poor
AEZII	Most parts of Central, Eastern, Lusaka, Southern Provinces, and parts of Western Province — Western Semi-arid Plains	800-1000mm	100-140 days	Common soils are red to brown clayey to loamy soil types that are moderately to strongly leached.	Good
AEZ III	Northern, Luapula, Copperbelt, Northwestern Provinces	1100-1700mm	120-150 days	Leached and acidic sands	Moderate

Source: Compiled by author from (Siegel, 2005; FEWS NET, 2013; Chikowo, n.d)/ http://www.yieldgap.org/zambia

2.3.2 Agricultural productivity growth in Zambia: A trend overview

Sub-Saharan Africa as a region experienced slow and in some cases negative agricultural productivity growth during the period from 1960 to the 1970s. However, since the 1980s it has shown positive trends, even though productivity levels are still low compared to other regions (Fuglie & Rada, 2013; Block, 2010). A review of the existing work on agricultural productivity growth trends shows that several attempts have been made to estimate this factor by region and country.

Table 2 shows annual agricultural productivity growth rates for Zambia over time estimated by various authors. Yu and Nin-Pratt (2011) showed that TFP grew slowly by 1.3 percent for Zambia between 1984 and 2006. But, in the second period, between 1995 and 2006 TFP grew slightly by 2.0 percent. Additionally, Yu and Nin-Pratt (2011) further examine partial productivity measures (labour and land productivity) to better understand TFP. The top nine performing countries in SSA based on TFP growth are listed over a period of improved performance, 1995-2006. Among these, Zambia showed on average relatively high annual TFP growth (1.98 percent) and sustained growth in labour (1.17 percent) and land productivity (1.76 percent).

Earlier, Block (2010) estimates for the period 1961-2007 showed that labour and land productivity in Zambia grew by 0.36 and 2.46 percent annually during the same period, respectively. Fuglie and Rada (2013) estimated 0.8 percent TFP growth for the period 1961-2008, and 1.61 percent for 1985-2008. Alene (2010) estimated 1 percent TFP growth between 1970 and 2004. Avila and Evenson (2011) estimated 1.12 percent during the period 1961-1980 when productivity growth was slow and/or negative for SSA. However, between 1981 and 2001 they found negative productivity growth, 0.7 percent per annum. Fulginiti, Perrin and Yu (2004) estimated 0.82 percent TFP growth per annum between 1962-1991 relatively closer to what was found earlier, 0.999 percent, by Fulginiti and Perrin (1998). Regarding the sources of TFP growth upon decomposition, evidence is indeterminate (Table 2). For instance, Yu and Nin-Pratt (2011) showed that TFP growth is explained by efficiency gains rather than technological advances. This is consistent with the findings by Fulginiti and Perrin (1998). In contrast, Alene (2010) found that efficiency growth contributed negatively towards TFP growth, whereas the contribution of technological change was positive.

Table 2: Annual Agricultural Productivity Growth Trends - Zambia (1961-2008)

Author	Period	No. of SSA/African/DC countries	TFP growth	Efficiency Growth	Technology Change	Labour Productivity Growth	Land Productivity Growth
Yu and Nin-Pratt (2011)	1984-2006	26	1.3	1.3	1		
	1995-2006	26	2.0	1.9	1.1		
	1995-2006	9	1.98			1.17	1.76
Block (2010)	1961-2007	46				0.36 (0.441)	2.46 (1.21)
Fuglie and Rada (2013)	1961-2008	31	0.8 (0.59)				
	1985-2008	31	1.61(1.07)				
Alene (2010)	1970-2004	53	1 (0.3)	-0.4(0.2)	1.4(0.1)		
	1970-2004	53	1.1(1.8)	-1.0(-0.1)	2.2(1.9)		
Avila and Evenson (2011)	1961-1980	Entire Africa	1.12(1.20)				
	1981-2001	Entire Africa	-0.70(1.68)				
Fulginiti *et al*.(2004)	1962-1999	41	0.82(0.83)				
Fulginiti and Perrin (1998)	1961-1985	18 DCs*	0.999(0.984)	1.024(1.005)	0.976(0.979)		

Source: Authors' own compilation from selected previous agricultural productivity studies
Notes: Figures in brackets are respective mean values for the total number of countries for each period. Also, see specific study for details on the estimation methods and number of SSA and/or African countries considered.
*- Developing countries

2.4 Related empirical literature on adoption and impacts of SALMPs.

Empirical literature on the relationship between SALMPs and agricultural productivity, specifically crop productivity, is growing. All these studies focus on a similar set of research questions and test similar hypotheses. While doing so, they employ primarily cross-sectional data with a few studies using on panel data. Equally, while similar methods and procedures are used to test the relationship, the type and number of SALMPs (individual and combined) analysed differ in many cases.

2.4.1 Research questions asked

Primarily, the empirical literature on SALMPs and agricultural crop productivity can be categorised into three groups. The first, looks at the adoption of individual sets of SALMPs only (e.g., D'Souza *et al*., 1993; Arellanes & Lee, 2003; Ajayi *et al*., 2003; Nkonya *et al*., 2004; Smith, 2004; Marenya & Barret, 2007; Hall *et al*., 2009; Wollni *et al*., 2010; Tey *et al*., 2012; Teklewold *et al.*, 2013; Sitko *et al.*, 2014; Kuntashula, 2014; Khonje *et al*., 2015) and their combinations (e.g., Dorfman, 1996; Kassie *et al*., 2015a,b; Manda *et al*., 2015; Arslan *et al*., 2016). The second, examines adoption and associated effects/impacts on crop productivity (e.g., Wu & Babcock, 1998; Smith, 2004; Pender & Gebremedhin, 2007; Kuntashula, 2014; Khonje *et al*., 2015; Kassie *et al*., 2015a,b; Manda *et al*., 2015; Arslan, Belotti & Lipper, 2016). The third, solely on the effects of these SALMPs on crop productivity (e.g., Pender *et al*., 2004; Arslan *et al*., 2015).

Essentially, these empirical studies (on impact analysis) are motivated by research question(s) and/or hypothesis about the relationship between SALMPs and agricultural crop productivity. For example, while agreeing that the potential effects of CF practices on yields are positive, Arslan *et al*. (2015) ask three questions: (1) how large is the effect? (2) how much of this effect can be attributed to the practice itself? and (3) how do these practices interact with climatic variables? Most available impact studies on SALMPs and crop productivity are motivated by either the first or second question. This applies to the rest of the studies in the aforementioned groups two and three given their study methods, findings and conclusions, whereas those in groups one and two (in addition to impact questions) ask what factors drive the adoption of these practices.

2.4.2 Methods and data used

Methods and data used comparatively vary among SALMPs and agricultural crop productivity studies. To model individual SALMPs and their respective combinations, dummy variables have been used to indicate adoption and non-adoption of practices. For instance, for Zambia, residue retention, crop rotation and improved maize varieties (Manda *et al*., 2015); improved maize varieties only (Khonje *et al*., 2015); fertilizer trees, minimum tillage, crop rotations and crop varieties (Kuntashula *et al*., 2015); and improved fallows (Kuntashula, 2014). The corresponding combinations involve creation of composite dependent variables to represent different sets of combined SALMPs, applicable only to Manda *et al*. (2015) among the studies for Zambia.

Modelling adoption decisions of these practices has involved the use of non-linear binary and polychotomous choice models. Binary choice models, like the logit and probit probability models have been used to model adoption decisions for single practices only (e.g., D'Souza *et al*., 1993; Arellanes & Lee, 2003; Nkonya *et al*., 2004; Pender & Gebremedhin, 2007; Khonje *et al*., 2015; Kuntashula *et al*., 2015; Kuntashula, 2014; Kassie *et al*., 2011). In contrast, multinomial models have been used for polychotomous choices. These include the mixed logit probability model (Manda *et al*., 2015); multinomial logit (e.g., Wu & Babcock, 1998; Kassie *et al*., 2015 a, b); multivariate and ordered probit models (e.g., Wollni *et al*., 2010; Teklewold *et al*., 2013; Arslan *et al*., 2016). This modelling has been done using mostly cross sectional data except for Wu and Babcock (1998); Kassie *et al*. (2015a), and Arslan *et al*. (2016), who use panel data.

The multinomial logit (MNL), multivariate and ordered probit models have so far stood out to be the main estimators for estimating models with polychotomous outcome variables. The MNL is advantageous in that: (i) evaluation of alternative combinations of agricultural practices in addition to individual ones, can be done with ease, (ii) both interaction between alternative practices and self-selection are accounted for (Wu & Babcock, 1998; Kassie *et al*., 2015 a, b). Nevertheless, the MNL has some limitations. Wu and Babcock (1998) indicated that the assumption of independence of irrelevant alternatives (an unappealing control to place on farmer conduct) as the main limitation of the MNL, even though estimation is made more convenient. On the other hand, authors like Dorfman (1996), and Teklewold *et al*. (2013) argued that the adoption decision is inherently multivariate. In such a case, other estimators like the multivariate probit (MVP) can be applied. The multivariate probit is attractive for modelling choice behaviour as it permits a flexible correlation structure for the unobservable covariates (Huguenin *et al*., 2008). Moreover, more recently, Teklewold *et al*. (2013) found that estimates from the MVP largely differed across all equations estimated. This indicated the appropriateness of differentiating between practices as heterogeneity in adoption of agricultural practices was found and analysis of each separate practice is supported rather than grouping the practices into a single variable (Teklewold *et al*., 2013).

To determine the effects/impacts of these agricultural practices on crop productivity, most of the studies use partial productivity measures — yield and/or output value per unit area of the crop, focusing mainly on staple crop(s). For instance, maize yield (e.g., Arslan *et al*., 2016; Manda *et al*., 2015; Kassie *et al*., 2015a; Arslan *et al*.,2015; Kuntashula, 2014; Wu & Babcock, 1998); maize income per hectare (Kassie *et al*., 2015a); net crop income per hectare (e.g., Khonje *et al*., 2015; Kassie *et al*., 2011),while some consider the crop output gross value per unit area (e.g., Pender *et al*., 2004, 2007; Smith, 2004). Estimators applied include: Ordinary Least Squares (OLS), Instrumental Variable (IV), Random Effects (RE), Fixed Effects (FE) and Propensity Score Matching (PSM) techniques. Among these, FE is the most favoured by numerous panel data studies — on impacts of agricultural practices (e.g., Arslan *et al*., 2015, 2016; Kassie *et al*., 2015a).

2.4.3 Results of past studies

2.4.3.1 Factors driving the adoption of SALMPS

From the adoption literature, factors influencing adoption decisions of individual sets of SALMPs and their combinations fall under the following categories: (1) household demographics (2) physical capital and wealth, (3) social capital, (4) access to services/information, (5) location characteristics, and (6) field characteristics, crop stresses and weather factors. A good number of these covariates are also hypothesised to influence crop productivity.

The first category of household demographics represents human capital variables which include: age, gender and education level of the household head as well as the household size. Several authors found these covariates to significantly influence adoption decisions in relation to certain sustainable agricultural practices, while for others the effect was not significant. For instance, the age of the household head by D'Souza *et al*. (1993); Ajayi *et al*. (2004); Teklewold *et al*. (2013); Sitko *et al*. (2014); Manda *et al*. (2015) and Kuntashula *et al*. (2015). Among these, Kassie *et al*. (2015b); Khonje *et al*. (2015), and Arslan *et al*. (2016) found age of the household head to be insignificant in explaining adoption decisions. Significant gender effects were found by Teklewold *et al*. (2013); Sitko *et al*. (2014); Manda *et al*. (2015) and Arslan *et al*. *et al*. (2016), whereas Kassie *et al*. (2015b) found none. Likewise, significant education effects were found by D'Souza *et al*. (1993); Dorfman (1996); Wu and Babcock (1998); Khonje *et al*. (2015), whereas Sitko *et al*. (2014); Manda *et al*. (2015) and Arslan *et al*. (2016) found mixed effects. Ajayi *et al*. (2004), Teklewold *et al*. (2013) and Kassie *et al.* (2015b) found no significant influence of the household heads' education level. Lastly, varied effects of the household size/adult equivalents — indicators of labour availability were found by Ajayi *et al*. (2004) and Sitko *et al*. (2014), although Manda *et al*. (2015) and Khonje *et al*. (2015) found explicit significant effects on adoption decisions. Conversely, Teklewold *et al*. (2013) and Kassie *et al*. (2015b) found none.

The second category of physical capital and wealth characteristics comprise the following: farm size, livestock ownership, value of assets owned, access to and amount of off-farm income. D'Souza *et al*. (1993), Khonje *et al*. (2015) and Kuntashula *et al*. (2015) found determinate and significant adoption effects for some of these covariates, whereas Dorfman (1996) and Kassie *et al*. (2015b) found none. Mixed effects were found by Ajayi *et al*. (2004); Teklewold *et al*. (2013); Sitko *et al*. (2014); Manda *et al*. (2015) and Arslan *et al*. (2016). Social capital is another category and it includes elements such as: participation in a government agricultural related programmes, farmer cooperative/association membership, kinship ties, number of relatives and grain traders. Several studies that found at least of one of these covariates to be significant e.g., Khonje *et al*. (2015), while Wu and Babcock (1998) did not. Teklewold *et al*. (2013), Sitko *et al*. (2014); Manda *et al*. (2015); Kassie *et al*. (2015b); Arslan *et al*. (2016) are other studies that found both significant and non-significant adoption effects of several social capital factors listed. Access to input subsidy programmes, credit, agricultural commodity price information and information on agricultural practices create the fourth category of access to services/information. For this category, Wu and Babcock (1998) and Khonje *et al*. (2015) found significant effects for some of the factors. But, Teklewold *et al*. (2013), Manda *et al*. (2015); Kassie *et al*. (2015b), Kuntashula *et al*. (2015) and Arslan *et al*. (2016) found mixed adoption effects.

The fifth category encompass location characteristics such as distances to key services and infrastructure — input and output markets, nearest tarmac, feeder road, main town and agricultural camp office. Agro-ecological zone location also qualifies as a location characteristic. Among the studies that found some of these factors to have significant adoption effects is that by Khonje *et al*. (2015), while Kassie *et al*. (2015b) found none. Mixed adoption effects were found by Sitko *et al*. (2014), Manda *et al*. (2015), Kuntashula *et al*. (2015) and Arslan *et al*. (2016). Lastly, field characteristics, crop stresses and weather factors involve variables such as: distance from homestead to the plot, tenure status of field, soil depth, slope of the field, susceptibility to soil erosion/flooding, pests and diseases, exposure to improved fallows, drought, rainfall distribution and temperature. D'Souza *et al*. (1993), Wu and Babcock (1998) and Ajayi *et al*. (2004) found significant adoption effects for at least one of the listed factors. The rest of the studies by Teklewold *et al*. (2013), Sitko *et al*. (2014), Manda *et al*. (2015), Kassie *et al*. (2015b), Khonje *et al*. (2015), Kuntashula *et al*. (2015) and Arslan *et al*. (2016) found mixed adoption effects. Overall, the influence of numerous cited variables on adoption decisions is indeterminate. This is because of the different types of practices analysed from one study to another. For studies were the adoption effects of covariates analysed were determinate, they looked at a single practice.

2.4.3.2 Crop productivity impacts of SALMPS

In Uganda, Pender *et al*. (2004) analyse ways to intensify agricultural productivity and reduce land degradation. Among the land management practices analysed, they find that crop rotation reduces the value of production using OLS and IV regression models. They also find this negative effect for manure and compost under the IV regression model only. For the highlands of Tigray in Ethiopia, Pender and Gebremedhin (2007) assess drivers and impacts of similar practices in crop production. They find that contour ploughing, reduced tillage, and manure/compost (except under the IV model) application have significant positive effects on the value of production.

Unlike Pender *et al*. (2004) and Pender and Gebremedhin (2007), Manda *et al*. (2015) analyse the adoption and impacts of individual and different combinations of SALMPs. Using a multinomial endogenous treatment effects model, Manda *et al*. (2015) show that adoption of improved seed varieties for maize in isolation has greater impacts on maize yields for Eastern Zambia. Also, an agricultural practices bundle consisting rotation of maize with legumes and retention of crop residues has a greater impact on household incomes. They attribute the limited impact of improved seed varieties for maize to high inorganic fertilizer costs. Similarly, Khonje *et al*. (2015) arrive at a similar conclusion using the same data for the same area. Estimating the impact of improved maize varieties only, they conclude that adopting improved maize varieties results in significant gains in crop incomes. Contrasting Manda *et al*. (2015), they use both endogenous switching regression and PSM techniques for impact analysis.

Kassie *et al*. (2015a) also apply endogenous switching regression models using panel data for Ethiopia. They estimate the impacts of cropping system diversification (CSD), conservation tillage (CT) and improved variety (IMV) and their combinations. Their results show that the impact on net maize income per hectare is greater when these practices are adopted in a bundle. Kassie *et al*. (2015b) apply the same methods using cross sectional data for Malawi. However, they only analyse two technology choices, crop diversification and minimum tillage, and their combination. They find and conclude that greater maize yield effect is associated with joint adoption of crop diversification and minimum tillage. Using panel data, Arslan *et al*. (2015) find legume intercropping, inorganic fertilizer and improved seed variety to have significant positive effects on maize yield, whereas the effect of crop rotation is negative. Nonetheless, they do not analyse maize yield effects associated with different combinations of these practices. Similarly, Arslan *et al*. (2016) estimate the impacts of individual and combined sets of agricultural practices on maize yields using FE. They find that soil and water conservation practices, in isolation and combination with other practices and weather shocks, significantly and positively affect maize yields. Other practices such as the use of inorganic fertilizers yield similar positive effects. These effects are much greater when the use of inorganic fertilizers is combined with other sets of agricultural practices. Separate use of improved seeds is found not to have a statistically significant effect. But, a combination of: intercropping, inorganic fertilizer, improved seed use and soil and water conservation practices is found to have the highest yield gain effects.

2.5 Conceptual framework

Agricultural innovations/technologies/practices are usually promoted in bundles. As a result, it is not often that farmers will adopt single practices. This strategy builds their resilience against negative shocks related to agricultural production activities. Among these shocks and constraints comprise: low crop productivity, limited access to credit and unfavourable climatic and field conditions (Dorfman, 1996; Teklewold *et al*., 2013; Manda *et al*., 2015; Kassie *et al*., 2015a, b).

The adoption selection model analyses identified SALMPs that fall into five sets following Branca *et al*. (2011) and Smith *et al*. (2007): (a) improved agronomic practices (HYV), (b) integrated nutrient management practices (INM), (c) tillage and residue management practices, (d) water management practices, and (e) agroforestry practices. In view of that, modelling adoption decisions, in this study like others, stem from the random utility theory. Assuming each set of SALMPs is an option for a farm household i, the farm household is expected to select a particular set of SALMPs that maximises its' expected utility denoted by h_{ijt} subject to field and household level characteristics. Thus, the farm household will select any set of SALMPs j, over any other optional SALMPs set m provided $h_{ijt} > h_{imt}, j \neq m$ in period t.

2.6 Conclusion

A review of agricultural productivity growth over the years for Zambia shows that it has been fostered, greatly, by technological change and land productivity growth. This has implications for the screening and promotion of SALMPs that are argued to have a positive and significant impact on the land resource. Moreover, high labour intensive practices are more likely to be associated with low adoption rates and yields.

Individual sets of SALMPs and the respective combinations analysed differ among the studies reviewed. Also, selection of these SALMPs for analysis is mostly purposive. Furthermore, the influence of covariates on adoption decisions of SALMPs is mixed. Likewise, crop productivity measures vary, but the use of partial measures is still dominant in the literature. These include yield and/or output value per unit area (typically for a single crop). While it is well theorized that agro-ecological conditions influence SALMPs adoption decisions, few studies test this preposition. Mainly, due to the limited representativeness of the data used. In terms of impact analysis, combining different sets of SALMPs seem to lead to greater positive gains in the outcome variable(s). However, the number of studies that analyse such combinations, using panel data, is limited.

This study therefore will add to the available literature on the adoption and impacts of individual sets of SALMPs and the associated combinations. The contribution of this project include: (1) the use of nationally representative panel data to analyse adoption decisions controlling for agro-ecological location variables, historical rainfall and temperature data (compared to using indicative variables as is typical) based on farmer perceptions; (2) factors influencing adoption of the different sets of SALMPs are determined by using a panel sample consisting of first-time adopters only — those who did not adopt any set of SALMPs in 2012 and those that later adopted, and/or dis-adopted in 2015. Among the sets of SALMPs analysed is AF practices, whose analysis is limited in the available literature; (3) in addition to estimating the crop productivity (maize yield) impacts, this study also estimates the gross value of maize produced as well as the net revenue impacts of individual and combined sets of SALMPs. This impact analysis is also extended to a panel sample of first-time adopters only as in the case for the selection model.

CHAPTER THREE

RESEARCH METHODS AND PROCEDURES

3.1 Introduction

This chapter provides a description of the data, analytical methods and procedures as well as variables that were analysed to achieve the stated study objectives. Firstly, it presents a description of the data type, data source and associated sampling techniques. Secondly, the selection model used is specified. Thirdly, the general model form used to estimate crop productivity, gross value of production and net revenue impacts of the different sets of SALMPs is also specified. Lastly, explanatory covariates used in the regression models are specified and defined.

3.2 Data and sampling

The data used for this study is panel in nature. This data comprised of data collected in the 2012 and 2015 RALS. The two surveys were implemented by IAPRI in partnership with the Zambia's Central Statistical office (CSO). The RALS 2012 and 2015 employed a two-stage stratified sample design. In the first stage, the Primary Sampling Unit (PSU) was identified and defined as one or more Standard Enumeration Areas (SEAs). A typical SEA had a minimum of 30 farm households (IAPRI, 2016).

This panel data represents events in relation to agriculture for the 2010/11 (2012 RALS) and 2013/14 (2015 RALS) agricultural production and corresponding marketing seasons. The sample constitutes representative rural farm households engaged in agricultural production activities (crop and livestock production). Data captured in the 2012 and 2015 RALS include: demographic characteristics of household members, farm land and use, crop management, main source of labour for various crops, crop sales from own production, livestock sales, fertilizer acquisition, acquisition of seed and/or planting material, household assets/implements, off-farm income activities, access to agricultural information, distances to infrastructure, and kingship ties among others (RALS, 2012 & RALS, 2015).

The sample size for the RALS 2012 is 8,840 households, while the total number of re-interviewed panel households is 7,254 (IAPRI, 2016). The panel is balanced with a total of 14,508 households interviewed in both waves. The data was then merged with historical temperature and rainfall data. This weather data is from the current (1950 – 2000) climate data from WordClim's website at the "10 arc-minutes"[3].

3.3 Model for identifying factors affecting the adoption of SALMPS

To identify factors influencing the adoption of SALMPs, a panel selection model — correlated random-effects multivariate probit (CRE-MVP) was applied. The model specification follows that described in Wooldridge (2013:497-499) and applied by Arslan *et al*. (2016) and Namonje and Chapoto (2016). The choice of the MVP is supported by Teklewold *et al*. (2013) that argued that the adoption decision is inherently multivariate and the need to differentiate between practices due to heterogeneity in adoption decisions pertaining to agricultural practices. Consequently, analysis of each separate practice rather than grouping the practices into a single variable is sustained (Teklewold *et al*., 2013).

Taking utility maximization as the driving force behind adoption decisions concerning SALMPs then:

$$h_{ijt}^{*} = \beta_j x_{ijt} + \varepsilon_{ijt} \qquad (1)$$

where

$$\varepsilon_{ijt} = \alpha_{ij} + v_{ijt} \qquad (2)$$

Where h_{ijt}^{*} denotes the latent variable describing the *i*th farm households' behaviour in adopting the *j*th set of SALMPs, *j*=1, 2,…, *m* over any other alternative sets of SALMPs *m* in period *t*, x_{ijt} – denotes a vector of exogenous covariates likely to influence the adoption decision; ε_{ijt} is the error term which contains unobserved individual-specific effect, α_{ij} and v_{ijt} the idiosyncratic error term. The term, α_{ij} is split up into a part that is related to the time-averages of independent variables and a part r_{ij} — unrelated to the independent variables. Equation 3 defines the unobserved individual-specific effect.

[3] http://www.worldclim.org/current

$$\alpha_{ij} = \propto + \gamma_j \bar{x}_{ijt} + r_{ij} \tag{3}$$

then

$$h_{ijt}^{*} = \beta_0 + \propto + \beta_j x_{ijt} + \gamma_j \bar{x}_{ijt} + r_{ij} + v_{ijt} \tag{4}$$

where

$$h_{ijt} = \begin{cases} 1 \; if \; i \; adopts \\ 0 \; otherwise \end{cases} \tag{5}$$

While h_{ijt}^{*} is the latent dependent variables, h_{ijt} is the observed choice binary dependent variable. It indicates the households' adoption behaviour for each set of SALMPs and is defined by equation 5. The term $\bar{x}_{ijt}$ denotes the group means of time varying covariates in adoption models which are included as extra regressors following Mundlak (1978) and Wooldridge (2013:497-499).

3.4 Model for determining crop productivity, gross value of production and net revenue impacts of SALMPS

To determine crop productivity, gross value of production and net revenue impacts of different individual and combined sets of SALMPs, this study followed steps similar to Mason and Smale (2013); Arslan *et al*. (2016). The model was estimated using the fixed effects (FE) estimator to control for unobserved heterogeneity given the specification:

$$y_{it} = \theta_t + x_{it}\beta + h_{it}\delta + c_i + \epsilon_{it} \tag{6}$$

where y_{it} denotes the natural logarithm of the impact outcome variables — crop productivity — maize yield (kg/ha), gross value of maize produced and net maize revenue in Zambian Kwacha per hectare (ZMW/ha) for a typical farm household *i* at time *t* ; x_{it} is a vector of time varying control covariates which are likely to affect crop productivity and the other outcomes; h_{it} is the J — vector of binary variables indicating the adoption of individual sets of SALMPs and the respective combinations — these are interacted with the time dummy (year=1 if time=2015) for the full sample; c_i is time-constant heterogeneity, and ϵ_{it} is the error term that varies with time.

Table 3: Description of choice, impact and explanatory variables used in the Selection and FE regression models

Variables	Definition
Choice Variables	
Improved agronomic practices (HYV)	Dummy, 1=yes if improved maize seed varieties were used
Agroforestry (AF)	Dummy, 1=yes if trees were planted on crop land/crops on tree land
Integrated Nutrient Management (INM)	Dummy, 1=yes if manure/compost was applied and/or inorganic fertilizer was used
Tillage and Residue Management (TRM)	Dummy, 1=yes if crop residues were retained in the field and/or minimum tillage practices (planting basins, zero tillage) were implemented
Water Management Practices (WM)	Dummy, 1=yes if field is irrigated and/or stone buds/earthen buds/terraces/drainage/ditches/grass barriers built and/or contour farming were implemented
Household characteristics	
Age	Age of Household head in years
Gender	Male headed household
Education level	Education level of the household head in years
Household size	Number of household members — Indicator of labour availability
Impact Variable	
Crop productivity	Maize yield (kg/ha)
Gross value of maize produced	Gross value of maize produced (ZMW/ha)
Net maize revenue	Net revenue from maize sold (ZMW/ha)
Resource constraints	
All animal / equipment assets (ZMW per HH)	Value of productive assets (ZMW)
Farm size	Comprises all cultivated land and land on fallow in hectares
Tropical Livestock Units	Indicator of livestock ownership
Net off farm income	Net household income less farm income (ZMW) per annum
Access to fertilizer loan	Dummy, 1=yes if got fertilizer through a loan purchase from private trader/retailer or purchase from out-grower scheme or others
Access to maize seed loan	Dummy, 1=yes if got maize seed loan through an out-grower loan or seed retailer loan or other loan
Social capital factors and government support	
FISP recipient	Dummy, 1=yes if acquired seed and/or fertilizer from the Farmer Input Support Programme (FISP) programme
Kinship ties	Dummy, 1=yes of household head/spouse related to the chief/headman in the village or locality

Member of a farmer cooperative	Dummy, 1=yes if member of a farmer cooperative
Access to information and key infrastructure/facility/service provider	
Received advice on CF	Dummy, 1=yes if household received information/advice on conservation farming (CF)
Distance to the nearest agricultural camp/block office	Distance in kilometres from the homestead to the nearest Agricultural camp/block office
Distance to the nearest agro-dealer	Distance in kilometres from the homestead to the nearest Agro-dealer
Distance to the nearest fertilizer retailer	Distance in kilometres from the homestead to the nearest private fertiliser retailer (during the fertiliser selling season, i.e., October/November)
Distance to the nearest market	Distance in kilometres from the homestead to the nearest established market place with many buyers & sellers of locally produced agricultural products
Field characteristics	
Distance from the homestead to the field	Distance from the homestead to the largest maize field in kilometres
Field tenure	Dummy, 1=yes if state land titled or formal customary land titled
Field prone to soil erosion/flash flooding	Dummy, 1=yes if field is prone to soil erosion and/or flash flooding
Field in a wetland/dambo area	Dummy, 1=yes if field is in a wetland/dambo area
Agro-ecological zone	
AEZ I, Luangwa-Zambezi Rift Valleys	Dummy, 1=Luangwa-Zambezi Rift Valleys
AEZ IIa, Central, Southern and Eastern Plateaus	Dummy, 1= Central, Southern and Eastern Plateaus
AEZ IIb, Western Semi-Arid Plains	Dummy, 1= Western Semi-Arid Plains
AEZ III, Northern High Rainfall Zone	Dummy, 1=Northern High Rainfall Zone
Weather factors	
Average monthly temperature degrees Celsius (^{o}C)	Average monthly temperature degrees Celsius (^{o}C)
Average monthly precipitation (mm)	Average monthly precipitation during the growing season (mm)

Source: Compiled by the author from RALS 2012 and 2015 questionnaires and reviewed literature

CHAPTER FOUR

DESCRIPTIVE ANALYSIS

4.1 Introduction

This chapter presents and discusses the summary statistics of variables used in the analysis in four stages. Firstly, it examines adoption of SALMPs by agro-ecological zones per year. Secondly, it shows descriptive statistics on the use of individual and combined sets of SALMPs by year at household level. Thirdly, it presents correlation matrices for the five sets of SALMPs for each period. Lastly, summary statistics of selected covariates most likely to affect the adoption of SALMPs sets as well as crop productivity, gross value of production and net revenue are presented.

4.2 Descriptive statistics

4.2.1 Adoption of SALMPS by Agro-Ecological Zones in ZAMBIA

Tables 4 and 5 present the adoption distribution of SALMPs sets by the major agro-ecological zones (AEZs) in Zambia for period one (2012) and two (2015) of the RALS survey, respectively. The results show that the most practiced set of SALMPs in period one is TRM practices, adopted by about 63 percent of the sample. In the second period, INM practices is the most adopted set of SALMPs, adopted by about 67 percent of the sample. The least adopted set is that of AF practices accounting for about 3 and 5 percent in the two periods, respectively.

By AEZ, the Central, Southern and Eastern plateau (AEZ IIa) has the highest HYV adoption rate, slightly above 60 percent in both periods, whereas the Western Semi-Arid Plains (AEZ IIb) has the lowest, less than 30 percent on average. Adoption of AF practices is low, less than 10 percent, across all AEZs in both periods, except for AEZ I in period two. Like HYV, adoption of INM practices is highest in AEZ IIa (about 70 percent in 2012 and 78 percent in 2015), whereas AEZ IIb has the lowest adoption rates. Nonetheless, AEZ IIb has the highest adoption rates of TRM practices, over 65 percent, in both periods. Further, the adoption WM practices is lowest in AEZ IIb, less than 10 percent, but highest in AEZ IIa, slightly above 30 percent, in period one and two.

Table 4: Adoption of SALMPs sets by Agro-ecological zones in Zambia — 2012

	AEZ I		AEZ IIa		AEZ IIb		AEZ III		Total Sample	
SALMPs	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
HYV	0.449	0.498	0.615	0.487	0.179	0.384	0.549	0.498	0.544	0.498
AF	0.055	0.228	0.047	0.211	0.008	0.093	0.018	0.134	0.033	0.178
INM	0.412	0.493	0.697	0.460	0.205	0.404	0.580	0.494	0.591	0.492
TRM	0.688	0.464	0.605	0.489	0.754	0.431	0.617	0.486	0.627	0.484
WM	0.146	0.353	0.317	0.465	0.0194	0.138	0.188	0.391	0.228	0.419

Source: Authors computations from RALS 2012 & 2015 data
*SD: Standard Deviation

Table 5: Adoption of SALMPs sets by Agro-ecological zones in Zambia — 2015

	AEZ I		AEZ IIa		AEZ IIb		AEZ III		Total Sample	
SALMPs	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
HYV	0.532	0.499	0.678	0.467	0.244	0.430	0.623	0.485	0.613	0.487
AF	0.165	0.371	0.078	0.268	0.004	0.066	0.010	0.101	0.051	0.221
INM	0.503	0.500	0.780	0.414	0.272	0.445	0.657	0.475	0.670	0.470
TRM	0.319	0.467	0.482	0.500	0.679	0.467	0.482	0.500	0.481	0.500
WM	0.290	0.454	0.324	0.468	0.0560	0.230	0.232	0.422	0.264	0.441

Source: Authors computations from RALS 2012 & 2015 data
*SD: Standard Deviation

4.2.2 Adoption of individual and combined sets of SALMPs at household level

Differences in adoption rates of individual and different combinations of SALMPs sets between 2012 and 2015 are presented in Table 6. The upper panel presents summary statistics for non-mutually exclusive sets of SALMPs. Generally, there was significant increase in the proportion of households that implemented most sets of SALMPs from 2012 to 2015, except for TRM practices. Further analysis of the five sets of SALMPs resulted in thirty-two mutually exclusive sets. Overall, the adoption rates for both individual and combined sets of SALMPs wass relatively low — below 25 percent for each year. About 12 percent of the households did not adopt any of the individual and combined sets of SALMPs in both years. Nevertheless, the most commonly implemented set of SALMPs in isolation was TRM practices — about 17 percent and 10 percent in 2012 and 2015, respectively. AF practices were the least practiced, accounting for less than 1 percent in both periods.

In 2012, a combination of HYV, INM and TRM practices had the highest adoption rate of about 24 percent. However, this reduced to about 18 percent in 2015. The second highly adopted combination, in both periods, was HYV and INM only. The adoption rate in 2012 was about 12 percent. This is less compared to about 20 percent in 2015. The set of SALMPs comprising a combination of all five sets was among the least adopted, about 1 percent in both years.

Table 6: Adoption of Individual and Combined sets of SALMPs by year (N=13,996)

Non-Mutually Exclusive sets of SALMPs	2012	2015	Difference	(t statistics)	(p-value)
HYV	0.544	0.613	0.069	8.322	0.000
AF	0.033	0.051	0.019	-5.483	0.000
INM	0.591	0.670	0.080	-9.823	0.000
TRM	0.627	0.481	-0.146	17.551	0.000
WM	0.228	0.264	0.036	-4.972	0.000
Mutually Exclusive sets SALMPs					
None	0.117	0.123	0.006	-1.092	0.275
AF only	0.002	0.003	0.002	-2.200	0.028
WM only	0.028	0.023	-0.006	2.142	0.032
WM,AF	0.001	0.001	-0.001	1.155	0.248
TRM only	0.168	0.099	-0.069	12.137	0.000
TRM,AF	0.003	0.004	0.001	-0.886	0.376
TRM,WM	0.031	0.027	-0.005	1.608	0.108
TRM,WM,AF	0.002	0.002	0.000	0.000	1.000
INM only	0.026	0.034	0.008	-2.676	0.007
INM,AF	0.001	0.002	0.001	-2.001	0.045
INM,WM	0.014	0.014	0.000	-0.145	0.884
INM,WM,AF	0.001	0.001	0.000	-0.230	0.818
INM,TRM	0.044	0.036	-0.008	2.337	0.019
INM,TRM,AF	0.002	0.002	0.001	-0.929	0.353
INM,TRM,WM	0.015	0.015	0.000	0.000	1.000
INM,TRM,WM,AF	0.002	0.002	0.000	0.000	1.000
HYV only	0.013	0.018	0.006	-2.806	0.005
HYV,AF	0.000	0.001	0.001	-1.508	0.132
HYV,WM	0.005	0.004	-0.001	0.494	0.622
HYV,WM,AF	0.000	0.001	0.001	-1.508	0.132
HYV,TRM	0.031	0.017	-0.014	5.323	0.000
HYV,TRM,AF	0.001	0.001	-0.000	0.277	0.781
HYV,TRM,WM	0.006	0.004	-0.002	1.291	0.197
HYV,TRM,WM,AF	0.000	0.001	0.001	-1.415	0.157
HYV,INM	0.118	0.200	0.083	-13.449	0.000
HYV,INM,AF	0.003	0.009	0.006	-4.958	0.000
HYV,INM,WM	0.041	0.076	0.034	-8.629	0.000
HYV,INM,WM,AF	0.003	0.008	0.005	-4.090	0.000
HYV,INM,TRM,	0.239	0.179	-0.060	8.780	0.000
HYV,INM,TRM,AF	0.006	0.007	0.001	-0.926	0.354
HYV,INM,TRM,WM	0.071	0.079	0.008	-1.892	0.058
HYV,INM,TRM,WM,AF	0.006	0.006	-0.000	0.214	0.831

Source: Authors computations from RALS 2012 & 2015 data

4.2.3 Correlation matrices for SALMPS

Tables 7 and 8 present the correlation matrices for the five sets of SALMPs by year. As expected, the use of HYV is highly correlated with the use of INM practices in both periods. This indicates a high degree of complementarity between these two practices. Generally, the use of HYV is found to be positively correlated with the use of other sets of SALMPs in both periods. Similarly, AF practices are equally complementary with INM and WM practices in both periods. While INM practices are complementary with TRM and WM practices in 2012, they are only complementary with WM practices in 2015. Lastly, TRM practices are complementary with WM practices in both periods. The complementarity between HYV and INM practices is somewhat consistent with arguments made by Manda *et al*. (2015), Arslan *et al*. (2016) and as summarized by Branca *et al*. (2011) from various studies, for these two combinations and the rest.

Table 7: Correlation Matrix — 2012

	HYV	AF	INM	TRM	WM
HYV	1.0000				
AF	0.0297*	1.0000			
INM	0.6766*	0.0470*	1.0000		
TRM	0.0818*	0.0123	0.0586*	1.0000	
WM	0.0461*	0.1109*	0.0916*	- 0.0464*	1.0000

Source: Authors computations from RALS 2012 & 2015 data
* p<0.05

Table 8: Correlation Matrix — 2015

	HYV	AF	INM	TRM	WM
HYV	1.0000				
AF	0.0317*	1.0000			
INM	0.6700*	0.0349*	1.0000		
TRM	-0.0000	-0.0009	0.0167	1.0000	
WM	0.0851*	0.0813*	0.1175*	0.0408*	1.0000

Source: Authors computations from RALS 2012 & 2015 data
* p<0.05

4.3 Summary statistics for outcome variables for non-mutually exclusive SALMPS.

Three impact variables are considered in the analysis. These include: maize yield (quantity in kilograms harvested per hectare planted) as a measure of crop productivity, gross value of maize produced and net revenue per hectare. The gross value of maize produced equals the product of the quantity of maize harvested in kilograms and the price per kilogram. Similarly, the net maize revenue[4] equals the difference between the total value of maize sales (a product of the quantity of maize sold in kilograms and the price per kilogram) less variable costs. These variable costs comprise of total input costs (seed and fertilizer) and transportation costs (input and maize output). Maize is analysed as it the main staple crop.

Table 9 shows summary statistics for outcome variables for non-mutually exclusive sets of SALMPs. The use of HYV and INM practices is associated with greater maize productivity, gross value and net revenue per hectare. Similar summary statistics for mutually exclusive individual and combined sets of SALMPs are presented in the appendices — Tables 29 and 30. Combinations involving both HYV and INM practices had greater maize productivity levels for both years, 2012 and 2015. On average, maize productivity levels were over 3,000 kg/ha.

Table 9: Summary statistics for outcome variables for non-mutually exclusive SALMPs.

Maize yield (kg/ha)	2012	2015	Difference	(t statistics)	(p-value)
HYV	3,288.746	3,222.137	-66.610	1.275	0.202
AF	3,039.493	2,872.595	-166.899	0.846	0.398
INM	3,190.058	3,109.160	-80.898	1.641	0.101
TRM	2,726.134	2,795.737	69.603	-1.272	0.203
WM	2,668.740	2,981.973	313.233	-4.095	0.000
Gross value of maize produced (ZMW/ha)					
HYV	3,060.738	3,220.000	159.262	-3.390	0.001
AF	2,877.411	2,702.387	-175.024	0.945	0.345
INM	3,007.470	3,115.776	108.306	-2.433	0.015
TRM	2,568.506	2,787.587	219.082	-4.406	0.000
WM	2,472.932	2,898.836	425.905	-6.332	0.000
Net maize revenue (ZMW/ha)					
HYV	1,419.077	1,237.830	-181.248	4.220	0.000
AF	1,291.989	1,057.415	-234.574	1.104	0.270
INM	1,350.795	1,174.700	-176.095	4.200	0.000
TRM	1,312.122	1,177.783	-134.339	2.610	0.009
WM	1,190.324	1,135.749	-54.575	0.754	0.451

Source: Authors computations from RALS 2012 & 2015 data

4.4 Summary statistics for selected explanatory variables

Descriptive statistics of key selected explanatory covariates are presented in Table 10. The p-values are used to compare difference in means between 2012 and 2015 cases. The list of selected explanatory variables is founded on the reviewed literature and have been categorised

[4] Figure 3 in the appendices shows the distribution of the net maize revenue per hectare.

as: household demographics, resource constraints, social capital factors, access to information and key infrastructure, field characteristics, agro-ecological zone dummies and weather factors.

4.4.1 Household demographics

Most of the household demographics pertain to the household head. For instance, age, gender and education level. Between 2012 and 2015, there is a significant difference in the mean values of these factors except for the years of education. In addition, there is also a difference in the household size — indicator of labour availability, between the two periods.

4.4.2 Resource constraints

Indicators of wealth in this case, the value of productive assets, farm size, livestock ownership as indicated by the number of tropical livestock units (TLUs) and net off-farm income are captured under the resource constraint category. Even though the value of productive assets is greater in 2015 compared to 2012, the difference is not significant. The same applies to the TLUs. On the contrary, farm size and the amount of net off-farm income are significantly different between the two periods. The farm size increased by about 0.22 hectares from about 2.96 hectares in 2012 to about 3.18 hectares in 2015. Likewise, the net off farm income significantly increased from about 5,167 ZMW in 2012 to about 7,772 ZMW in 2015. Additionally, there was also a significant increase in access to input credit — fertilizer and seed loans by about 10 and 1 percent, respectively.

4.4.3 Social capital factors

Several social capital factors have been argued by a number of studies to have some influence on household adoption decisions with respect to agricultural technologies (e.g., Teklewold *et al*., 2013; Manda *et al*., 2015; Kassie *et al*., 2015b). In this study, being a beneficiary of the government Farmer Input Support Programme (FISP) was considered as a social capital factor. This is because beneficiary farmers are able to access improved inputs like improved seed varieties and inorganic fertilizer at a subsided price. Thus, financially constrained farmers are cushioned against the high cost of these improved inputs. The results of descriptive analysis show that households benefiting from FISP significantly increased from 2012 to 2015 by about 2 percent.

Considering most of the land in the rural areas is under the customary law, having kinship ties with the either the village chief or headman is qualified as a social capital/network factor. Farm households with such kinship ties are more likely to have secured access to key agricultural resources such as land. With secured land tenure, these households may experiment with different agricultural practices which may entail having some level of land tenure security. Like in the case of FISP beneficiaries, the number of households with kinship ties significantly increased by about 4 percent between the two periods. Lastly, farmer cooperative membership is equally vital as a formal organization for knowledge exchange — interactions among individual farmers and extension staff. The percentage of farm households that became members of farmer cooperatives significantly increased by about 5 percent between the two periods.

4.4.4 Access to information and key infrastructure

In addition to the foregoing identified factors most likely to influence adoption decisions, access to information and key infrastructure is equally of utmost importance. Amazingly, the percentage of farm households that reported receiving advice/information on CF significantly increased from about 57 percent in 2012 to about 82 percent in 2015, representing a 25 percent increase. As a measure of access to key infrastructure/service providers, the distance from the homestead to nearest agricultural camp office, agro-dealer, private fertilizer retailer and market were captured. The results show a significant reduction in the distances to all these points between 2012 and 2015.

4.4.5 Field characteristics

There are many field level characteristics that are likely to influence adoption of different sets of SALMPs. Among the field characteristics considered include: distance from the homestead to the field, field tenure status, whether the field is prone to soil erosion/flash flooding and whether it located in a wetland/dambo area. On average, the distance from the homestead to the largest maize field decreased about 1 km between 2012 and 2015. The percentage of households that indicated having fields prone to soil erosion/flashing flooding and located in a wetland/dambo area significantly increased by about 4 and 2 percent, whereas those with fields on title significantly decreased by about 5 percent.

4.4.6 Agro-ecological zone dummies and weather factors

Finally, agro-ecological zone (AEZ) dummies and weather factors — average temperatures and precipitation are also included as explanatory variables. Historical temperatures averaged about 21^{o}C, whereas the average historical precipitation during the growing season averaged 942 mm. These variables control for climate variability effects. Further, agro-ecological zones give an idea of how suitable the area is for agricultural production in terms of soil types in addition to temperature and rainfall conditions. Consequently, they are expected to affect adoption of certain sets of SALMPs.

Table 10: Summary statistics of selected explanatory variables by year

	2012	2015	Difference	(t statistics)	(p-value)
Age of Household head in years	46.270	49.092	2.822	-11.282	0.000
Male headed household (1=yes)	0.814	0.791	-0.023	3.484	0.000
Education level of the household head in years	6.037	5.939	-0.098	1.588	0.112
Household size	6.059	6.346	0.286	-6.229	0.000
Productive assets (ZMW per HH)	20,548.306	26,416.922	5,868.615	-1.466	0.143
Tropical Livestock Units (TLUs)	3.927	3.886	-0.041	0.221	0.825
Farm size (all cultivated land plus fallow)	2.960	3.179	0.219	-3.978	0.000
Net off farm income per annum	5,167.316	7,771.896	2,604.580	-6.133	0.000
Loan for fertilizer (1=yes)	0.010	0.111	0.101	-25.726	0.000
Loan for seed (1=yes)	0.003	0.015	0.012	-7.349	0.000
FISP beneficiary, 1=Yes	0.422	0.445	0.023	-2.764	0.006
Kinship ties (1=yes)	0.511	0.549	0.039	-4.576	0.000
Member of a farmer cooperative, 1=yes	0.480	0.525	0.045	-5.313	0.000
Received advice on CF, 1=yes	0.572	0.817	0.245	-32.617	0.000
Distance to the nearest agricultural camp office (km)	10.675	7.699	-2.976	84.634	0.000
Distance to the nearest agro-dealer (km)	20.873	17.989	-2.884	64.510	0.000
Distance to the nearest fertilizer retailer (km)	25.937	22.872	-3.065	62.124	0.000
Distance to the nearest market (km)	15.973	13.897	-2.076	46.983	0.000
Distance from the homestead to the largest maize field (km)	2.452	1.387	-1.065	21.283	0.000
Land tenure, 1=titled	0.097	0.044	-0.053	12.409	0.000
Field prone to soil erosion, 1=yes	0.274	0.314	0.040	-5.163	0.000
Field located in wetland, 1=yes	0.146	0.161	0.015	-2.413	0.016
AEZ I (1=Luangwa-Zambezi Rift Valleys)	0.083	0.083	0.000	0.000	1.000
AEZ IIa (1= Central, Southern and Eastern Plateaus)	0.421	0.421	0.000	0.000	1.000
AEZ IIb (1= Western Semi-arid Plains)	0.066	0.066	0.000	0.000	1.000
AEZ III (1=Northern High Rainfall Zone)	0.429	0.429	0.000	0.000	1.000
Average monthly temperature degrees Celsius (^{o} C)	21.239	21.239	0.000	0.000	1.000
Average monthly precipitation — growing season (Nov-Mar) (mm)	942.494	942.494	0.000	0.000	1.000

Source: Authors computations from RALS 2012 & 2015 data

CHAPTER FIVE

FACTORS INFLUENCING THE ADOPTION OF SUSTAINABLE AGRICULTURAL AND LAND MANAGEMENT PRACTICES (SALMPs)

5.1 Introduction

This chapter addresses one of the main specific objectives of the thesis. It presents the results and a thorough discussion on factors affecting the adoption of the five sets of SALMPs under analysis. Empirical findings from the multivariate correlated random effects probit model facilitate this discussion. Additionally, the marginal predicted probability of each outcome, as well as the joint probability of success and failure in each outcome are presented.

5.2 Determinants of adoption

Analysis of household adoption decisions involved identifying factors that affect the probability of adopting the different sets of SALMPs using the multivariate CRE probit model. The sample used, excluded some observations. The dropped observations include: (1) households that first adopted any of the five sets of SALMPs in 2012 and then later in 2015, (2) households that adopted any of the five sets of SALMPs in 2012 but did not in 2015. The remaining sample comprised: (1) households that did not adopt any of the practices in 2012 but later adopted in 2015, (2) those that neither adopted in 2012 nor 2015. This implies that the sample used for the selection model comprised of new or first-time adopters only. The resulting data set was a balanced panel with a sample size of 1,890 observations.

Table 12 presents the results from the estimated multivariate CRE probit model. It highlights factors influencing the adoption of SALMPs in Zambia. The category against which the results are compared is the non-adoption reference category. The Wald test, $\chi^2 = 48{,}225$; $P > \chi^2 = 0.000$ indicates a very good model fit. Overall, parameter estimates of the model differ across the equations estimated. This indicates the appropriateness of differentiating between sets of SALMPs (Teklewold *et al*., 2013).

Results from the estimated model show that the age of household head has a significant positive effect on the adoption of two sets of SALMPs, HYV and TRM practices. Further, the coefficient on the high order variable for age, age squared, is negative and significant for these two practices. This indicates that increase in age increases the probability of adopting HYV and TRM practices up to a certain point. Beyond this point, the influence of age becomes negative. Overall, this finding does not really support the argument by Manda *et al*. (2015) that the effect of age on adoption decisions is indeterminate. All things considered, older farmers are more likely to adopt these two practices, well, at least up a certain age.

While it is well documented that the gender of the household head has influence on adoption decisions related to agricultural practices, this study found no significant gender effects for most sets of SALMPs. Nonetheless, the results show that households headed by males are more likely to adopt AF practices. Overall, the gender effects are somewhat consistent with those by Teklewold *et al*. (2013) and Arslan *et al*. (2016) who found no significant effect for most practices.

The household heads' level of education is another vital factor that is most likely to influence agricultural practices adoption decisions. Surprisingly, the results suggest that the household heads' level of education has no significant effect on the adoption of any five sets of SALMPs. This finding is not consistent with that by Teklewold *et al*. (2013), Manda *et al*. (2015) and Arslan *et al*. (2016) — who found significant education effects on the adoption of some practices. Another key factor is labour.

Kuyvenhoven and Ruben (2002) point out that labour intensive practices are most likely to be associated with lower yields. In this study the household size was used as an indicator for labour availability. The results show that the probability of adopting HYV and INM practices is significantly higher with increase in the household size. Among the recent studies, using household size as an indicator of labour availability, Manda *et al*. (2015) found similar results although the effect on the adoption of improved maize varieties was negative. Teklewold *et al*. (2013) and Arslan *et al*. (2016) found no significant effect at all on the adoption of sustainable agricultural practices analysed.

The results further highlight the important role wealth plays in influencing adoption decisions. One of the wealth proxies — farm size (land cultivated plus that on fallow) for a typical farm household, significantly affects the adoption of most sets of SALMPs. Specifically, the probability of adopting HYV, INM and TRM practices increases with increase in the farm size as found in Kassie *et al*. (2013), Manda *et al*. (2015) and Arslan *et al*. (2016) —for some practices. Like the household heads' age, the probability of adopting practices like HYV, INM and TRM increases up to some point as signalled by the significant coefficients of the squared term for farm size. Past this point, any further increase in farm size will most likely result in lower probability of adoption. Just like the farm size, increase in the amount of net off farm income increases the likelihood of adopting some SALMPs sets namely HYV and AF practices. The positive effect on the probability of adopting HYV is not surprisingly as this is a somewhat cost intensive agricultural input.

Other indicators of a farm households' wealth like the value of productive assets and livestock ownership, equally have significant effects on the probability of adopting specific sets of SALMPs. For instance, the study findings show that the probability of adopting WM practices is higher as the value of productive assets increases. However, livestock ownership as indicated by TLUs, significantly lowers the probability of adopting HYV and AF practices. Ownership of livestock signals potential availability of animal manure (organic fertilizer). This partially explains the positive, though not statistically significant, effect on the probability of adopting INM practices.

To examine the effects of credit access, access to input (fertilizer and seed) loans were used as indicators in this analysis. As expected, access to a fertilizer loan has a positive effect on the probability of adopting INM practices. However, this positive effect is significantly insignificant. Interestingly, for TRM and WM practices the effect is positive and statistically significant. Equally, access to a seed loan increases the probability of adopting HYV and INM practices. In summation, the wealth and liquidity status of a farm household is indicative of the households' ability to acquire improved inputs in addition to building resilience against various agricultural and livelihood shocks consistent with Teklewold *et al*. (2013).

The study findings further show that rural farm households that benefit from the Farmer Input Support Program (FISP) are by far more likely to adopt HYV and INM practices as anticipated. Unlike the findings by Manda *et al*. (2015), kinship ties have a significant effect (negative) on at least one set of SALMPs, AF practices. Other social capital and network factors such as cooperative membership is found to have a positive but not significant effect on the adoption of most sets of SALMPs. More profoundly, access to information/advice on conservation farming significantly increases the chances of adopting most sets of SALMPs. This finding is not that surprising as most of these sets of SALMPs are directly and/or indirectly promoted under CF programmes/packages.

Access to key agricultural related infrastructure and services equally stands paramount in influencing adoption decisions. The results show that increase in the distance to the market lowers the probability of adopting any of the five sets of SALMPs overall. This negative effect is, however, statistically significant for the adoption of HYV, INM, TRM and WM practices. Likewise, increase in the distance to the agricultural camp significantly lowers the likelihood of adopting INM, TRM and WM practices, whereas adoption of HYV is more likely. Interestingly, increase in the distance to the private fertilizer retailer positively affects the probability of adopting INM practices — although, this effect is not statistically significant.

Regarding plot level characteristics, the results indicate that increase in the distance from the homestead to the (largest maize) field significantly lowers probability of adopting most of the five sets of SALMPs. Unexpectedly, the results also suggest that having titled fields significantly lowers the probability of adopting AF practices. Ideally, land tenure security is supposed to incentivise farm households to make medium to long term land investments like AF practices. Moreover, the results also show that the probability of adopting WM practices is statistically significantly more likely on fields prone to soil erosion and/or flash flooding. This makes sense as soils in such fields are most likely to have depleted levels of nutrients and essential elements. WM practices help control soil erosion and/or flash flooding. Additionally, having fields located in a wetland and/or dambo area significantly lowers the probability of adopting AF practices.

For agro-ecological location, farm households located in AEZ IIa — Central, Southern and Eastern Plateaus are statistically significantly less likely to adopt WM practices in comparison to those in AEZ I — Luangwa-Zambezi Rift Valleys. Likewise, those in AEZ IIb — Western Semi-arid Plains, are less likely to adopt HYV, AF and WM practices, whereas adoption of TRM practices is more likely. For those in AEZ III — Northern High Rainfall Zone, the likelihood of adopting AF practices is significantly lower (most probably because the practice of *chiteme* system type of farming where trees are cut down and burnt a common practice in this region). Mining activities are also more wide spread in several parts of this zone. In addition, higher average temperatures significantly lower the likelihood of adopting most sets of SALMPs. These include, HYV, INM, TRM and WM practices. Similarly, increase in the average rainfall during the growing season period significantly reduces the probability of adopting HYV and INM practices, while the adoption of WM practices is more likely.

5.3 Marginal and joint probabilities for adoption of SALMPS

Table 11 presents the marginal probit predicted probability of success for each outcome and joint probabilities — the probit predicted joint probability of both success and failure in every-outcome. On average, the highest probability of adoption is for TRM practices (0.236) followed by INM practices (0.188) and HYV (0.158), whereas the least is for AF practices (0.018). The average joint probabilities for adoption and dis-adoption of all SALMPs are, respectively, 0.001 and 0.605.

Table 11: Marginal and Joint Probabilities for Adoption of SALMPs

Probabilities	Observations	Mean	Std. Dev.
Marginal			
HYV	1,306	0.158	0.259
AF	1,306	0.018	0.082
INM	1,306	0.188	0.280
TRM	1,306	0.236	0.249
WM	1,306	0.122	0.198
Joint			
All SALMPs adopted	1,293	0.001	0.009
None of the SALMPs adopted	1,306	0.605	0.359

Source: Authors computations from RALS 2012 & 2015 data

Table 12: Factors influencing the adoption of SALMPs

Explanatory variables	HYV		AF		INM		TRM		WM	
Age of the household head in years	0.365***	(0.119)	0.361	(0.309)	0.150	(0.127)	0.349***	(0.113)	0.120	(0.151)
Age of the household head squared	-0.00223*	(0.001)	-0.001	(0.003)	-0.001	(0.001)	-0.00209**	(0.001)	0.001	(0.001)
Male headed household, dummy 1=yes	0.036	(0.181)	0.668*	(0.344)	-0.247	(0.188)	-0.169	(0.144)	-0.082	(0.187)
Years of education for the household head	-0.002	(0.071)	-0.165	(0.136)	-0.048	(0.057)	-0.044	(0.049)	-0.093	(0.058)
Household size	0.217***	(0.081)	-0.161	(0.149)	0.272***	(0.082)	0.111	(0.071)	0.114	(0.081)
Farm size in hectares	0.260**	(0.110)	-0.744	(0.573)	0.169**	(0.074)	0.192***	(0.058)	0.102	(0.129)
Farm size squared	-0.0210**	(0.010)	0.336**	(0.153)	-0.00911***	(0.003)	-0.00547***	(0.002)	-0.004	(0.008)
Logged net off farm income (ZMW per annum)	0.161*	(0.086)	0.334**	(0.142)	-0.050	(0.080)	-0.011	(0.064)	-0.021	(0.070)
Logged value of productive assets (ZMW)	0.161	(0.098)	-0.245	(0.255)	-0.048	(0.109)	-0.084	(0.088)	0.247**	(0.111)
Tropical Livestock Units (TLUs)	-0.0501*	(0.026)	-0.269**	(0.118)	0.031	(0.038)	-0.002	(0.026)	0.022	(0.037)
Access to a fertilizer loan, dummy 1=yes	-0.253	(0.402)	-0.502	(0.411)	0.462	(0.345)	0.707**	(0.304)	0.590*	(0.321)
Access to a maize seed loan, dummy 1=yes	1.614**	(0.760)	-4.307***	(0.898)	6.025***	(0.408)	0.160	(0.583)	0.486	(0.342)
FISP beneficiary, dummy 1=yes	1.884***	(0.267)	1.813***	(0.413)	1.955***	(0.282)	0.027	(0.235)	0.023	(0.241)
Kinship ties to the village chief/headman, dummy 1=yes	-0.009	(0.145)	-0.748**	(0.291)	-0.139	(0.134)	0.095	(0.115)	-0.073	(0.148
Member of a farmer cooperative, dummy 1=yes	0.160	(0.201)	-0.598*	(0.325)	0.321	(0.206)	0.059	(0.189)	-0.048	(0.211)
Received advice on CF, dummy 1=yes	0.196	(0.164)	2.455***	(0.777)	0.262*	(0.154)	0.397***	(0.121)	0.412***	(0.158)
Distance to the nearest market (km)	-0.147***	(0.053)	-0.004	(0.095)	-0.128**	(0.064)	-0.0854**	(0.042)	-0.126***	(0.048)
Distance to the agricultural camp office (km)	0.107**	(0.052)	-0.115	(0.148)	-0.0929*	(0.054)	-0.124***	(0.046)	-0.109**	(0.051)
Distance to the nearest private fertilizer retailer (km)	0.006	(0.038)	-0.361***	(0.100)	0.035	(0.048)	0.011	(0.044)	0.025	(0.048)
Distance to the nearest agro-dealer (km)	-0.032	(0.051)	0.361***	(0.082)	-0.061	(0.047)	-0.015	(0.045)	0.020	(0.051)
Distance from the homestead to the largest maize field (km)	-0.232***	(0.058)	-0.519	(0.333)	-0.305***	(0.088)	-0.424***	(0.061)	-0.211***	(0.078)
Field tenure, 1=titled	0.018	(0.371)	-6.920***	(1.200)	-0.401	(0.279)	0.171	(0.336)	-0.251	(0.391)
Field prone to soil erosion/flash flooding, 1=yes	0.200	(0.170)	0.329	(0.264)	0.199	(0.171)	0.045	(0.143)	1.465***	(0.177)
Field located in a wetland/dambo area, 1=yes	-0.227	(0.225)	-0.525*	(0.285)	-0.143	(0.201)	0.042	(0.152)	0.084	(0.169)
AEZ IIa, dummy 1=yes	0.191	(0.259)	0.448	(0.531)	0.159	(0.234)	0.314	(0.295)	-0.604**	(0.286)
AEZ IIb, dummy 1=yes	-0.638**	(0.305)	-8.291***	(3.191)	0.011	(0.329)	1.152***	(0.325)	-2.592***	(0.438)
AEZ III, dummy 1=yes	-0.082	(0.292)	-2.056***	(0.697)	0.007	(0.285)	0.503	(0.313)	-0.495	(0.321)
Average monthly temperature (^{o} C)	-0.341***	(0.060)	0.184	(0.122)	-0.363***	(0.060)	-0.143***	(0.055)	-0.160***	(0.062)
Average — growing season (Nov-Mar) (mm)	-0.00130**	(0.001)	-0.001	(0.001)	-0.00128**	(0.001)	0.000	(0.000)	0.00108**	(0.001)
Constant	4.597**	(1.906)	-14.66***	(4.928)	6.003***	(1.835)	0.406	(1.655)	1.635	(1.741)

Note: means of the following continuous variables are controlled for

Clustered Robust standard errors in parentheses (at SEA level).

*** p<0.01, ** p<0.05, * p<0.1

CHAPTER SIX

CROP PRODUCTIVITY IMPACTS OF SUSTAINABLE AGRICULTURAL AND LAND MANAGEMENT PRACTICES

6.1 Introduction

This chapter addresses the overall objective of this thesis. It presents a systematic discussion on the crop productivity impacts of adopting different sets of SALMPs. The results emerge from different model specifications based on two panel samples. The idea behind having different model specifications is to estimate impacts of mutually and non-mutually exclusive sets of SALMPs. On one hand, analysis of non-mutually exclusive sets of SALMPs involved estimating the impacts of the five sets of SALMPs without any interactions. On the other hand, analysis of mutually exclusive sets of SALMPs involved estimating the impacts of individual and combined sets of SALMPs which were interacted with the time variable.

The first panel sample that facilitated the estimation of the different specified models comprised all the observations of adopters and non-adopters in both years, 2012 and 2015 — full panel sample. This sample contained observations which included: (1) households that first adopted any of the five sets of SALMPs in 2012 and then later in 2015, (2) households that adopted any of the five sets of SALMPs in 2012 but did not in 2015, (3) households that did not adopt any of the practices in 2012 but later adopted in 2015 and (4) those that neither adopted in 2012 nor 2015. Consequently, to estimate pure adoption impacts of the different sets of SALMPs a reconstructed panel sample was used. It consisted of households that did not adopt any of the SALMPs in 2012 but later adopted in 2015 and those that did not adopt in neither 2012 nor 2015 — first-time adopters. This sample helped to determine whether first-time adopters are doing better or worse off after adopting the different sets of SALMPs. The estimator used to obtain the parameter estimates is the fixed effects (FE).

6.2 Crop productivity impacts of individual sets OF SALMPS

Since the adoption rate of some sets of SALMPs like AF practices is very low (Table 6), models with and without this option were estimated. Table 13 presents crop productivity impacts of non-mutually exclusive sets of SALMPs without any interactions using FE. Parameter estimates under columns (1) and (2) are based on the full panel sample, whereas those under columns (3) and (4) represent those of first-time adopters. These two panel samples comprise of observations with positive maize yield values.

The results, across all model specifications and samples, show that adopting non-mutually exclusive sets of SALMPs, HYV, INM and TRM practices has positive impacts on maize yields. However, the impacts of INM practices are only statistically significant for the full panel sample. Further, the crop productivity impacts of HYV and TRM practices are larger for the sample containing first time adopters only. The associated yield gains are over 30 percent and 20 percent, respectively. Overall, these results are practically the same with and without AF practices for each sample.

6.3 Crop productivity impacts of individual and combined sets of SALMPS — full panel sample

Model specifications and panel samples used to estimate impacts of non-mutually exclusive individual sets of SALMPs (Section 6.2) were applied to estimate the impacts of mutually exclusive individual and combined sets of SALMPs. Since farmers seldom adopt only one practice, analysis of mutually exclusive sets of SALMPs helped to determine crop productivity impacts that can be attributed to each specific set (individual or combined). The summary statistics in the chapter four show that a high proportion of farmers adopted a combination of HYV, INM and TRM practices, and HYV and INM practices. Hence the need to estimate the impacts of such mutually exclusive combined sets of SALMPs.

Table 14 presents results based on the full panel sample and all five sets of SALMPs with the respective combinations included. All the treatment variables are interacted with a dummy for time equal to 1 if the year is 2015. Among the individual sets of SALMPs, only TRM practices have a positive and significant effect on maize yields. The associated yield gain is about 40 percent. The rest of the sets with positive and statistically significant impacts on maize yield, involve combinations of specific individual sets of SALMPs. For instance, on one hand, a combination of AF and WM practices only, INM and AF practices only and HYV, WM and AF practices only are associated with significant yield gains over 100 percent.

Table 13: Crop productivity impacts of non-mutually exclusive sets of SALMPs

Variables	Full Sample				First-time Adopters only			
	1		2		3		4	
Year dummy, 1=2015	-0.013	(0.038)	-0.014	(0.038)	-0.199	(0.206)	-0.202	(0.205)
HYV	0.289***	(0.039)	0.289***	(0.039)	0.350**	(0.148)	0.354**	(0.148)
INM	0.185***	(0.046)	0.185***	(0.046)	0.214	(0.147)	0.213	(0.147)
TRM	0.102***	(0.027)	0.101***	(0.028)	0.266*	(0.137)	0.265*	(0.137)
WM	0.014	(0.029)	0.012	(0.029)	-0.065	(0.162)	-0.070	(0.162)
AF	-0.047	(0.063)			-0.148	(0.245)		
Age of the household head in years	-0.009	(0.005)	-0.009	(0.005)	-0.032	(0.019)	-0.0329*	(0.019)
Years of education for the household head	0.011	(0.008)	0.011	(0.008)	0.028	(0.030)	0.028	(0.030)
Household size	-0.007	(0.010)	-0.007	(0.010)	0.011	(0.044)	0.012	(0.044)
Logged net off farm income (ZMW per annum)	0.0202**	(0.009)	0.0201**	(0.009)	-0.002	(0.034)	-0.002	(0.034)
Tropical Livestock Units (TLUs)	0.002	(0.002)	0.002	(0.002)	0.009	(0.008)	0.009	(0.008)
Logged value of productive assets (ZMW)	0.0429***	(0.012)	0.0429***	(0.012)	0.059	(0.047)	0.060	(0.047)
Farm size in hectares	-0.0550***	(0.010)	-0.0552***	(0.010)	-0.042	(0.055)	-0.046	(0.054)
Farm size squared	0.00122***	(0.000)	0.00123***	(0.000)	-0.002	(0.003)	-0.002	(0.003)
Distance from the homestead to the field	-0.001	(0.004)	-0.001	(0.004)	-0.016	(0.022)	-0.016	(0.022)
Distance to the agricultural camp office (km)	-0.003	(0.007)	-0.003	(0.007)	-0.031	(0.029)	-0.029	(0.029)
Distance to the nearest market (km)	-0.006	(0.007)	-0.006	(0.007)	0.018	(0.033)	0.016	(0.032)
Distance to the nearest private fertilizer retailer (km)	0.000	(0.008)	0.001	(0.008)	-0.031	(0.038)	-0.029	(0.038)
Distance to the nearest agro-dealer (km)	-0.002	(0.007)	-0.002	(0.007)	0.023	(0.026)	0.021	(0.026)
Constant	7.333***	(0.344)	7.335***	(0.344)	8.390***	(1.259)	8.436***	(1.240)
Observations	8,453		8,453		830		830	
R-squared	0.058		0.058		0.112		0.111	
Number of id	5,261		5,261		581		581	
F-statistic	10.68		11.05		2.557		2.688	
Prob > F	0		0		0		0	

Source: Authors computations from RALS 2012 & 2015 data. HYV, INM, TRM, WM, and AF are dummies for each SALMP.
Clustered Robust standard errors in parentheses (at SEA level).
*** p<0.01, ** p<0.05, * p<0.1

On the other hand, yield gains associated with: HYV and INM practices only, HYV, INM and WM practices only, and HYV, INM and TRM practices only, respectively, are 19 percent, 23 percent and 18 percent.

Table 14: Crop productivity impacts of individual and combined sets of SALMPs

Variables	Coefficient	Standard error
Year dummy, 1=2015	-0.173*	(0.096)
(Year dummy, 1=2015) × AF	0.372	(0.497)
(Year dummy, 1=2015) × WM	-0.26	(0.216)
(Year dummy, 1=2015) × AF,WM	1.644**	(0.723)
(Year dummy, 1=2015) × TRM	0.403***	(0.122)
(Year dummy, 1=2015) × TRM,AF	-0.391	(0.444)
(Year dummy, 1=2015) × TRM,WM	0.262	(0.196)
(Year dummy, 1=2015) × TRM,WM,AF	-0.121	(0.361)
(Year dummy, 1=2015) × INM	-0.0281	(0.181)
(Year dummy, 1=2015) × INM,AF	1.012**	(0.464)
(Year dummy, 1=2015) × INM,WM	-0.15	(0.219)
(Year dummy, 1=2015) × INM,WM,AF	0.0833	(0.523)
(Year dummy, 1=2015) × INM,TRM	0.0299	(0.164)
(Year dummy, 1=2015) × INM,TRM,AF	0.0149	(0.482)
(Year dummy, 1=2015) × INM,TRM,WM	0.244	(0.18)
(Year dummy, 1=2015) × INM,TRM,WM,AF	0.883	(0.599)
(Year dummy, 1=2015) × HYV	0.162	(0.259)
(Year dummy, 1=2015) × HYV,AF	-0.669	(0.785)
(Year dummy, 1=2015) × HYV,WM	0.423	(0.33)
(Year dummy, 1=2015) × HYV,WM,AF	1.444*	(0.863)
(Year dummy, 1=2015) × HYV,TRM	0.114	(0.172)
(Year dummy, 1=2015) × HYV,TRM,AF	0.394	(0.52)
(Year dummy, 1=2015) × HYV,TRM,WM	-0.331	(0.413)
(Year dummy, 1=2015) × HYV,TRM,WM,AF	0.0873	(0.54)
(Year dummy, 1=2015) × HYV,INM	0.187*	(0.0989)
(Year dummy, 1=2015) × HYV,INM,AF	0.172	(0.269)
(Year dummy, 1=2015) × HYV,INM,WM	0.227*	(0.125)
(Year dummy, 1=2015) × HYV,INM,WM,AF	0.334	(0.416)
(Year dummy, 1=2015) × HYV,INM,TRM	0.181*	(0.0998)
(Year dummy, 1=2015) × HYV,INM,TRM,AF	0.303	(0.257)
(Year dummy, 1=2015) × HYV,INM,TRM,WM	0.106	(0.115)
(Year dummy, 1=2015) × HYV,INM,TRM,WM,AF	0.375	(0.25)
Age of the household head in years	-0.00876*	(0.00528)
Years of education for the household head	0.0103	(0.00744)
Household size	-0.00615	(0.00976)
Logged net off farm income (ZMW per annum)	0.0190**	(0.00896)
Tropical Livestock Units (TLUs)	0.00191	(0.00207)
Logged value of productive assets (ZMW)	0.0419***	(0.0122)
Farm size in hectares	-0.0560***	(0.00975)
Farm size squared	0.00125***	(0.000318)
Distance from the homestead to the field	-0.0014	(0.00377)
Distance to the agricultural camp office (km)	-0.00164	(0.00683)
Distance to the nearest market (km)	-0.0054	(0.00753)
Distance to the nearest private fertilizer retailer (km)	0.000176	(0.00767)
Distance to the nearest agro-dealer (km)	-0.00194	(0.00683)
Constant	7.441***	(0.344)

Source: Authors computations from RALS 2012 & 2015 data
*Note: n=8,453, number of id=5,261, r-squared=0.077
Clustered Robust standard errors in parentheses (at SEA level).
*** p<0.01, ** p<0.05, * p<0.1

Results from the model without AF practices show that only the impact of TRM practices is statistically significant among the individual sets of SALMPs (Table 15). The associated gain in yield is about 37 percent. A combination of INM, TRM and WM practices only, HYV and INM practices only, HYV,INM and WM practices only and HYV,INM and TRM practices yield about 34, 18, 23 and 19 percent, respectively.

Table 15: Crop productivity impacts of individual and combined sets of SALMPs — without AF practices

Variables	Coefficient	Standard error
Year dummy, 1=2015	-0.172*	(0.0962)
(Year dummy, 1=2015) × WM	-0.144	(0.204)
(Year dummy, 1=2015) × TRM	0.374***	(0.124)
(Year dummy, 1=2015) × TRM,WM	0.247	(0.179)
(Year dummy, 1=2015) × INM	-0.0193	(0.176)
(Year dummy, 1=2015) × INM,WM	-0.14	(0.213)
(Year dummy, 1=2015) × INM,TRM	0.043	(0.158)
(Year dummy, 1=2015) × INM,TRM,WM	0.336*	(0.175)
(Year dummy, 1=2015) × HYV	0.114	(0.245)
(Year dummy, 1=2015) × HYV,WM	0.437	(0.315)
(Year dummy, 1=2015) × HYV,TRM	0.12	(0.158)
(Year dummy, 1=2015) × HYV,TRM,WM	-0.163	(0.355)
(Year dummy, 1=2015) × HYV,INM	0.180*	(0.097)
(Year dummy, 1=2015) × HYV,INM,WM	0.227*	(0.124)
(Year dummy, 1=2015) × HYV,INM,TRM	0.186*	(0.0976)
(Year dummy, 1=2015) × HYV,INM,TRM,WM	0.119	(0.11)
Age of the household head in years	-0.00879*	(0.00532)
Years of education for the household head	0.0114	(0.00751)
Household size	-0.00689	(0.00988)
Logged net off farm income (ZMW per annum)	0.0194**	(0.00894)
Tropical Livestock Units (TLUs)	0.00179	(0.00207)
Logged value of productive assets (ZMW)	0.0435***	(0.0122)
Farm size in hectares	-0.0561***	(0.00973)
Farm size squared	0.00124***	(0.000321)
Distance from the homestead to the field	-0.00126	(0.00378)
Distance to the agricultural camp office (km)	-0.00153	(0.00671)
Distance to the nearest market (km)	-0.00612	(0.00744)
Distance to the nearest private fertilizer retailer (km)	0.000739	(0.00772)
Distance to the nearest agro-dealer (km)	-0.00212	(0.00683)
Constant	7.418***	(0.346)

Source: Authors computations from RALS 2012 & 2015 data
*Note: n=8,453, number of id=5,261, r-squared=0.07
Clustered Robust standard errors in parentheses (at SEA level).
*** p<0.01, ** p<0.05, * p<0.1

6.4 Crop productivity impacts of individual and combined sets of SALMPS — first time adopters panel sample

Table 16 presents results following model specifications applied under section 6.2, but now on a panel sample for first-time adopters only. None of the individual sets of SALMPs has a significant impact on maize yields in isolation. However, a combination of INM, TRM and WM practices only, INM, TRM, WM and AF practices only, HYV and AF practices only, HYV and INM practices only, HYV, INM, WM and AF practices only and HYV, INM and TRM practices only have significant yield impacts.

Table 16: Crop productivity impacts of of SALMPs — first time adopters' panel sample

Variables	Coefficient	Standard error
Year dummy,1=2015	-0.197	(0.24)
AF	0.227	(0.542)
WM	0.18	(0.297)
TRM	0.354	(0.224)
TRM,AF	-0.051	(0.294)
TRM,WM	-0.220	(0.338)
TRM,WM,AF	-0.214	(0.348)
INM	-0.261	(0.303)
INM,WM	0.147	(0.541)
INM,TRM	0.319	(0.279)
INM,TRM,AF	0.106	(0.584)
INM,TRM,WM	1.448***	(0.232)
INM,TRM,WM,AF	1.568***	(0.234)
HYV	0.308	(0.263)
HYV,AF	0.952***	(0.285)
HYV,WM	0.526	(0.591)
HYV,TRM	0.275	(0.367)
HYV,INM	0.776***	(0.249)
HYV,INM,AF	0.287	(0.317)
HYV,INM,WM	0.473	(0.315)
HYV,INM,WM,AF	-1.083***	(0.181)
HYV,INM,TRM	1.050***	(0.255)
HYV,INM,TRM,WM	0.278	(0.386)
Age of the household head in years	-0.033	(0.023)
Years of education for the household head	0.039	(0.029)
Household size	0.024	(0.044)
Logged net off farm income (ZMW per annum)	-0.018	(0.035)
Tropical Livestock Units (TLUs)	0.013	(0.009)
Logged value of productive assets (ZMW)	0.062	(0.048)
Farm size in hectares	-0.032	(0.056)
Farm size squared	-0.002	(0.003)
Distance from the homestead to the field	-0.020	(0.023)
Distance to the agricultural camp office (km)	-0.026	(0.027)
Distance to the nearest market (km)	0.005	(0.035)
Distance to the nearest private fertilizer retailer (km)	-0.021	(0.038)
Distance to the nearest agro-dealer (km)	0.026	(0.026)
Constant	8.214***	(1.37)

Clustered Robust standard errors in parentheses (at SEA level).
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Among these, a combination of HYV, INM, WM and AF practices has negative yield impacts, whereas the impacts for the rest are largely positive (over 75 percent yield gains) and highly significant.

Table 17 presents results of the impact analysis without the AF practices treatment variable. Like in the foregoing analysis, none of the individual sets of SALMPs is found to have a significant impact on maize yields in isolation. Combinations with positive and statistically significant impacts this time around include: INM, TRM and WM practices only (over 100 percent), HYV and INM practices only (74 percent) and HYV, INM and TRM practices only (slightly over 100 percent).

Table 17: Crop productivity impacts of individual and combined sets of SALMPs— first time adopters' panel sample — without AF practices

Variables	Coefficient	Standard error
year	-0.174	(0.232)
WM	0.174	(0.290)
TRM	0.324	(0.215)
TRM,WM	-0.234	(0.302)
INM	-0.267	(0.298)
INM,WM	0.143	(0.545)
INM,TRM	0.255	(0.257)
INM,TRM,WM	1.459***	(0.201)
HYV	0.346	(0.247)
HYV,WM	0.537	(0.587)
HYV,TRM	0.257	(0.366)
HYV,INM	0.740***	(0.239)
HYV,INM,WM	0.315	(0.318)
HYV,INM,TRM	1.033***	(0.252)
HYV,INM,TRM,WM	0.265	(0.385)
Age of the household head in years	-0.035	(0.021)
Years of education for the household head	0.038	(0.029)
Household size	0.028	(0.043)
Logged net off farm income (ZMW per annum)	-0.017	(0.034)
Tropical Livestock Units (TLUs)	0.011	(0.009)
Logged value of productive assets (ZMW)	0.067	(0.047)
Farm size in hectares	-0.027	(0.054)
Farm size squared	-0.002	(0.003)
Distance from the homestead to the field	-0.019	(0.022)
Distance to the agricultural camp office (km)	-0.025	(0.027)
Distance to the nearest market (km)	0.005	(0.034)
Distance to the nearest private fertilizer retailer (km)	-0.022	(0.036)
Distance to the nearest agro(dealer (km)	0.027	(0.025)
Constant	8.210***	(1.316)
Observations	906	
Number of id	657	
R-squared	0.167	

Source: Authors computations from RALS 2012 & 2015 data

Clustered Robust standard errors in parentheses (at SEA level).

*** p<0.01, ** p<0.05, * p<0.1

6.5 Crop productivity: marginal effects of SALMPs

Table 31 in the appendices shows the marginal effects of the five sets of SALMPs on crop productivity. For the full sample, columns 1 and 2 show the marginal effects of each set of SALMPs with and without AF practices, respectively. Similarly, columns 3 and 4 present the marginal effects for the first-time adopters' sample. The results show positive and significant, at 10 percent level, marginal effects of HYV for first-time adopters without AF practices. Equally, marginal effects of TRM practices across the four model specifications are positive and significant at 1 percent level. The marginal effect of TRM practices is slightly greater when all five sets are accounted for using both the full and first-time adopters' panel samples. Under the full sample, the results show that the marginal effects of TRM practices are about 46 and 43 percent with and without controlling for AF practices, respectively. This is similar to the first-time adopters' sample where the marginal effects with and without AF practices are, respectively, about 45 and 42 percent.

6.6 Summary

This chapter presented the crop productivity impacts of SALMPs. For both samples, non-mutually exclusive sets of SALMPs HYV, INM and TRM practices have a positive impact on crop productivity levels. The impact of HYV (35 percent) is greater for first-time adopters in comparison to 29 percent for the full-sample. Similarly, TRM practices impact on the crop productivity for the full sample is about 10 percent, whereas for the first-time adopters it is about 27 percent. INM practices have about 19 percent impact on the crop productivity for the full sample. But, the impact on first-time adopters is not statistically significant.

Further, results from the analysis of mutually exclusive sets of SALMPs show that the impact of SALMPs on crop productivity levels is positive. TRM practices is the only individual set with positive and significant impact on crop productivity. On average, the gain in crop productivity ranges from 18 to 19 percent for the widely practiced combinations, HYV and INM practices, and HYV, INM and TRM practices for the full sample with and without AF practices. Interestingly, the marginal effects of HYV and INM practices, though positive, are not significant for the full sample, whereas that of TRM practices is positive and statistically significant.

Analysis of mutually exclusive sets of SALMPs on a sample of first-time adopters shows that none of the individual sets has a significant impact on crop productivity. However, impacts of several combined sets of SALMPs are positive and significant. For instance, the impacts of widely practiced sets, HYV and INM practices and HYV, INM and TRM practices, are over 70 and 100 percent, respectively. This applies to models with and without AF practices. Furthermore, the marginal effect of HYV is positive but only significant without AF practices. The marginal effect of TRM practices is positive and significant with and without AF practices. These results show that first-time adopters are better off when specific sets of SALMPs are adopted in combinations.

CHAPTER SEVEN

GROSS VALUE OF PRODUCTION AND NET REVENUE IMPACTS OF SUSTAINABLE AGRICULTURAL AND LAND MANAGEMENT PRACTICES

7.1 Introduction

In addition to the yield impacts of SALMPs, this chapter presents the gross value of production and net revenue impacts of individual and combined sets of SALMPs. A similar approach used to estimate the yield impacts in chapter six is equally applied here. The results emerge from different model specifications based on two panel samples. The idea behind having different model specifications is to estimate the gross value of production and net revenue impacts of mutually and non-mutually exclusive sets of SALMPs. On one hand, analysis of non-mutually exclusive sets of SALMPs involved estimating the impacts of the five sets of SALMPs without any interactions. On the other hand, analysis of mutually exclusive sets of SALMPs involved estimating the impacts of individual and combined sets of SALMPs which are interacted with the time variable.

The first panel sample used contained observations which included: (1) households that first adopted any of the five sets of SALMPs in 2012 and then later in 2015, (2) households that adopted any of the five sets of SALMPs in 2012 but did not in 2015, (3) households that did not adopt any of the practices in 2012 but later adopted in 2015 and (4) those that neither adopted in 2012 nor 2015. But, to estimate pure adoption impacts the different models specifications were also estimated using a reconstructed panel sample comprising of households that did not adopt any of the SALMPs in 2012 but later adopted in 2015, and those that did not adopt in both years — first-time adopters.

7.2 Gross value of production and net revenue impacts of individual sets of SALMPs — full panel sample

Table 18 presents gross value of maize produced (columns 1 and 2) and net maize revenue (columns 3 and 4) impacts of non-mutually exclusive individual sets of SALMPs — with and without the treatment variable for AF practices. The results show that using at least HYV is associated with about 24 percent gain in the gross value of maize produced, whereas the gain

Table 18: Gross value of maize produced and net revenue impacts of non-mutually exclusive sets of SALMPs — full sample

Variables	ln (gross value of maize produced (ZMW/ha))		Net maize revenue (ZMW/ha)	
	1	2	3	4
year	0.0531	0.0522	6.304	6.859
	(0.0359)	(0.0358)	(84.53)	(84.07)
HYV	0.238***	0.238***	230.2**	230.1**
	(0.0383)	(0.0383)	(99.17)	(99.15)
INM	0.183***	0.183***	-388.7***	-388.2***
	(0.0468)	(0.0468)	(130.7)	(130.8)
TRM	0.0848***	0.0846***	63.46	63.30
	(0.0266)	(0.0266)	(68.63)	(68.73)
WM	-0.00739	-0.00847	-44.71	-43.42
	(0.0275)	(0.0274)	(70.24)	(69.92)
AF	-0.0287		22.78	
	(0.0565)		(180.2)	
Age of the household head in years	-0.0103**	-0.0103**	-30.62***	-30.64***
	(0.00512)	(0.00512)	(10.42)	(10.41)
Years of education for the household head	0.0156**	0.0156**	24.32	24.32
	(0.00737)	(0.00738)	(21.20)	(21.18)
Household size	-0.0131	-0.0130	-8.035	-8.033
	(0.00989)	(0.00987)	(23.03)	(23.02)
Logged net off farm income (ZMW per annum)	0.0190**	0.0190**	37.22	37.19
	(0.00866)	(0.00866)	(23.42)	(23.40)
Tropical Livestock Units (TLUs)	0.00112	0.00114	2.404	2.406
	(0.00201)	(0.00201)	(9.318)	(9.316)
Logged value of productive assets (ZMW)	0.0395***	0.0395***	56.20	56.08
	(0.0124)	(0.0124)	(34.38)	(34.41)
Farm size in hectares	-0.0728***	-0.0729***	-9.671	-9.490
	(0.00998)	(0.00997)	(20.89)	(20.77)
Farm size squared	0.00160***	0.00160***	-0.0834	-0.0880
	(0.000315)	(0.000315)	(0.507)	(0.504)
Distance from the homestead to the field	0.00105	0.00102	1.879	1.901
	(0.00351)	(0.00351)	(8.738)	(8.743)
Distance to the agricultural camp office (km)	-0.00301	-0.00301	-24.97**	-24.95**
	(0.00545)	(0.00545)	(10.75)	(10.74)
Distance to the nearest market (km)	-0.00183	-0.00198	15.92	16.03
	(0.00747)	(0.00745)	(14.46)	(14.46)
Distance to the nearest private fertilizer retailer (km)	-0.00128	-0.00121	20.27	20.27
	(0.00692)	(0.00690)	(14.61)	(14.62)
Distance to the nearest agro-dealer (km)	-0.00245	-0.00248	-11.83	-11.81
	(0.00674)	(0.00673)	(14.49)	(14.49)
Constant	7.517***	7.519***	1,381*	1,380*
	(0.331)	(0.331)	(735.6)	(736.4)
Observations	8,993	8,993	4,875	4,875
R-squared	0.063	0.063	0.029	0.029
Number of id	5,801	5,801	3,654	3,654
F-statistic	11.02	11.54	2.853	3.011
Prob > F	0	0	6.49e-05	3.76e-05

Clustered Robust standard errors in parentheses (at SEA level).
*** p<0.01, ** p<0.05, * p<0.1

in net maize revenue is about 230 ZMW/ha with and without controlling for AF practices. Additionally, INM and TRM practices have a statistically significant positive impact on the gross value of maize produced of about 18 and 8 percent, respectively. However, the impact of INM practices on the net revenue is negative (-389 ZMW/ha) and statistically significant, while that of TRM practices is positive but insignificant.

7.3 Gross value of production impacts of individual and combined sets of SALMPs — full panel sample

Table 19 presents gross value of maize produced impacts of mutually exclusive individual and combined sets of SALMPs. Interestingly, TRM is the only individual set of SALMPs with a statistically significant and positive impact on the gross value of maize produced. The gain in value is about 38 percent. A combination of WM and AF practices, INM, TRM and WM practices, HYV, WM and AF practices, HYV and INM practices, HYV, INM and WM practices, HYV, INM and TRM practices, HYV, INM, TRM and WM practices, and HYV, INM, TRM, WM and AF practices yield positive and significant gross value gains. Among these, widely practiced combinations, HYV, INM and TRM practices and HYV and INM practices yield about 17 and 16 percent gain in the gross value of maize produced, respectively.

7.4 Gross value of production impacts of individual and combined sets of SALMPs without AF practices

Table 20 shows gross value of production impacts without the option for AF practices. The results show that the gross value of maize produced impacts of individual sets of SALMPs is only positive and significant for TRM practices (38 percent). Several combinations of SALMPs were also found to have positive and significant impact on the gross value of maize produced. These combinations are: INM, TRM and WM practices (33 percent), HYV and WM practices (37 percent), HYV and INM practices (17 percent), HYV, INM and WM practices (23 percent), HYV, INM and TRM practices (17 percent) and HYV, INM, TRM and WM practices (32 percent).

Table 19: Logged Gross value of maize produced impacts of individual and combined sets of SALMPs— full panel sample

Variables	Coefficient	Standard error
Year dummy, 1=2015	-0.121*	(0.0718)
(Year dummy, 1=2015) × AF	-0.416	(0.407)
(Year dummy, 1=2015) × WM	0.103	(0.127)
(Year dummy, 1=2015) × WM,AF	1.150**	(0.586)
(Year dummy, 1=2015) × TRM	0.376***	(0.085)
(Year dummy, 1=2015) × TRM,AF	0.0626	(0.357)
(Year dummy, 1=2015) × TRM,WM	0.106	(0.118)
(Year dummy, 1=2015) × TRM,WM,AF	-0.195	(0.274)
(Year dummy, 1=2015) × INM	0.00158	(0.123)
(Year dummy, 1=2015) × INM,AF	0.129	(0.535)
(Year dummy, 1=2015) × INM,WM	0.0209	(0.141)
(Year dummy, 1=2015) × INM,WM,AF	-0.0952	(0.411)
(Year dummy, 1=2015) × INM,TRM	-0.00056	(0.106)
(Year dummy, 1=2015) × INM,TRM,AF	0.154	(0.244)
(Year dummy, 1=2015) × INM,TRM,WM	0.279**	(0.128)
(Year dummy, 1=2015) × INM,TRM,WM,AF	0.593	(0.552)
(Year dummy, 1=2015) × HYV	-0.0299	(0.18)
(Year dummy, 1=2015) × HYV,AF	-0.474	(0.321)
(Year dummy, 1=2015) × HYV,WM	0.303	(0.221)
(Year dummy, 1=2015) × HYV,WM,AF	1.796***	(0.318)
(Year dummy, 1=2015) × HYV,TRM	0.0845	(0.131)
(Year dummy, 1=2015) × HYV,TRM,AF	0.415	(0.358)
(Year dummy, 1=2015) × HYV,TRM,WM	0.152	(0.293)
(Year dummy, 1=2015) × HYV,TRM,WM,AF	0.11	(0.474)
(Year dummy, 1=2015) × HYV,INM	0.169**	(0.075)
(Year dummy, 1=2015) × HYV,INM,AF	0.046	(0.21)
(Year dummy, 1=2015) × HYV,INM,WM	0.209**	(0.096)
(Year dummy, 1=2015) × HYV,INM,WM,AF	0.439	(0.412)
(Year dummy, 1=2015) × HYV,INM,TRM	0.162**	(0.074)
(Year dummy, 1=2015) × HYV,INM,TRM,AF	0.172	(0.191)
(Year dummy, 1=2015) × HYV,INM,TRM,WM	0.299***	(0.082)
(Year dummy, 1=2015) × HYV,INM,TRM,WM,AF	0.428**	(0.192)
Age of the household head in years	-0.001	(0.001)
Years of education for the household head	0.007**	(0.003)
Household size	-0.007**	(0.003)
Logged net off farm income (ZMW per annum)	0.0173***	(0.006)
Tropical Livestock Units (TLUs)	-0.00153	(0.001)
Logged value of productive assets (ZMW)	0.052***	(0.008)
Farm size in hectares	-0.028***	(0.006)
Farm size squared	0.001***	(0.000)
Distance from the homestead to the field	0.009***	(0.003)
Distance to the agricultural camp office (km)	-0.000	(0.005)
Distance to the nearest market (km)	0.007	(0.005)
Distance to the nearest private fertilizer retailer (km)	0.004	(0.005)
Distance to the nearest agro-dealer (km)	0.002	(0.005)
Constant	6.436***	
	-0.142	
Observations	8,993	
Number of id	5,801	

Source: Authors computations from RALS 2012 & 2015 data

Clustered Robust standard errors in parentheses (at SEA level).

*** p<0.01, ** p<0.05, * p<0.1

Table 20: Gross value of production impacts of SALMPS without AF practices

Variables	Coefficient	Standard error
Year dummy, 1=2015	-0.131*	(0.070)
(Year dummy, 1=2015) × WM	0.165	(0.126)
(Year dummy, 1=2015) × TRM	0.379***	(0.084)
(Year dummy, 1=2015) × TRM,WM	0.103	(0.113)
(Year dummy, 1=2015) × INM	0.0183	(0.12)
(Year dummy, 1=2015) × INM,WM	0.0222	(0.138)
(Year dummy, 1=2015) × INM,TRM	0.0189	(0.103)
(Year dummy, 1=2015) × INM,TRM,WM	0.326**	(0.132)
(Year dummy, 1=2015) × HYV	-0.0338	(0.169)
(Year dummy, 1=2015) × HYV,WM	0.367*	(0.205)
(Year dummy, 1=2015) × HYV,TRM	0.112	(0.126)
(Year dummy, 1=2015) × HYV,TRM,WM	0.167	(0.265)
(Year dummy, 1=2015) × HYV,INM	0.173**	(0.075)
(Year dummy, 1=2015) × HYV,INM,WM	0.226**	(0.089)
(Year dummy, 1=2015) × HYV,INM,TRM	0.172**	(0.073)
(Year dummy, 1=2015) × HYV,INM,TRM,WM	0.316***	(0.080)
Age of the household head in years	-0.001	(0.001)
Years of education for the household head	0.007**	(0.003)
Household size	-0.007**	(0.003)
Logged net off farm income (ZMW per annum)	0.018***	(0.006)
Tropical Livestock Units (TLUs)	-0.002	(0.001)
Logged value of productive assets (ZMW)	0.052***	(0.008)
Farm size in hectares	-0.028***	(0.006)
Farm size squared	0.001***	(0.000
Distance from the homestead to the field	0.009***	(0.003)
Distance to the agricultural camp office (km)	-0.000	(0.005)
Distance to the nearest market (km)	0.006	(0.005)
Distance to the nearest private fertilizer retailer (km)	0.004	(0.005)
Distance to the nearest agro-dealer (km)	0.002	(0.005)
Constant	6.434***	(0.143)
Observations	8,993	
Number of id	5,801	

Clustered Robust standard errors in parentheses (at SEA level).
*** p<0.01, ** p<0.05, * p<0.1

7.5 Net revenue impacts of individual and combined sets of SALMPs — full panel sample

In addition to the gross value of production impacts, net revenue impacts were estimated as well. Table 21 shows these net revenue impacts. Among the individual sets of SALMPs, HYV when used in isolation has a negative and significant net revenue impacts of about 640 ZMW/ha. Combinations involving WM and AF practices, HYV and AF practices, and HYV, TRM and AF practices are the only ones with positive and significant impacts on the net revenue. HYV and INM practices, HYV, INM and WM practices, HYV, INM, WM and AF practices and HYV, INM and TRM practices have significant negative impacts.

Table 21: Net revenue impacts of SALMPs— full panel sample

Variables	Coefficient	Standard error
Year dummy, 1=2015	236.1*	(121.6)
(Year dummy, 1=2015) × WM	-366.7	(283.2)
(Year dummy, 1=2015) × WM,AF	885.7***	(177.4)
(Year dummy, 1=2015) × TRM	-32.75	(160.9)
(Year dummy, 1=2015) × TRM,AF	-135	(190.5)
(Year dummy, 1=2015) × TRM,WM	118.7	(200.7)
(Year dummy, 1=2015) × INM	-305.4	(237.6)
(Year dummy, 1=2015) × INM,WM	-383.5	(256.1)
(Year dummy, 1=2015) × INM,WM,AF	226.3	(487.7)
(Year dummy, 1=2015) × INM,TRM	-108.3	(179.2)
(Year dummy, 1=2015) × INM,TRM,AF	-18.47	(365)
(Year dummy, 1=2015) × INM,TRM,WM	-639.1**	(266.2)
(Year dummy, 1=2015) × INM,TRM,WM,AF	-685.9	(423.6)
(Year dummy, 1=2015) × HYV	-640.4***	(244.3)
(Year dummy, 1=2015) × HYV,AF	634.9***	(143.3)
(Year dummy, 1=2015) × HYV,WM	-159.3	(369)
(Year dummy, 1=2015) × HYV,WM,AF	-162.7	(506)
(Year dummy, 1=2015) × HYV,TRM	-315.5	(263.8)
(Year dummy, 1=2015) × HYV,TRM,AF	1,942***	(170.2)
(Year dummy, 1=2015) × HYV,TRM,WM	412.8	(305)
(Year dummy, 1=2015) × HYV,TRM,WM,AF	224.3	(310)
(Year dummy, 1=2015) × HYV,INM	-403.9***	(138.5)
(Year dummy, 1=2015) × HYV,INM,AF	-453.5	(398.6)
(Year dummy, 1=2015) × HYV,INM,WM	-385.8**	(166)
(Year dummy, 1=2015) × HYV,INM,WM,AF	-1,333***	(499.7)
(Year dummy, 1=2015) × HYV,INM,TRM	-399.3***	(136.3)
(Year dummy, 1=2015) × HYV,INM,TRM,AF	-40.28	(327.3)
(Year dummy, 1=2015) × HYV,INM,TRM,WM	-185.5	(152)
(Year dummy, 1=2015) × HYV,INM,TRM,WM,AF	130.1	(427.7)
Age of the household head in years	-0.859	(1.561)
Years of education for the household head	18.19***	(5.949)
Household size	-4.971	(6.849)
Logged net off farm income (ZMW per annum)	26.21**	(11.4)
Tropical Livestock Units (TLUs)	-1.754	(1.818)
Logged value of productive assets (ZMW)	39.78**	(16.02)
Farm size in hectares	48.46***	(11.13)
Farm size squared	-1.288***	(0.339)
Distance from the homestead to the field	15.93***	(5.775)
Distance to the agricultural camp office (km)	-3.386	(7.009
Distance to the nearest market (km)	19.57*	(10.83)
Distance to the nearest private fertilizer retailer (km)	21.17**	(9.145)
Distance to the nearest agro-dealer (km)	2.922	(9.883)
Constant	-884.7***	(260.2)
Observations	4,875	
Number of id	3,654	

Source: Authors computations from RALS 2012 & 2015 data

Clustered Robust standard errors in parentheses (at SEA level).

*** p<0.01, ** p<0.05, * p<0.1

7.6 Net revenue impacts of SALMPs — without AF practices

Table 22 shows net revenue impacts without the option for AF practices. The results show that the net maize revenue impacts of individual and combined sets of SALMPs with statistically significant impacts are negative. For example, the use of HYV only significantly reduces the net maize revenue by about 591 ZMW/ha. Among the combinations, INM, TRM and WM practices, HYV and INM practices, HYV, INM and WM practices and HYV, INM and TRM reduce the net maize revenue by about 644, 400, 447 and 385 ZMW/ha, respectively.

Table 22: Net revenue impacts of SALMPs— full panel sample without AF practices (n=4,875)

Variables	Coefficient	Standard error
Year dummy, 1=2015	229.8*	(121)
(Year dummy, 1=2015) × WM	-320.6	(276.3)
(Year dummy, 1=2015) × TRM	-31.15	(157.6)
(Year dummy, 1=2015) × TRM,WM	122.2	(200.2)
(Year dummy, 1=2015) × INM	-217.3	(245.9)
(Year dummy, 1=2015) × INM,WM	-359.1	(244.9)
(Year dummy, 1=2015) × INM,TRM	-97.38	(175.1)
(Year dummy, 1=2015) × INM,TRM,WM	-643.6***	(245.1)
(Year dummy, 1=2015) × HYV	-590.8**	(237.8)
(Year dummy, 1=2015) × HYV,WM	-186.3	(335.4)
(Year dummy, 1=2015) × HYV,TRM	-225.3	(262.1)
(Year dummy, 1=2015) × HYV,TRM,WM	453.1	(293)
(Year dummy, 1=2015) × HYV,INM	-399.7***	(137.1)
(Year dummy, 1=2015) × HYV,INM,WM	-447.3***	(163.9)
(Year dummy, 1=2015) × HYV,INM,TRM	-384.5***	(134.7)
(Year dummy, 1=2015) × HYV,INM,TRM,WM	-163.7	(149.1)
Age of the household head in years	-0.801	(1.558)
Years of education for the household head	17.80***	(5.89)
Household size	-4.378	(6.811)
Logged net off farm income (ZMW per annum)	27.06**	(11.38)
Tropical Livestock Units (TLUs)	-1.829	(1.817
Logged value of productive assets (ZMW)	38.93**	(15.98
Farm size in hectares	47.55***	(11.2)
Farm size squared	-1.288***	(0.343)
Distance from the homestead to the field	15.59***	(5.857)
Distance to the agricultural camp office (km)	-4.203	(7.005)
Distance to the nearest market (km)	19.78*	(10.77)
Distance to the nearest private fertilizer retailer (km)	20.86**	(9.119)
Distance to the nearest agro-dealer (km)	4.075	(9.942)
Constant	-894.6***	(258.7)
Number of id	3,654	

Clustered Robust standard errors in parentheses (at SEA level).
*** p<0.01, ** p<0.05, * p<0.1

7.7 Gross value of production and net revenue impacts of SALMPs — first time adopters panel sample

Table 23 presents gross value of production and net revenue impacts of non-mutually exclusive sets of SALMPs for first-time adopters with and without controlling for AF practices. These impacts are presented under columns 1, 2 and 3, respectively. The results show that HYV and

TRM practices have positive and significant impacts on the gross value of maize produced of about 44 and 31 percent, respectively. Column 3 presents the impacts of SALMPs on the net revenue. The impact estimates with and without AF practices are identical, hence column 3 only. The impact of HYV and INM practices on net revenue are negative, whereas that of TRM and WM practices are positive. However, they are all not statistically significant.

Table 23: Gross value of production and net revenue impacts of non-mutually exclusive sets of SALMPs — First-time adopters

	Gross value(ZMW/Ha)		**Net revenue(ZMW/Ha)**			
	1		**2**		**3**	
Year dummy, 1=2015	-0.25	(0.189)	-0.253	(0.189)	-148.6	(1,139)
HYV	0.439***	(0.144)	0.443***	(0.144)	-106.7	(665)
INM	0.174	(0.143)	0.172	(0.143)	-1,122	(696)
TRM	0.308**	(0.138)	0.306**	(0.138)	447	(479.8)
WM	-0.0404	(0.161)	-0.0455	(0.16)	625.6	(553.2)
AF	-0.158	(0.23)				
Age of the household head in years	-0.0259	(0.016)	-0.46	(0.337)	290.4	(369.6)
Years of education for the household head	0.0385	(0.029)	0.14	(0.129)	246.8**	(106.5)
Household size	-0.0117	(0.043)	0.0109	(0.133)	-122.3	(110)
Logged net off farm income (ZMW per annum)	-0.002	(0.032)	0.16	(0.147)	278.9**	(136.2)
Tropical Livestock Units (TLUs)	0.0106	(0.008)	-0.0509*	(0.029)	-16.39	(19.39)
Logged value of productive assets (ZMW)	0.0382	(0.046)	0.0358	(0.159)	-40.8	(138.4)
Farm size in hectares	-0.0944*	(0.054)	-0.157	(0.293)	-196.4	(301.8)
Farm size squared	0.00254	(0.003)	0.0115	(0.019)	4.803	(20.9)
Distance from the homestead to the field	-0.0166	(0.020)	0.0331	(0.034)	-49.24	(41.19)
Distance to the agricultural camp office (km)	-0.0535**	(0.027)	-0.172*	(0.098)	51.18	(91.52)
Distance to the nearest market (km)	0.0408	(0.034)	0.174	(0.117)	114	(86.54)
Distance to the nearest private fertilizer retailer (km)	-0.0417	(0.038)	-0.191	(0.129)	-112.7	(103.9)
Distance to the nearest agro-dealer (km)	0.0203	(0.025)	0.212*	(0.11)	44.91	(75.57)
Constant	8.608***	(1.125)	22.61	(14.61)	-13,744	(15,943)
Observations	906		251		287	
R-squared	0.132		0.568		0.481	
Number of id	657		216		247	
F-statistic	3.019		15.71		5.197	
Prob > F	3.68E-05		0		2.67E-09	

Source: Authors computations from RALS 2012 & 2015 data

Clustered Robust standard errors in parentheses (at SEA level).

*** p<0.01, ** p<0.05, * p<0.1

7.8 Gross value of production impacts of individual and combined sets of SALMPs — first time adopters panel sample

Table 24 presents gross value of production impacts of mutually exclusive individual and combined sets of SALMPs on first time adopters with AF practices. TRM practices and HYV are the only single sets with a positive and statistically significant impact on the gross value of maize produced per hectare. These impacts about 38 and 47 percent, respectively. Moreover, among the combinations, the impact on the gross value of production is positive for widely practices combinations: HYV and INM practices (79 percent) and HYV, INM and TRM practices (over 100 percent), whereas it is negative for HYV, INM, WM and AF practices.

Table 24: Gross value of production impacts of mutually exclusive sets of SALMPs — First-time adopters

Variables	Coefficient	Standard error
Year dummy, 1=2015	-0.265	(0.23)
AF	0.185	(0.552)
WM	0.242	(0.299)
TRM	0.384*	(0.221)
TRM,AF	-0.135	(0.37)
TRM,WM	-0.036	(0.376)
TRM,WM,AF	-0.278	(0.327)
INM	-0.311	(0.306)
INM,WM	-0.104	(0.671)
INM,TRM	0.315	(0.25)
INM,TRM,AF	0.38	(0.729)
INM,TRM,WM	1.268***	(0.208)
INM,TRM,WM,AF	1.085***	(0.229)
HYV	0.465*	(0.278)
HYV,AF	1.048***	(0.292)
HYV,WM	0.306	(0.563)
HYV,TRM	0.301	(0.368)
HYV,INM	0.786***	(0.24)
HYV,INM,AF	0.206	(0.303)
HYV,INM,WM	0.582*	(0.296)
HYV,INM,WM,AF	-0.397**	(0.181)
HYV,INM,TRM	1.186***	(0.249)
HYV,INM,TRM,WM	0.469	(0.361)
Age of the household head in years	-0.024	(0.021)
Years of education for the household head	0.051*	(0.030
Household size	-0.001	(0.043)
Logged net off farm income (ZMW per annum)	-0.018	(0.034)
Tropical Livestock Units (TLUs)	0.014	(0.010)
Logged value of productive assets (ZMW)	0.044	(0.048)
Farm size in hectares	-0.096*	(0.055)
Farm size squared	0.002	(0.003)
Distance from the homestead to the field	-0.022	(0.021)
Distance to the agricultural camp office (km)	-0.048*	(0.026)
Distance to the nearest market (km)	0.026	(0.037)
Distance to the nearest private fertilizer retailer (km)	-0.034	(0.039)
Distance to the nearest agro-dealer (km)	0.019	(0.026)
Constant	8.481***	(1.284)
Observations	906	
Number of id	657	
R-squared	0.182	

Source: Authors computations from RALS 2012 & 2015 data

Clustered Robust standard errors in parentheses (at SEA level).

*** p<0.01, ** p<0.05, * p<0.1

7.9 Gross value of production impacts of individual and combined sets of SALMPs without AF practices — first time adopters panel sample

While Table 24 controlled for AF practices, Table 25 presents gross value impacts of SALMPs without AF practices. The results show that the only SALMP with a significant impact on the gross value of maize production is HYV. The associate gross value gain is about 50 percent. HYV and INM practices is one of the combinations with a positive and significant impact equal to about 75 percent. The other combinations are that of HYV, INM and TRM practices (over 100 percent), INM, TRM and WM practices (over 100 percent) and, HYV, INM and WM practices (48 percent).

Table 25: Gross value of production impacts of mutually exclusive sets of SALMPs without AF practices—First-time adopters (n=906)

Variables	Coefficient	Standard error
Year dummy, 1=2015	-0.24	(0.223)
WM	0.242	(0.292)
TRM	0.352	(0.214)
TRM,WM	-0.0875	(0.335)
INM	-0.318	(0.3)
INM,WM	-0.108	(0.674)
INM,TRM	0.303	(0.247)
INM,TRM,WM	1.228***	(0.181)
HYV	0.496*	(0.259)
HYV,WM	0.322	(0.555)
HYV,TRM	0.281	(0.367)
HYV,INM	0.748***	(0.231)
HYV,INM,WM	0.477*	(0.284)
HYV,INM,TRM	1.170***	(0.245)
HYV,INM,TRM,WM	0.46	(0.36)
Age of the household head in years	-0.026	(0.020)
Years of education for the household head	0.051*	(0.029)
Household size	0.002	(0.043
Logged net off farm income (ZMW per annum)	-0.017	(0.033)
Tropical Livestock Units (TLUs)	0.013	(0.010)
Logged value of productive assets (ZMW)	0.047	(0.047)
Farm size in hectares	-0.091*	(0.053)
Farm size squared	0.002	(0.003)
Distance from the homestead to the field	-0.020	(0.020)
Distance to the agricultural camp office (km)	-0.046*	(0.026)
Distance to the nearest market (km)	0.026	(0.035)
Distance to the nearest private fertilizer retailer (km)	-0.034	(0.037)
Distance to the nearest agro-dealer (km)	0.021	(0.025)
Constant	8.485***	(1.231)
Number of id	657	
R-squared	0.175	

Clustered Robust standard errors in parentheses (at SEA level).
*** p<0.01, ** p<0.05, * p<0.1

8.0 Net revenue impacts of individual and combined sets of SALMPs — first time adopter panel sample

After controlling for AF practices, only TRM and INM practices have significant impact on the net maize revenue as individual sets of SALMPs. This impact happens to be negative (Table 26). The impact of combined sets with significant coefficients is negative and positive for some. Combinations with negative and significant impacts include: INM and TRM practices, HYV and INM practices, and HYV, INM, TRM and WM practices. INM, TRM and WM practices is the only combination with a positive and significant impact. However, without AF practices only HYV has negative and significant impact on impact on the net maize revenue (Table 27). Also, all combinations with significant impacts, are negative.

Table 26: Net maize revenue impacts of mutually exclusive sets of SALMPs with AF practices—first-time adopters

Variables	Coefficient	Standard error
Year dummy, 1=2015	1,215	(754.3)
TRM	-1,041**	(466.7)
TRM,WM	-253.5	(775.4)
INM	-3,482***	(1,147)
INM,TRM	-1,933**	(814.1)
INM,TRM,WM	2,219***	(659.2)
HYV,INM	-1,705**	(809.4)
HYV,INM,WM	-868.5	(533)
HYV,INM,TRM	-465.1	(474.5)
HYV,INM,TRM,WM	-2,030***	(503.3)
Age of the household head in years	62.58	(285.7)
Years of education for the household head	149	(111.7)
Household size	-53.92	(75.33)
Logged net off farm income (ZMW per annum)	88.85	(128.7)
Tropical Livestock Units (TLUs)	4.967	(25.47)
Logged value of productive assets (ZMW)	-28.84	(138.9)
Farm size in hectares	37.16	(332.5)
Farm size squared	3.859	(21.57)
Distance from the homestead to the field	-53.45*	(31.44)
Distance to the agricultural camp office (km)	129.3	(110.8)
Distance to the nearest market (km)	-29.31	(105.1)
Distance to the nearest private fertilizer retailer (km)	85.24	(115.3)
Distance to the nearest agro-dealer (km)	-24.09	(118.3)
Constant	-5,679	(11,376)
Observations	287	
Number of id	247	
R-squared	0.738	

Source: Authors computations from RALS 2012 & 2015 data
Clustered Robust standard errors in parentheses (at SEA level).
*** p<0.01, ** p<0.05, * p<0.1

Table 27: Net maize revenue impacts of mutually exclusive sets of SALMPs without AF practices—First-time adopters

Variables	Net maize revenue (ZMW/ha)	
Year dummy, 1=2015	255.9	(186.1)
WM	-430.2	(521.4)
TRM	-50.45	(228.4)
TRM,WM	-274.3	(209.8)
INM	-1,019	(681.3)
INM,WM	-1,146**	(516.5)
INM,TRM	-836.8***	(250.2)
INM,TRM,WM	419.4	(439.4)
HYV	-539.8**	(213.7)
HYV,WM	-55.15	(293.5)
HYV,TRM	247.3	(408.8)
HYV,TRM,WM	-514.3**	(211.4)
HYV,INM	-317.8	(292.6)
HYV,INM,WM	-25.56	(303.3)
HYV,INM,TRM	-85.17	(267.8)
HYV,INM,TRM,WM	120.1	(290.8)
Age of the household head in years	-1.802	(3.866)
Years of education for the household head	-4.158	(21.55)
Household size	-37.88*	(21.05)
Logged net off farm income (ZMW per annum)	22.09	(33.2)
Tropical Livestock Units (TLUs)	-11.05	(8.709)
Logged value of productive assets (ZMW)	2.038	(48.03)
Farm size in hectares	76.76	(69.53)
Farm size squared	-5.029	(6.183)
Distance from the homestead to the field	4.526	(15.76)
Distance to the agricultural camp office (km)	-35.71	(32.46)
Distance to the nearest market (km)	50.33	(35.55)
Distance to the nearest private fertilizer retailer (km)	-45.9	(29.8)
Distance to the nearest agro-dealer (km)	61.82	(40.16)
Constant	182.9	(597.3)
Observations	287	
Number of id	247	

Source: Authors computations from RALS 2012 & 2015 data
Clustered Robust standard errors in parentheses (at SEA level).
*** p<0.01, ** p<0.05, * p<0.1

8.1 The fraction of net revenue attributed to each individual and combined set SALMPs

Table 28 shows the percentage difference from the mean net revenue, 1215.398 ZMW/ha, of SALMP impacts. Only significant results are presented. For non-mutually exclusive sets of SALMPs, the predicted net revenue is expected to increase by about 19 percent for HYV, whereas that for INM practices falls by about 32 percent. Similarly, for the mutually exclusive sets: WM and AF practices, HYV and AF practices, and HYV, TRM and AF practices, the predicted net revenues are expected to increase by over 50 percent with AF practices controlled for. This applies to the full sample. The predicted net revenues for the rest of the combinations are negative — also true without AF practices. Comparable analysis on a sample of first time adopters shows that only the predicted net revenues for a combination of INM,TRM and WM practices are expected to increase by over 100 percent, while net revenues for the rest of the combinations (for models with and without AF practices) are expected to fall. These results show mixed expected net revenue impacts of SALMPs, even though for the most they are negative.

Table 28: The fraction of net revenue attributed to each set of individual and combined sets SALMP

Non-mutually exclusive sets-full sample	Net revenue(ZMMW/ha) Impact	% difference from the mean
HYV	+230.2	+18.94
INM	-388.7	-31.98
Mutually exclusive sets - full sample with AF practices		
WM,AF	+885.7	+72.87
INM,TRM,WM	-639.1	-52.58
HYV	-640.4	-52.69
HYV,AF	+634.9	+52.24
HYV,TRM,AF	+1942	+159.78
HYV,INM	-403.9	-33.23
HYV,INM,WM	-385.8	-31.74
HYV,INM,WM,AF	-1333	-109.68
HYV,INM,TRM	-399.3	-32.85
Mutually exclusive sets - full sample without AF practices		
INM,TRM,WM	-643.6	-52.95
HYV	-590.8	-48.61
HYV,INM	-400	-32.91
HYV,INM,WM	-447.3	-36.80
HYV,INM,TRM	-384.5	-31.64
Mutually exclusive sets - first time adopters sample with AF practices		
TRM	-1041	-85.65
INM	-3482	-286.49
INM,TRM	-1933	-159.04
INM,TRM,WM	+2219	+182.57
HYV,INM	-1705	-140.28
HYV,INM,TRM,WM	-2030	-167.02
Mutually exclusive sets - first time adopters sample without AF practices		
INM,WM	-1146	-94.29
INM,TRM	-836.8	-68.85
HYV	-539.8	-44.41
HYV,TRM,WM	-514.3	-42.32

Source: Authors computations from RALS 2012 & 2015 data

8.2 Gross value of production and net revenue: marginal effects of SALMPs

Table 32 presents marginal effects of the five sets of SAMPLs for the gross value of maize production and net revenue for the full sample. The results show that the marginal effects of

INM and TRM practices are positive for the gross value of production — with and without AF practices (columns 1 and 2). However, the marginal effect of INM practices is only significant for a full sample where AF practices are controlled for. In addition, the marginal effects of TRM practices are statistically significant under both specifications (columns 1 and 2) and are almost of equal magnitude. Columns 3 and 4 present the changes in the net revenue with respect to the change in each set of SALMPs. Column 3 controls for AF practices and show negative and significant marginal effects of WM practices on the net maize revenue. However, without AF practices this impact is no longer significant, whereas that of HYV is negative and now significant.

Table 33 shows marginal effects of SALMPs on a sample of first-time adopters. The change in the gross value of maize produced with respect to HYV and TRM practices is positive and statistically significant. With and without AF practices, columns 1 and 2, the difference in the size of the effects is relatively marginal. However, the change in the net maize revenue with respect to HYV, INM, TRM and WM is negative and significant when AF practices are controlled for. Without AF practices, only the marginal effect of HYV is still negative and significant.

8.3 Summary

This chapter presented the gross value of production and net revenue impacts of SALMPs for both mutually and non-mutually exclusive sets of SALMPs. For the non-mutually exclusive sets, the findings show positive and significant gross value of maize produced and net revenue impacts of HYV, while both INM and TRM practices significantly impact the gross value of maize produced only. Nonetheless, the impact of INM practices on the net revenue is negative and significant.

Moreover, the results from the analysis of mutually exclusive sets of SALMPs shows that TRM practices is the only individual set with a positive and significant impact (38 percent) on the gross value of maize produced. The impacts of widely practiced combinations of SALMPs, HYV and INM practices and HYV, INM and TRM practices, on the gross value of production are also positive and statistically significant. The gain in the gross value of production is higher when additional sets of SALMPs are included. This is true for both samples. The marginal effects of the five sets of SALMPs are only positive and significant for TRM and WM practices.

While the TRM practices marginal effect is significant for both models with and without AF practices, the marginal effect of WM practices is significant without AF practices. Net revenue impacts of individual sets of SALMPs with significant impacts are negative. The impacts are however mixed for various combinations of SALMPs. The marginal effects of HYV are negative and significant for the model without AF practices, whereas WM practices marginal effects are significant with AF practices.

For first-time adopters, the results show that HYV and TRM practices (non-mutually exclusive) have positive and significant impacts on the gross value of maize produced of about 44 and 31 percent, with and without AF practices, respectively. However, the impacts of the four sets of SALMPs on the net revenue are mixed and not statistically significant.

Gross value of production impacts of mutually exclusive individual and combined sets of SALMPs show significant impacts for TRM practices (38 percent) and HYV (47 percent) only, as individual sets. Widely practiced combinations also have positive and significant impacts: HYV and INM practices (79 percent) and HYV, INM and TRM practices (over 100 percent). Without AF practices, HYV is the only SALMP with a positive and significant impact (50 percent). The marginal effects of HYV and TRM practices are the only positive and significant ones, for models with and without AF practices.

For the net revenue impacts, individual sets with significant impacts have negative effects. However, the impact of various combined sets with significant impacts is mixed for the model with AF practices controlled for. However, without AF practices, none of the individual sets of SALMPs have a statistically significant impact on the net maize revenue and all significant combinations have a negative impact. Further, INM, TRM and WM practices is the only combination with a significant and positive impact on the net revenue. Moreover, the marginal effects of HYV, INM, TRM and WM practices are negative and significant only for the model with AF practices. Without AF practices, only HYV has significant negatively marginal effects. Overall, the gross value of production impacts of SALMPs are positive and significant, whereas the net revenue impacts are not.

CHAPTER EIGHT

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

8.1 Introduction

This chapter presents the main highlights of the study. These summaries and conclusions draw on the findings of the study at both descriptive and econometric analysis stages. The main study implications relating to the adoption and impacts of sustainable land and agricultural management practices based the econometric results are also presented.

8.2 Summary and conclusions

Owing to the attention climate smart agriculture is receiving, it is important to identify comprehensively, which agricultural practices are climate smart and sustainable, what factors influence their adoption and what their impact is on outcomes such as crop productivity. These questions ought to be answered within context, as agricultural practices are argued to be location and time specific. It is against this background that this study sought after achieving the main objective — determining the crop productivity impacts of individual and combined sets of SALMPs in Zambia using panel data for the 2012 and 2015 RALS surveys. Specifically, the study sought to (i) describe the distribution of SALMPs adoption sets by Agro-ecological zone, (ii) identify the optimal individual and combined sets of SALMPs for a typical rural farm household, (iii) identify factors influencing the adoption of different sets of SALMPs, and to (iv) determine the level of maize productivity per hectare for a rural farm household for different SALMPs practices. Consequently, the main findings of the descriptive and econometric analyses are summarized in sections 8.2.1 and 8.2.2, respectively.

8.2.1 Descriptive analysis

The set of SALMPs most practised is not constant with time. In the sample, the most practiced sets of SALMPs were HYV, TRM and INM practices, in 2012 and 2015, respectively, whereas AF practices were the least adopted in both periods. Generally, adoption of the five sets of SALMPs varies across AEZs by year. For instance, adoption of HYV is highest in AEZ IIa and least in AEZ IIb in both years. This also applies to INM practices. Adoption of TRM practices is highest in the Western Semi-arid Plains (AEZ IIb) compared to the other AEZs in both periods. The Central, Southern and Eastern plateau (AEZ IIa) has the highest WM adoption rate, slightly above 30 percent in both periods, whereas the Western Semi-arid Plains (AEZ IIb) has the lowest.

Among the mutually exclusive individual sets of SALMPs, TRM practices only are the most adopted in both years, 2012 (17 percent) and 2015 (10 percent), while AF practices are the least. As for the combined sets, HYV, INM and TRM practices only was adopted by the majority, 24 percent in 2012, whereas 20 percent representing the majority adopted HYV and INM practices in 2015. In terms of complementarity, HYV was found to be complementary with most sets of SALMPs.

Maize productivity levels averaged slightly above 3,000 kgs/ha for combinations that involved both HYV and INM practices. Equally, the farm size increased by about 0.22 hectares. Furthermore, there was increase in the amount of the net off farm income amounting to about an average of 2,605 ZMW/annum. Access to input loans for fertilizer and seed significantly increased between the two years by 10 and 1 percent, respectively. Similarly, so did the number of households benefiting from FISP, those having kinship ties and farmer cooperative membership. This increase was less than 6 percent for each of these factors. While farmer cooperative membership increased on by about 5 percent, the percentage of those that reported receiving advice on conservation farming (CF) increased by about 25 percent.

Among the field characteristics, there was significant decrease in the distance from the homestead to the largest maize field. Likewise, the proportion of households with fields on title reduced between the two periods. The descriptive statistics also show that the percentage of farm households that indicated having fields prone to soil erosion/flash flooding and located in a wetland/dambo increased by about 4 and 2 percent, respectively.

8.2.2 Econometric analysis

8.2.2.1 Selection model

Econometric results from the selection model show a number of factors that have an effect on the adoption of SALMPs. These factors fall under the following main categories: household, resource constraint, social capital and government support, access to information and key agricultural related infrastructure/services, field characteristics, agro-ecological zone characteristics and other weather factors had a significant effect on the adoption decisions for some practices. For example, the age and gender of the household head as well as the household size were found to have a positive and significant effect in explaining adoption decisions for some sets of SALMPs. Household wealth proxy variables — farm size, net off farm income, value of productive assets and livestock ownership were also found to have significant effects (positive and negative) in explaining adoption of certain sets of SALMPs. Access to input loans also affected adoption decisions.

Benefiting from a government support programme such as FISP was found to have positive and significant effect on the adoption of HYV and INM practices as expected. The effect of kinship ties was found to be negative for AF practices. Cooperative membership, another social capital and network factor had negative effects on the adoption of AF practices, whereas the influence on the other sets was insignificant. Unlike the others, social capital and network factors as well as having access to information on conservation farming positively and significantly affected the adoption of most sets of SALMPs.

Considering the importance of having access to key agricultural related infrastructure and services, it is not surprising that increased distance to such facilities was found to have significant effects on the adoption of different sets of SALMPs. For instance, increase in the distance to the market, significantly lowered the likelihood of adopting most of the SALMPs sets. In addition, plot level attributes such the distance from the homestead to the largest maize field, tenure status of the field, exposure to field shocks such as soil erosion/flash flooding and whether the field is in a wetland/dambo area were also found to have significant effects on adoption decisions for some sets of SALMPs.

Lastly, agro-ecological location and weather factors such as average monthly temperatures and precipitation during the growing season equally influence agricultural technology adoption decisions. WM practices are less likely to be adopted in AEZ IIa, in comparison to the hotter region, AEZ I. Adoption of HYV, AF and WM practices is less likely in AEZ IIb compared to AEZ I, whereas the adoption of TRM practice is more likely. In AEZ III, AF adoption is equally less likely compared to AEZ I. Additionally, higher average temperatures lower the likelihood of adopting practices whose effects are realised in a short-term. Examples of such practices include HYV, INM, TRM and WM practices. Similarly, adoption of HYV and INM practices reduces with increase in the average precipitation, whereas the adoption of WM practices is more likely.

8.2.2.2 Impact models

Overall, results of the impact analysis show that the five sets of SALMPs analysed have significant impacts on maize yields. For the full sample, non-mutually exclusive individual sets of SALMPs have significant positive impacts on maize yield, except for WM and AF practices. This is also true when only first time adopters are analysed, even though in addition to WM and AF practices, the impact of INM practices is not statistically significant. However, HYV and TRM practices are the only practices with positive and significant impacts as mutually exclusive individual sets (for the full sample only). For the most part, the impact of widely practiced sets of SALMPs, HYV and INM practices and, HYV, INM and TRM practices, is positive and significant. This shows and supports the complementarity among the use of improved seed fertilizer, inorganic and/or organic fertilizers and minimum tillage methods. Similar sets equally have positive and significant impacts on the gross value of maize produced. Generally, first-time adopters are better-off when specific sets of SALMPs are adopted in bundles.

While the positive crop productivity and gross value of maize produced impacts are evident, especially widely adopted sets of SALMPs, the net maize revenue impacts per hectare are for the most part negative. This suggests that the productivity gains may not be large enough to offset variable production costs. Limited maize sales among farm households employing these practices can also help explain this overall negative net revenue impact.

8.3 Main implications

The study has shown that adoption decisions pertaining to different sets of SALMPs are influenced by several factors, among others, from household and field level to the agro-ecological zone location and weather factors. For climate smart agriculture, the need for regional agricultural policy planning needs to be reinforced. This will result in the design and implementation of appropriate regional specific agricultural interventions to enhance the adoption of suitable individual and combined sets of SALMPs. Moreover, the findings have also shown that adoption of different sets of SALMPs has positive and significant crop productivity effects. However, these productivity effects still need to be enhanced for positive and significant net revenue impacts. In addition, maize commercialization through value addition among smallholder farmers should be promoted as well.

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APPENDICES

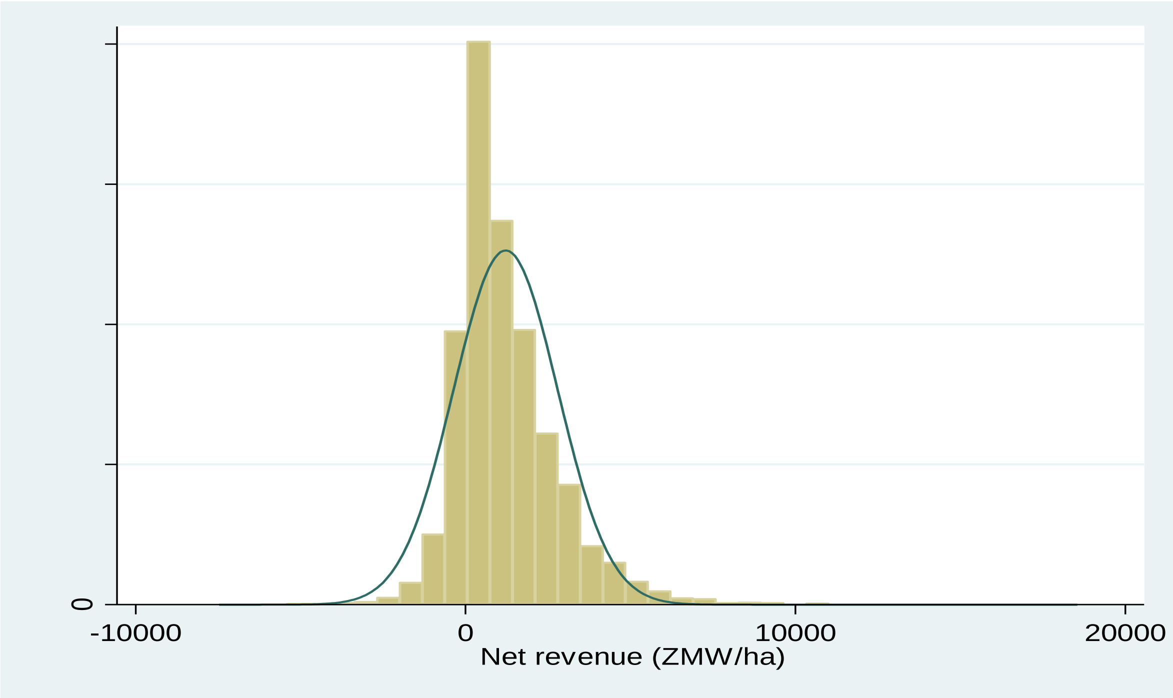

Figure 3: Histogram for the net maize revenue per hectare

Table 29: Summary statistics for the outcome variables by set of SAMPLs — 2012

Sets of SALMPs	Statistics	Yield (kgs/ha)	Gross value of maize produced (ZMW/ha)	Net maize revenue (ZMW/ha)
None	mean	1657.377	1665.765	854.6467
	p50	1212.895	1283.951	520
AF	mean	2027.141	2291.551	.
	p50	2042.315	2308.704	.
WM	mean	1617.807	1671.319	999.6962
	p50	1352.551	1302.006	810.25
WM,AF	mean	1030.673	1165.109	163.3333
	p50	536.6667	606.6667	163.3333
TRM	mean	1397.427	1394.012	842.9655
	p50	1064.815	1040	608.4042
TRM,AF	mean	2007.884	2188.278	1378.583
	p50	1629.167	1991.667	689.1667
TRM,WM	mean	1704.198	1712.218	1056.291
	p50	1301.44	1343.333	525.4321
TRM,WM,AF	mean	2257.723	2569.856	3183.304
	p50	2129.63	2407.407	3183.304
INM	mean	2065.171	2174.945	556.5809
	p50	1763.333	1782.716	358.0247
INM,AF	mean	2065.741	1946.296	502.572
	p50	1859.877	2102.469	502.572
INM,WM	mean	1973.055	2096.212	562.3787
	p50	1737.778	1805.556	275.8796
INM,WM,AF	mean	2880.019	3068.345	850.3414
	p50	2261.667	2063.492	714.1314

Table 29 (*continued*).

INM,TRM	mean	2027.041	2019.516	681.8402
	p50	1663.139	1604.938	338.3333
INM,TRM,AF	mean	2044.298	1885.421	223.4952
	p50	1866.502	1590.488	103.7037
INM,TRM,WM	mean	2061.464	2020.555	886.7076
	p50	1419.753	1538.333	571.2228
INM,TRM,WM,AF	mean	2713.693	3039.46	944.6574
	p50	1419.753	1604.938	715.0617
HYV	mean	2027.663	1799.151	952.0032
	p50	1466.25	1560	740.7407
HYV,AF	mean	3751.698	2549.056	845.679
	p50	2300	2600	845.679
HYV,WM	mean	1928.586	1917.61	1203.73
	p50	1495	1539.352	1009.875
HYV,WM,AF	mean	2034.979	2228.807	1994.753
	p50	2271.605	2567.901	1994.753
HYV,TRM	mean	2153.633	1916.991	1290.452
	p50	1495	1440	850
HYV,TRM,AF	mean	1875.561	2111.969	285.18
	p50	747.5	845	285.18
HYV,TRM,WM	mean	1834.814	1693.713	1102.988
	p50	1428.627	1387.222	534.9794
HYV,TRM,WM,AF	mean	2070	1552.5	264
	p50	2070	1552.5	264
HYV,INM	mean	3315.891	3185.88	1447.44
	p50	2814	2789.63	1243.288
HYV,INM,AF	mean	3518	3362.113	1604.204
	p50	2981.481	2674.897	1142.387
HYV,INM,WM	mean	3259.633	2944.751	1296.932
	p50	2839.506	2674.591	1232
HYV,INM,WM,AF	mean	3379.637	2774.501	1691.755
	p50	3066.667	2833.333	1414.194
HYV,INM,TRM	mean	3510.328	3321.187	1526.883
	p50	2913.333	3033.333	1246.957
HYV,INM,TRM,AF	mean	3732.996	3351.557	1186.342
	p50	2895.833	2697.5	829.6296
HYV,INM,TRM,WM	mean	3315.888	2929.076	1256.919
	p50	2861.25	2535.802	816.0998
HYV,INM,TRM,WM,AF	mean	3608.419	3368.44	1403.807
	p50	3350	2822.857	894.95

Table 30: Summary statistics for the outcome variables by set of SAMPLs — 2015

Sets of SALMPs	Statistics	Yield (kgs/ha)	Gross value of maize produced (ZMW/ha)	Net maize revenue (ZMW/ha)
None	mean	1337.8	1433.396	895.9141
	p50	1100	1136.087	613.3333
AF	mean	1240.756	1320.627	558.6
	p50	1150	1040	558.6
WM	mean	1481.106	1628.214	765.492
	p50	1150	1283.951	649.6377
WM,AF	mean	2602.407	2428.102	390
	p50	2502.315	1853.704	390
TRM	mean	1569.556	1608.379	948.402
	p50	1204.897	1300	700
TRM,AF	mean	1680.759	1780.921	435.5556
	p50	1380	1560	435.5556
TRM,WM	mean	1682.534	1600.188	914.2223
	p50	1419.753	1337.449	808
TRM,WM,AF	mean	1439.36	1425.148	.
	p50	1313.272	1464.506	.
INM	mean	1808.499	1871.226	403.4695
	p50	1437.5	1574.803	254
INM,AF	mean	1602.093	1802.95	1196.253
	p50	1316	1423.217	864
INM,WM	mean	1664.277	1762.13	60.4993
	p50	1419.753	1560	-20.48001
INM,WM,AF	mean	1991.518	2614.985	915.4938
	p50	1399.877	1582.469	915.4938
INM,TRM	mean	1923.766	1955.002	492.1715
	p50	1419.753	1604.938	259.3786
INM,TRM,AF	mean	1395.812	1524.78	298.5642
	p50	1533.333	1451.852	-98.76543
INM,TRM,WM	mean	1867.978	1943.414	199.4212
	p50	1703.704	1882.963	88.2716
INM,TRM,WM,AF	mean	2361.204	2399.412	438.6728
	p50	1987.654	2206.79	295.0309
HYV	mean	1693.541	1828.124	1209.989
	p50	1285.764	1371.5	733.3333
HYV,AF	mean	1432.265	1458.357	603.2939
	p50	1322.5	1303.922	617.2839
HYV,WM	mean	2227.719	2189.153	770.9908
	p50	1774.691	1843.621	653.6729
HYV,WM,AF	mean	2509.059	2246.819	648.254
	p50	2713.503	2354.868	648.254
HYV,TRM	mean	1648.975	1678.239	1051.802
	p50	1380	1390.947	728.8
HYV,TRM,AF	mean	1708.2	2051.008	2459.04
	p50	1444.599	1633.025	2459.04
HYV,TRM,WM	mean	2282.109	2179.482	1394.285
	p50	2186.065	2110	1145
HYV,TRM,WM,AF	mean	2227.069	2496.98	380.7408
	p50	1859.877	2040.741	380.7408
HYV,INM	mean	3122.664	3221.591	1201.342
	p50	2760	2875	882.4062
HYV,INM,AF	mean	3189.595	2994.096	1022.469
	p50	2666.77	2430.453	574.6471
HYV,INM,WM	mean	3378.977	3338.679	1272.455
	p50	2875	3017.833	925.2174

Table 30 (*continued*).

HYV,INM,WM,AF	mean	3475.92	2869.266	451.6455
	p50	3360.082	2448.333	514.7817
HYV,INM,TRM	mean	3322.026	3382.854	1250.68
	p50	2875	3000	949
HYV,INM,TRM,AF	mean	3984.207	3675.15	1713.749
	p50	3147.711	2944.444	909.7909
HYV,INM,TRM,WM	mean	3596.18	3479.296	1304.237
	p50	3105	3111.111	1058.667
HYV,INM,TRM,WM,AF	mean	3690.028	3456.141	1290.444
	p50	2839.506	3200	1359.044

Table 31: Crop productivity: Marginal effects of the five sets of SALMPS

	Full sample		First time adopters	
Variables	**1**	**2**	**3**	**4**
HYV	.001057	.1534716	.4114573	.4470739*
	(.0007196)	(.2533312)	(.2819809)	(.2654812)
INM	.0002463	.0013767	-.1479345	-.162066
	(.0002338)	(.1864082)	(.3162509)	(.3089761)
TRM	.4579833 ***	.4310059***	.4501858***	.4212188***
	(.1490641)	(.1498655)	(.2415939)	(.2320917)
WM	-.1517398	-.0330188	.2546934	.2433428
	(.251454)	(.2382213)	(.3343061)	(.3289563)
AF	.5763463		.2474593	
	(.5302003)		(.5534592)	

Source: Authors computations from RALS 2012 & 2015 data
Clustered Robust standard errors in parentheses (at SEA level).
*** p<0.01, ** p<0.05, * p<0.1

Table 32: Gross value of production and Net revenue: Marginal effects of the five sets of SALMPS — full sample

	ln(gross value of production)		Net revenue	
	1	**2**	**3**	**4**
HYV	.0007685	.0147739	-.5477998	-628.772*
	(.0004949)	(.1761484)	(.5297839)	(247.6681)
INM	.0002842*	.0406294	-.0893103	-250.806
	(.0001628)	(.127895)	(.212438)	(250.0831)
TRM	.4330951***	.4440162***	-148.9804	-146.7169
	(.1067986)	(.1032233)	(196.2198)	(193.0584)
WM	.252979	.3206192**	-539.3693*	-495.2391
	(.1568049)	(.1552529)	(323.3123)	(317.8638)
AF	-.2459391		-173.2834	
	(.4395782)		(167.7302)	

Table 33: Gross value of production and Net revenue: Marginal effects of the five sets of SALMPS — first time adopters

	ln(gross value of production)		Net revenue	
	1	2	3	4
HYV	.574553*	.6041219**	-104.6246***	-550.062**
	(.2960093)	(.2770606)	(32.09525)	(232.5799)
INM	-.2036928	-.2138457	-3586.62***	-1083.63
	(.3178697)	(.3096555)	(1161.584)	(685.3002)
TRM	.494552**	.4654465 **	-1188.601**	-78.21845
	(.2386812)	(.2304427)	(488.9818)	(258.7526)
WM	.340325	.3312088	-352.4009***	-472.5724
	(.3365018)	(.3304861)	(130.0086)	(542.3248)
AF	.2083528			
	(.5629856)			

Source: Authors computations from RALS 2012 & 2015 data

Clustered Robust standard errors in parentheses (at SEA level).

*** p<0.01, ** p<0.05, * p<0.1