Determinants of yield impact and adoption of conservation agriculture among smallholder farmers in Zimbabwe

by

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Submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy (Agricultural Economics)

in the

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

January 2016

DEDICATION

To my late mother Ellen Pedzisa and late sister Nyaya Pamela Pedzisa, your faith in my potential kept me going and pushed me this far.

DECLARATION

I, Tarisayi Pedzisa declare that the thesis, which I hereby submit for the degree of Doctor of Philosophy (Agricultural Economics) at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution.

Signature:……………………………………………………………………………………

Date: ……………………………………………………………………………………

ACKNOWLEDGMENT

I thank God above all others for giving me strength to persevere and accomplished this task. The writing of this thesis was made possible by the generous financial support from the University of Pretoria through the Center for Environmental Economics and Policy in Africa (CEEPA) and Post graduate study abroad bursary. I would like to thank all members of staff in Department of Agricultural Economics, Extension and Rural Development, University of Pretoria for their support and guidance. I am so grateful to my supervisor, Dr Rugube, for his mentorship, advice, guidance and for working tirelessly to ensure this thesis became a reality. I also want to thank my co–supervisor Prof Winter- Nelson who gave me hope, guidance and encouragement. Many thanks goes to Prof Kirsten the head of department, Prof Machethe, Dr Mungatana and Prof Binswanger- Mkhize for their valuable advice. Thank you Darlene du Plesiss, Yvonne Samuels and Zuna Botha for your administrative assistance.

I appreciate the role played by Prof Baylis in shaping the direction of this thesis and her most valuable suggestions. Many thanks to Dr Mazvimavi for facilitating access to the ICRISAT dataset used in writing this thesis. Your critical comments and helpful suggestions on the write-up are highly appreciated. I am indebted to ICRISAT-Bulawayo for the support received during the writing of this thesis especially office space and internet access.

My sincere thanks to the following people for their assistance and encouragement ; Catherine Donono, Thandi Nxcumalo, Shingai Manyonga, Cleopatra Ngulube, Sifiso Ncube, Nester Mashingaidze, Tendai Maravanyika, Kumbirayi Musiyiwa, Esther Masvaya and Cephas Mandingwa. A big thanks to my colleagues at UP; Thinah, Choolwe, Hywott, Thembi, Charity, Colleta, Cecilia, Julias, Elias, Hillary and the rest of the team.

Last but not least, I would like to thank my family for their unconditional support. A special thanks to my beloved father Anthony Kundishora Pedzisa and my siblings Kudzai, Fungai, Nyasha, Ruvimbo and not forgetting Max Pfuma, Joze Mutendereki and Farayi Ndoro. I salute my sons Takura and Tapiwa Ndoro for their endurance, thank you guys for hang in there.

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ABBREVIATION AND ACRONYMS

ACT	African Conservation Tillage Network
AGRITEX	Agricultural, Technical and Extension Services
AIDS	Acquired immunodeficiency syndrome
CA	Conservation Agriculture
CIMMYT	International Maize and Wheat Improvement Centre
CGIAR	Consultative Group on International Agricultural Research
CRP	CGIAR Research Program
CT	Conservation Tillage
DFID	Department for International Development
FAO	Food and Agriculture Organisation of the United Nations
GDP	Gross Domestic Product
GoZ	Government of Zimbabwe
HIV	Human immunodeficiency virus
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IFAD	International Fund for Agricultural Development
INRM	Integrated Natural Resource Management
MDG	Millennium Development Goal
MLE	Maximum-likelihood estimation
NGOs	Non-Governmental Organisations
NR	Natural Regions
PRP	Protracted Relief program
SAPs	Sustainable Agricultural Practices
SSA	Sub- Saharan Africa
STATA	Data Analysis and Statistical Software
SPSS	Statistical Package for the Social Sciences

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DEPARTMENT: Agricultural Economics, Extension and Rural Development

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ABSTRACT

The thesis assesses the yield advantage and adoption dynamics of conservation agriculture (CA) as a sustainable farming method that was introduced in Zimbabwe to address the problems of low productivity and declining soil quality. This study is based on five-year panel survey that was intended to monitor the impacts of CA on adopters. The study focused particularly on basin CA, which involves digging small pits with hand hoes during the off-season. This technology allows for early planting and the concentration of soil nutrients within the planting basin in order to reduce the risk of crop failure.

Specifically, this study attempts to:

a) Provide evidence that shows that CA adoption has a positive impact on maize yield;
b) Determine factors that condition farmers to apply more components of the CA package ; and
c) Answer the question why some farmers are abandoning CA, which they had adopted earlier.

The first part of the thesis used plot level data to model a single equation yield function where CA was assumed to have an intercept effect. Through a household fixed effect model, the impact on yield was measured and verified through ordinary least squares. The evaluation showed that the input with the greatest impact on yield was nitrogen fertiliser. The unambiguous finding of this analysis is the positive significant impact of CA technology on maize yield.

The second part of the thesis examined the determinants of adoption intensity using count regression models, specifically Poisson and negative binomial regression. The evaluation showed that more intense users of CA had higher productivity, lived in areas with higher production potential and received some form of input support from non-governmental organisations. There is a general tendency towards dis-adoption as farmers reduce the number of CA practices applied with time. However, the number of techniques applied in the current season increases albeit at a diminishing rate. This implies that CA is becoming more intensively practised in a relatively endogenous manner. However, unless conditions that make the practice easier to apply, CA cannot be expected to be maintained in Zimbabwe.

Finally the thesis applied a random effects logit model to measure abandonment of CA. Study findings suggest that poor vulnerable households are more likely to persist with CA confirming that CA is accessible to the poor who are the target group for this technology. Loss of input support through programmes has contributed to dis-adoption but it is not clear whether commercial fertiliser has been available in the absence of NGO programmes. In addition, there is a strong tendency toward dis-adoption in semi-arid and arid regions, raising the question about the suitability of CA in those regions.

The study finds results that appear to be at odds with each other: that the practice of CA leads to significantly higher yields of the most important crop, yet there is evidence of farmers discontinuing the practice. There is therefore need to explore the factors that constrain adoption and encourage abandonment in order to understand whether the future of sustainable agriculture in Africa lies in CA.

KEY WORDS: *Yield impact, conservation agriculture, household fixed effect, Adoption intensity, count regression, smallholder farmer, technology adoption, abandonment, probit.*

CHAPTER 1

INTRODUCTION

1.1 Background

Agriculture is a strategic sector to Africa particularly Sub- Saharan Africa (SSA) where 60% of the population depends on agriculture for their sustenance and livelihoods (FAO, 2009). Agriculture currently accounts for about 35% of SSA gross domestic product (GDP) and at least 40% of export value and provides approximately 70-80% of formal employment in SSA (IMF 2010; World Bank, 2010).Growth in agricultural GDP in SSA has been relatively strong in recent decades and cereal yields are rising in Africa on average (FAO Stat, 2014). Despite the importance of this sector in the region, growth in agricultural production per capita has lagged behind other regions (Todaro & Smith, 2009) and there is long standing food insecurity across the continent (World Bank, 2008). Sub-Saharan Africa has the highest rates of hunger and malnutrition in the developing world with about a third of the population, nearly 200 million people, lacking food (UNDP, 2012; Mitchell, 2010). Farmers' own production falls short of their subsistence requirements posing a challenge of increased hunger and poverty (FAO, 2006). The challenge is further worsened by predicted future climate change: it is expected that droughts will become severe affecting crop production if no changes are made to existing cropping systems (Dinar *et al.,* 2008; Boko *et al.,* 2007). Moreover, low-input agriculture characterising farming systems in Africa (often driven by poverty and lack of resources) further accelerate land degradation and soil fertility deterioration (Derpsch, 2008). Increasing crop production therefore remains an important challenge in SSA.

Thus, given the aforementioned challenges to smallholder agriculture in SSA, a key policy intervention is the promotion of sustainable agricultural technologies to break the vicious cycle of poverty and improve the land quality. Improving productivity is fundamental to a prolonged increase in agricultural production, which can be achieved through better technology and efficiency. This calls for agricultural methods that arrest soil degradation and improve soil quality over time. Conservation agriculture (CA) has emerged as an alternative farming practice to address problems of low crop productivity, soil organic matter decline, water run-off and soil erosion resulting from tillage-based conventional agriculture (Hobbs, 2007; Erenstein *et al.*, 2008). The technology is based on three principles of natural resource management, namely minimum soil disturbance, permanent soil cover and crop rotations

(FAO, 2008). In Zimbabwe, manure or chemical fertiliser is also added to enhance fertility because there are challenges to soil fertility management associated with mulching and crop rotation. Given the current fertility status on most farms, CA cannot be practised effectively without the addition of nutrients especially nitrogen and phosphorus, to the system (Nyamangara *et al.*, 2014). Hence, targeted application of small amounts of chemical fertiliser is a component of CA in Zimbabwe. Moreover, the gains from CA may grow over multiple seasons of practice and soil quality recovery (Umar *et al.*, 2012).

There is consensus among African governments that CA is one of the best food security and profitability options for farmers (Lusaka Declaration 2014). In addition, it is a climate-smart and environmentally sustainable solution that gives farmers the choice to apply CA principles to a range of food production systems. Practising CA farmers across Africa have provided feedback and documented significantly positive impacts on their incomes, livelihood and well-being and on the empowerment of women farmers. As a result many governments in Africa have channelled investment of resources towards the promotion of CA and to create an environment conducive for its adoption. However, scientists have been cautioned against promoting CA as a panacea to agricultural challenges associated with poor performance in SSA and no critical analysis of CA's potential in the region has been conducted (Giller, Witter, Corbeels & Titttonell, 2009). Insufficient attention has been paid to the testing, tailoring and targeting of the relevant components of CA across the diverse agro-ecological and socio-economic conditions of different countries. It is therefore necessary to overcome the constraints that prohibit the adoption of CA, especially among smallholder farmers in pursuit of food security goals.

In Zimbabwe, smallholder agriculture is important for food security and livelihood activity for many rural households. The share of the population engaged in smallholder agriculture accounts for about 70% of the population (Zimstat 2012). However, smallholder food production is far outweighed by food demand. As a result close to a quarter of Zimbabwe's population – about three million people − are currently food and nutrition insecure (Zimvac, 2012). This is a crisis at national level that requires sustainable solutions, since food aid results in a fiscal strain and can only be a short - term strategy. The Government of Zimbabwe (GoZ) has prioritised increased food production within the smallholder sector as a way of attaining Millennium Development Goal (MDG) number one, and eradicating hunger and poverty.

Since 2004, the Zimbabwe Ministry of Agriculture and numerous non-governmental organizations (NGOs), through various donor-funded initiatives, have promoted CA with the aim of sustainably addressing low productivity and improving food security among smallholder farmers (Marongwe *et al*., 2011). Conservation agriculture is thus seen as a long-term strategy for addressing perpetual food shortage and as an alternative to unsustainable hand-outs (Gukurume, Nhodo & Dube, 2010). In acknowledgement of the importance of CA, the GoZ launched a comprehensive National CA Implementation Framework in 2012 (MAMID, 2012). The framework aims to reach 500 000 farmers practising CA on at least 250 000 hectares by 2015, with a targeted yield of 1.5 tonnes per hectare from an estimated average yield 800kg per hectare on the smallholder maize crop (Muchinapaya, 2012). This will result in smallholder maize production under CA contributing to 20% of the nation's annual maize grain requirement.

There is a growing body of research emphasizing the importance of CA in the smallholder setting of Africa. The biophysical benefits of CA have been widely published based on results from the Americas and Australia (Wall, 2007; Kassam *et al*., 2009). There is also an increasing body of knowledge from Zimbabwe and other Southern African countries on the agronomic impacts of CA (Mupangwa, 2009; Thierfelder & Wall, 2010; Rusinamhodzi *et al.*, 2011; Ngwira *et al.*, 2012, Mashingaidze, 2013; Nyamangara *et al.*, 2013). Ample evidence exist to show that CA based on minimum tillage can result in higher yields, compared to normal farming practice based on deep ploughing conventional tillage (Nyagumbo, 2002; Kassam *et al*., 2009). Thus, CA is an appealing option for enhancing productivity for resource-poor farmers. Similarly there has been an accumulation of publications on CA adoption and constraints to its adoption (Mazvimavi & Twomlow, 2009; Sicili *et al*.; 2011; Nkala *et al*.; 2011; Nyanga, 2012; Arslan *et al.*, 2014). However, the applicability of CA to small-scale farmers in Africa has been questioned because it is not reflected in the adoption statistics especially the area committed to the technology (Gowing & Palmer, 2008; Giller *et al*., 2009). This study comes in the wake of a major investment shift by African governments, regional organisations and the donor community towards the promotion of CA as a viable option for smallholder agriculture.

1.2 Problem statement

Conservation agriculture is being promoted as a solution to the production challenges confronting rural smallholder families in SSA (Shaxon, 2006). However, little is known about the short-term impact of CA under typical smallholder farming conditions where adoption is mainly driven by meeting the immediate household food security needs. This emanates from the fact that few empirical studies consider the economic benefits of adopting CA in SSA and most accumulated evidence is for developed regions such as North America (FAO, 2001). The suitability and the impact of CA under smallholder farming conditions of Africa need to be investigated in response to current research agenda (Giller *et al.*, 2011). Erenstein *et al.* (2006), note that the economic benefits of CA in SSA are still difficult to quantify unambiguously and are constrained by location specificity, seasonal variability and corresponding risk implications. Rusinamhodzi *et al*. (2011), posit that the benefits of CA at plot level do not necessarily overcome the (economic) constraints at farm scale and that these benefits can only be realised in the longer term.

Farmers across Zimbabwe have shown scepticism for CA through a failure to expand their CA plots. While farmers welcomed the free inputs associated with CA they were not convinced enough to convert large amounts of their land. This is in spite of local research evidence and field experiences showing considerable benefits of increasing and sustaining crop production. There is evidence of yield gains of between 10 and more than 100%, depending on input levels and the experience of the farm household (Mazvimavi, 2011). While there is evidence of CA gains in the literature, there are also studies that present a sharply contrasting assessment of CA impacts. Giller *et al*. (2009), suggests that empirical evidence is not clear and consistent on CA contributions to yield gains. In Zimbabwe there is still no evidence at the individual household level that specifically shows the effects of the partial or full adoption of CA. Empirical studies that have been carried out to assess the impacts of CA in Zimbabwe use different methods and analytical approaches, ranging from on-station and on-farm agronomic experiments to broader socio-economic household surveys (Siziba, 2008; Mazvimavi & Twomlow, 2009; Mupangwa, 2009; Musara *et al.*, 2012; Nyamangara *et al.*, 2013; Ndlovu, Mazvimavi, An & Murendo, 2013). However, most of these studies use cross-sectional data and do not have a longitudinal dimension. In such analyses the measured impact of CA on yield can be biased by unmeasured or unobservable variation in household conditions. Studies that use longitudinal data focus on agronomic impacts such as yield and soil properties, but generally fail to control for household level covariates that may have important interactions in the production process. This study seeks to provide empirical evidence to support or dispute the supposition that CA adoption has a positive impact on maize yield and consequently food security.

The type of CA promoted in Zimbabwe is a manifestation of CA based on three principles. The CA in practice which will be referred to as CAzim for the purposes of this study is an 8 component package comprising of winter weeding, digging basins, crop residue mulching, targeted application of small doses of manure, basal and top dressing fertiliser, timely weeding and cereal- legume crop rotation. However, in practise farmers do not apply all the components of the package. Farmers tend to evaluate the technology and only adopt what they perceive as the most relevant components because of the heterogeneity in their socio- economic profiles, perceptions and livelihood objectives (Mazvimavi & Twomlow, 2009; Chiputwa *et al.*, 2011). The step-like implementation of complementary and synergetic practices that are meant to improve agricultural production has been cited as a major strength of CA (Dumaski *et al*., 2006). However, Erenstein (2003), contends that if farmers adopt CA partially rather than the whole package, larger impacts on yield may not be realised. There is a need to understand why some farmers adopt the complete package and others adopt CA only partly. The empirical question is based on understanding the factors involved, the characteristics of farms and farmers that are likely to affect the adoption intensity of CA and how this happens.

In Zimbabwe, resource-constrained farmers were targeted by NGOs and only applied fertiliser to their CA plots when it was supplied free of charge (Marongwe *et al.*, 2011). This may explain the observed rapid decline in the number of smallholder farmers practising CA when free inputs were no longer supplied (Mazvimavi & Nyamangara, 2012). Giller *et al.* (2009), note that in many cases adoption of CA was temporary: it only lasted for the course of active promotion of the technology by NGOs and research, but was not sustained beyond that. However, conditions that influence sustained use of CA have not been investigated adequately. There is a need to establish if CA is a technology offered to resource-poor farmers who are typically targeted by most donor programmes.

1.3 Focus of the study

The study assesses the adoption dynamics of CA as a new sustainable farming method that has been introduced in Zimbabwe to address the problems of low productivity and declining soil quality. The traditional farming practice, consisting of spring ploughing and sowing using a mouldboard plough, has resulted in land degradation and deteriorating soil fertility. With CA, farmers prepare their plots by hand during the off-season and sow their seeds in small basins – simple pits that can be dug with hand hoes without having to plough the whole field (Twomlow *et al.*, 2006). The concentration of water and available soil fertility amendments within the planting basin reduces the risk of crop failure, even under drought conditions. Farmers have an opportunity to plant with the first rains, since delayed planting after the optimum planting date reduces the yield potential by around 30% per month (Hove & Twomlow, 2007). In addition, farmers are encouraged to spread whatever crop residues might be available as a surface mulch to prevent soil losses early in the season, conserve moisture later in the season and enrich the soil with nutrients and organic matter as the residues decompose. The CA approach, based on strong and comprehensive extension support, enables farmers to apply relief inputs of fertiliser and seed more productively.

The study compared the maize yield from the CA plots with those from conventionally tilled plots and investigated the dynamics of CA adoption. CA systems promote improved management and targeted application of fertilisers, timeliness of operations such as planting, frequent weed control and timely fertiliser application. It is hypothesised that the resource use efficiency and productivity under the CA system are higher than under farmers' current practices: however, this will be assessed empirically. Through monitoring farmers who have adopted CA over time, the International Crops Research Institute for the Semi-arid Tropics (ICRISAT) created a database that was analysed in this study.

1.4 Objective of the study

The main purpose of the study was to estimate the returns to CA and investigate the dynamics of adoption of the technology among smallholder farmers in Zimbabwe. The study was thus guided by the following specific objectives:

1. To assess impact of the CA technology package on maize yield.
2. To determine the factors that condition farmers to take up more components of CA technology package.

3. To evaluate the determinants of abandonment of CA.

1.5 Research hypothesis

Achieving agricultural productivity growth will only be possible through the development and dissemination of improved crop management packages. Basin CA is promoted as a package and is expected to increase crop productivity over time. However, smallholder farmers in Zimbabwe are not expanding their CA plots or increasing the uptake of CA components and some farmers have abandoned the previously adopted CA technology (Giller *et al.*, 2009; Mazvimavi & Twomlow, 2009). This has resulted in the need to test the following hypotheses:

1. CA has a positive and significant impact on maize yield.
2. Gender, education level, CA experience, household size, NGO support have a positive effect whereas TLU index , age, plot size, number of plots and dry agro ecology have a negative influence on the number of CA components used.
3. Access to NGO inputs, CA experience, maize yield under CA and female headship have a negative influence on abandonment of CA. TLU index, total asset values, plot size have a positive influence on abandonment.

1.6 Justification and relevance

This study derives its justification from the fact that dissemination of better farming technologies is the surest way of boosting smallholder farming productivity. A better understanding of factors that condition farmers' adoption behaviour is important for designing pro-poor policies that could stimulate the adoption of sustained CA practices and productivity change. Most previous adoption studies in Zimbabwe and elsewhere were limited in assessing the determinants of adoption versus non-adoption (Siziba, 2008; Mazvimavi & Twomlow, 2009; Chiputwa *et al.*, 2011). A limited number of studies have empirically assessed factors that influence the abandonment of CA practices adopted earlier in the African context (Muchinapaya, 2012; Arslan *et al.*, 2014). This study extends the debate from determinants of adoption to the sustainability and suitability of the technology among the poorly resourced farmers who are the beneficiaries of the technology.

An important contribution to the academic field will be providing rigorous empirical evidence on the uptake of CA technology by smallholder farmer in Zimbabwe. The affordability of CA will be assessed through the abandonment of CA adoption, especially among the intended beneficiaries in Zimbabwe. In addition, this study will exploit the panel nature of the data, which is relatively uncommon in most African smallholder agricultural settings. This study takes advantage of the longitudinal nature of the data set to control for unobservable household level factors and the endogeneity of the technology. The study aims to provide evidence to justify continued investment in the promotion of CA in Zimbabwe, since there is an on-going literary debate among practitioners and academia on the suitability of CA for smallholder farmers.

1.7 Summary of research methods

The analyses of the thesis used a four-year panel data set collected among smallholder farmers practising CA in 12 districts of Zimbabwe. Three econometric approaches were used to analyse the data in order to fulfil each of the research objectives. Analysis of the yield impact of CA was based on plot-level data, whereas household data was used to predict the determinants of adoption intensity and abandonment of CA. The yield impact of CA was measured using ordinary least squares (OLS) and a household fixed effect was estimated to assess the robustness of results. For estimating the yield impact of CA, a single equation based on a production function is employed, whereby CA is assumed to have an intercept effect on the model. Count regression models were used to measure the determinants of adoption intensity of CA in terms of depth of technology use. The higher the number of techniques used, the more intense the use of CA, and the higher the level of productivity. Finally, a random effects probit model was employed to assess abandonment of CA using a balanced panel of household data., measured on a. Abandonment is measured on a 1/0 scale whereby 1 means that a farmer has no CA plots in that particular season and 0 otherwise.

1.8 Organisation of the thesis

The thesis is organised in seven chapters, beginning with introductory chapter one. In the second chapter, there is a basic outline of CA in SSA and in Zimbabwe in particular. Theoretical issues of adoption and abandonment are explored, followed by a review of empirical literature. Chapter three outlines the research design and approach used, detailing the sampling framework as well as the summary overview of data collected for the study. Chapter four presents an empirical analysis, which compares the performance of CA against conventional farming based on a production function. In Chapter five an empirical analysis of CA adoption intensity based on the number of technology components used is presented.

Chapter six presents an empirical analysis of determinants of CA abandonment. Chapter seven is a synthesis of chapter four to six and concludes the study, with implications for policy and future research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter provides a review of the literature relevant to CA adoption and dis-adoption. The chapter gives an overview of CA in SSA particularly in Zimbabwe, highlighting the merits of and constraints to the spread of this technology. Furthermore, the chapter reviews and compares various approaches to study adoption and dis-adoption found in the literature, discussing merits and drawbacks of different methods of analysis. The chapter specifically highlights the current state of CA research in Zimbabwe. Section 2.5 reviews empirical studies relevant to this research and Section 2.6 provides some theoretical models for studying technology adoption, including the theoretical framework used in this study.

2.2 Basic concepts

The concepts that relate to the technology under study will be defined in this section, together with different terminologies used in adoption studies. Defining adoption of CA is complicated by the complexity of the technology. Since CA encompasses a wide range of dissimilar practices, identifying adoption depends on how adoption is defined. Thus, it is important for this study to state explicitly how terms related to the technology and its adoption are used.

2.2.1 Conservation agriculture

According to the Food and Agriculture Organisation (FAO) (2001), CA constitutes a package of agronomic practices that includes: a) reduced or eliminated mechanical soil disturbance; b) soil cover with crop residues; and c) diversification of crop species grown in sequences and/or associations. Through the integrated management of available soil, water and biological resources, combined with limited external inputs, CA aims at making better use of agricultural resources (Friedrich, Derpsch & Kassam, 2012). Manual CA, as promoted among the poorer households in Africa, applies to conservation tillage through digging planting basins (Mazvimavi & Twomlow, 2009). The basin tillage system, a CA concept first developed by Oldrieve (1993), consists of simple pits made by hand hoes just before the first rains to enable farmers with no draft power to plant early (Hove & Twomlow, 2007). Mechanised CA is another version of CA recommended to households using animal traction. It involves the use of ox-drawn 'rippers' and seeders for reduced tillage. For commercial farmers, mechanised minimum tillage methods with leguminous crop rotations such as soya beans and sun hemp complete the ladder of CA technologies promoted. The terms, no- till (NT), zero till (ZT), minimum tillage (MT) and direct seeding (DS) are used interchangeably to denote minimum soil disturbance under the collective umbrella term conservation tillage.

The concept of CA aggregates a number of soil and water management and conservation practices under a single banner for delivery to farmers (Garcia-Torres *et al*., 2003; Knowler & Bradshaw, 2007). Although discussion of CA often emphasise minimal soil disturbance, Wall (2007) argues that the emphasis of CA should shift to a broader concept of a sustainable agricultural system that embraces practices as tillage reduction, retention of adequate mulch cover and use of crop rotations. Moving beyond conservation tillage, the eight standard practices that make up the CA technology package in Zimbabwe are defined by Zimbabwean Conservation Agriculture Task Force (2009) and Mazvimavi and Twomlow (2009): Digging basins, winter weeding, application of mulch, manure application, basal fertiliser application, top- dressing fertiliser application, timely post planting weeding and crop rotation. The type of CA promoted in Zimbabwe is bundled with fertiliser promotion. However, the codification of CA as a standardized package has been criticised by Giller *et al.* (2009) as a reason for low adoption in SSA. In any case, many farmers adopt only some of the eight elements of Zimbabwe's CA package, raising the question of how to define when CA is being practised. The CA practised in Zimbabwe as used this thesis does not only refer to the three principles of CA but to the eight practice package promoted in Zimbabwe. For the purposes of this thesis, the CA package promoted in Zimbabwe shall henceforth be referred to as CAzim to distinguish it from the general CA based on three principles.

2.2.2 Technology adoption

Many scholars have attempted to give a concise definition of what the adoption concept actually denotes. Rogers, (1983) defines the adoption process as the mental process through which an individual passes from first hearing about an innovation or technology to final adoption. According to Feder, Just and Zilberman (1985), adoption may be defined as the integration of an innovation into farmers' normal farming activities over an extended period of time. It can be measured by "both the timing and extent of new technology utilization by individuals" (Sunding & Zilberman, 2001). Diffusion on the other hand, is "the process in which an innovation is communicated through certain channels over time among the members of a social system" (Rogers, 2003).

Feder *et al.* (1985) distinguishes between individual adoption and aggregate adoption. Individual adoption is the degree of use of a new technology in a long-run equilibrium when the farmer has full information about the new technology and its potential. On the other hand, aggregate adoption is the process of spread of a technology within a region. In a similar vein, Thirtle & Ruttan (1987) define aggregate adoption as the spread of a new technique within a population. This is the adoption rate which is defined as the percentage of farmers who have adopted a given technology. In defining adoption, the first thing to consider is whether adoption is a discrete state with binary variables (a farmer either is an "adopter" or is not one) or whether adoption is a continuous measure. The definition of adoption varies across empirical studies and the appropriateness of each approach may depend on the particular context.

Adoption of innovations refers to the decision to apply an innovation and to continue to use it (Rogers, 2003). This is closely followed by the main options of active rejection, also known as dis-adoption, which occurs when farmers consider adoption of innovation (including its trial) but then decide not to adopt it, and passive rejection (also called non-adoption), which consists of never really considering the use of the innovation. Farmers do not accept innovations immediately; they need time to think over things before reaching a decision. An individual may decide to discontinue the use of an innovation for a variety of personal, institutional and social reasons, one of which might be the availability of another practice that is better at satisfying farmers' needs. Rogers (2003) notes that innovations are more likely to be adopted if they are less complex, lend themselves to trialling and yield results are observable to others.

What is meant by 'adoption' of CA in Africa can be ambiguous, and in some cases ambiguity extends to which potential components even constitute CA technology. Many reports of farmer adoption are made while projects are actively promoting CA and adoption figures may simply reflect the number of farmers involved in testing and adapting the technologies. The point at which a farmer can be said to have adopted the technology as opposed to simply testing it under promotional programmes may not be obvious. Torborn (2011) points out that CA adoption rates "remain subject to large margins of error" as a result of the numerous, often short-term, projects involved in CA. Furthermore, adoption rates vary by crop (maize and cotton), gender and length of experience with CA. Most farmers continue with conventional tillage and only part of the land is put under CA; a proportion increasing over time. Dis-adoption, which is the abandonment of technology after experimentation, is also known to occur, though reasons for dis-adoption are not fully known.

2.2.3 Adoption intensity

When measuring the intensity of adoption, a distinction has to be made between technologies that are divisible (e.g., improved seed, fertiliser and herbicide) and those that are indivisible (e.g. mechanisation, irrigation). With divisible technologies the decision process involves area allocations as well as level of use or rate of application (Feder *et al.*, 1985). The intensity of adoption of different technologies is measured by a variable that represents the breadth of technology used within a particular stage of production. The extent of adoption can be measured by the intensity of cultivation, for instance in terms of the number of farmers, total area within farms or harvest (CIMMYT, 1993). Intensity of adoption refers to the level of use of a given technology in any period. Bonabana-Wabbi (2002) and Arega (2009) report that adoption intensity refers to the number of technologies practised by the same farmer. Similarly the International Fund for Agricultural Development (2010), determined the intensity of adoption as the amount of modern inputs used per unit area, while Tsegaye *et al*. (2008) measured the intensity of adoption in the order of the number of components of the technology adopted by a farmer.

In the areas examined in this study, CA has often been promoted as a package. Adoption in this context could be viewed as a process in which more and more elements of the package are applied to the farm. The intensity of adoption of any CA principle depends on the farmer's ability to manage constraints arising from the application of the components compared to the benefits to be obtained (Jat *et al*., 2013). According to Saha *et al*. (1994), producers' adoption intensity is conditional on their knowledge of the new technology and on their decision to adopt.

2.2.4 Partial adoption

Partial adoption is defined as using only parts of the technology package recommended by the extension agent. Tsegaye *et al.* (2008) note that partial adoption is the practice of using the least involving components of a technology, which could be any of the individual components alone. In addition, partial adoption can be described by the concept of selective adoption which is the selection of some parts of a technology or modification and re-invention (Wetengere, 2010). Risk aversion also provides a possible explanation for partial adoption of technologies by poor farmers, as smallholder farmers face significant climatic and economic uncertainties and tend to be risk-averse (Marra et al, 2003). Selective adoption might suggest that incomplete use of a technical package is optimal and thus the adoption process will end with partial adoption instead of complete adoption.

When new technologies have multiple components, they may be adopted jointly or sequentially (Khanna, 2001). Sequential adoption has been identified as a pattern in which farmers adopt part of the package before adopting the whole packages (Byerlee & Polanco 1986). Factors such as profitability, riskiness, uncertainty, lumpiness of investment and institutional constraints were found to be some of the main reasons given for the sequential adoption of a package of technologies (Leather & Smale, 1991). In addition, Pannell *et al*. (2006) argue that adoption is not an all-or-nothing decision but occurs as a gradient, at sequential levels. The adoption of CA involves the use of a bundle of innovations rather than just a single element of productivity-enhancing factors. If farmers adopt partially rather than the whole package, the productivity improving effect of each of the components may not be realised (Otsuka & Kalirajan, 2006). The trend towards partial adoption raises questions of the divisibility of CA and the conditions necessary for a successful adoption process.

2.2.5 Dis-adoption

Dis-adoption is commonly referred to as discontinued adoption behaviour and is the decision to reject an innovation after having previously adopted it. Oladele (2005) reported two types of discontinuance. Replacement discontinuance involves rejecting an idea in order to adopt a better one that supersedes it. Disenchantment discontinuance occurs when it is decided to reject an idea as a result of dissatisfaction with its performance. Alexander, Fernandez-Cornejo and Goodhue (2003) and Darr and Chern (2002) describe discontinuance among Ohio farmers who previously adopted genetically modified crops as dis-adoption. Ogunfiditimi (1993), and Kolawole, Farinde, and Alao (2003) examine "abandoned adoption" to describe the discontinuation of the use of a previously adopted innovation and report varying degrees of discontinuance (immediate, gradual, immediate) among Nigerian farmers. The term continued adoption, which is the persistent use of an innovation, is closely related to sustainable adoption defined as the degree to which an innovation continues to be used over time after a diffusion programme ends (Rogers, 2003). Ogunsumi and Ewuola (2005) and Oladele and Kareem (2003) analyse sustained adoption among farmers and the concept is operationalised as the maintenance of the intensity of adoption by farmers.

2.3 Trends and overview of Conservation agriculture in Africa

In 2012 it was estimated that 9% of the world's cropland area was being farmed under CA (Friedrich *et al.*, 2012), the largest areas being in South America. The current manifestation of CA was introduced three decades ago and the number of farmers practising CA is expected to increase substantially in the near future (Ellis, 2000). Awareness and adoption of CA on the African continent are considered to be on the increase (Derpsch & Friedrich, 2010, Friedrich *et al.*, 2012).

However, the contribution of Africa in the total area under CA is still very low (1%, about 1 012 840 ha). The small contribution of SSA and more generally Africa to global figures on CA might be seen as the consequences of major difficulties of CA adoption faced by farmers. At the continent level, southern Africa is the sub-region with the lowest contribution, with a total estimated area of 30 000 ha under CA (Freidreich *et al.*, 2012). The situation is paradoxical, as southern Africa is believed to be one of the areas where the potential benefits of CA could be the highest (Lal, 2007). Whatever the potential, the adoption rates of CA are low in southern Africa with less than 1% of arable land under CA (Hove *et al.*, 2011).

Proponents of CA have emphasised its potential to increase the crop productivity of smallholder farmers in SSA sustainably. In addition, CA can address the major constraints on smallholder crop production in the region because it is associated with early planting, the judicious use of limited fertiliser input, *in-situ* water harvesting and improved management (Twomlow, Urolov, Jenrich, & Oldrieve, 2008). Because of its potential, CA has received increasing support for dissemination by international agencies and research organisations, leading to its incorporation into the agricultural policy of the New Partnership for Africa´s Development, Alliance for a Green Revolution in Africa and national agricultural programmes-s in SSA (Andersson & Giller, 2012). However, overall uptake of CA as a package in Africa has been disappointing (Friedrich *et al.*, 2012; Giller *et al.*, 2009) because of the substantial challenges associated with targeting, adapting and adopting CA particularly for smallholder farmers (Erenstein *et al.*, 2012). Gowing and Palmer (2008) examined evidence of CA benefits among small-scale farmers in Africa and concluded that CA did not overcome constraints on low-external-input systems. They noted that CA could yield the productivity gains required to achieve food security and poverty targets, but only if farmers had access to fertilisers and herbicides. Mazvimavi and Twomlow (2009) alluded to the fact that adoption of CA by smallholder farmers is likely to be partial, as opposed to full adoption.

For the last decade many African countries, particularly in southern and eastern Africa, have been exposed to no-tillage and CA systems (Friedrich *et al.*, 2012). The African Conservation Tillage Network was established in 1998 to promote CA as a sustainable means to alleviate poverty, make more effective use of natural and human resources and reduce environmental degradation. It has evolved into a Pan-African network with global links and is active in technology development, networking, information exchange and policy advocacy (ACT, 2004). Promotion programmes and activities have been implemented in Kenya, Tanzania, Zambia, Zimbabwe, Lesotho, Swaziland, Mozambique and Malawi in the last decade (Friedrich *et al.*, 2012). However, adoption is in the early stages of building capacities and setting up structures for up-scaling (FAO, 2008).

2.3.1 Justification of Conservation agriculture for smallholder farmers in SSA

A growing body of research emphasising the importance of CA within the smallholder setting of Africa has resulted in governments and the donor community shifting their investments towards the promotion of this technology (Arslan *et al*., 2014). CA is a sustainable farming option with the ability to address a broad set of farming constraints, such as low crop productivity, smallholder farmers' vulnerability to drought, low draft power ownership levels and increasing levels of soil degradation and loss of fertility (Lee, 2005, Kassam *et al*., 2009, Chiputwa *et al*., 2011). Work by the International Centre for Agricultural Research in the Dry Areas and the International Maize and Wheat Improvement Centre have shown the benefits of CA in terms of increases in crop yields, soil organic matter, water use efficiency and net revenue (Thierfelder & Wall, 2009). Adoption of CA practices result in better use of production inputs and therefore greater profitability, while reducing production costs. Furthermore, CA offers potential benefits of early planting for smallholder farmers with limited access to draft animal power (Twomlow *et al.*, 2008). More specifically, CA enables early planting, as land preparation is simplified and can be carried out before the first effective rains (Haggblade & Tembo, 2003). CA also shows the importance of utilizing cropping and crop diversification with legumes and cover crops instead of a fallow period, providing improved productivity, soil quality, N-fertiliser use efficiency and water use efficiency (IIRR & ACT, 2005, Derpsch *et al.*, 2010).

The introduction of CA usually leads to increased yields, due to the combined effect of several factors, such as earlier planting, more precise input management, and water harvesting (Baudron *et al.*, 2007). An incremental yield of 100% over conventional practices has several sources such that 30% will be attributed to higher input use, 25% early planting and water harvesting in basins 45% (Haggblade & Hazell, 2010). In Zambia, yields doubled for CA plots under maize and were 60% higher for cotton (Haggblade & Tembo, 2003). Similarly, Thierfelder and Wall (2009) observed higher grain yield in CA plots in Zimbabwe, which was indicative of higher rainfall use efficiency. Boahen *et al.* (2007) reported that maize yields in Ghana were up to three times higher with CA than in traditional slash and burn systems. Torborn (2011) observed that combining CA with good agronomic practices, such as the use of inorganic and organic fertilisers and integrated pest management can also help to increase yields. In Kenya, yields of maize, wheat, potato and beans were 50-200% higher in CA than in conventional systems (Kaumbutho & Kienzle, 2007). These results support the view that CA is important in establishing household food security for the poorer farmers in SSA and can help achieve the United Nations MDGs on food security (Hobbs 2007; Hobbs *et al*., 2008).

Conservation agriculture is perceived as a powerful tool of land management in dry areas. It allows farmers to improve their productivity and profitability especially in dry areas while conserving and even improving the natural resource base and the environment (Gowing & Palmer, 2008; Marongwe *et al*., 2011). The ability of CA to minimise water stress in crops is critically important as southern Africa braces for the hotter and drier weather predicted by climate change models (Lobell *et al.*, 2008; Hobbs, 2007). The water-retention characteristics of CA (Twarog, 2006) lead to more efficient use of rainfall, which considerably reduces the risk of crop failure due to drought (Friedrich, & Kassam, 2009; Erenstein, 2003). Conservation agriculture is thus used as an adaptation strategy to climate variability in a region that relies heavily on rain-fed agriculture (Hobbs, 2007). The benefits of CA include enhanced crop, soil and ecosystem health as well as associated ecosystem services, and improved climate change adaptability and mitigation (Reicosky, 2008; FAO, 2008). In addition, CA can significantly boost production and improve the food security and livelihoods of farming households, especially in arid and semi-arid regions (Steiner & Bwalya, 2003; ZCATF, 2009).

2.3.2 Constraints to adoption of Conservation agriculture in SSA

The majority of smallholder farmers reported to be practising CA in southern Africa are in fact practising minimum tillage with improved management (Baudron *et al*., 2007; Mazvimavi & Twomlow, 2009). The feasibility of merely planting without ploughing the land first has been questioned by many farmers, thus accepting CA, goes against traditionally cherished beliefs (Kassam, 2010). Aspects of CA may initially seem unusual to community members, and it may take time to understand the new approach and its advantages over traditional farming methods (Fanelli & Dumba, 2006). The biophysical constraints are an indication that CA is not a panacea, and cannot be adopted directly in all soils and edaphic /physiographic environments. In addition, uptake of CA technologies is more complicated than simple standard technologies because of the multi-components and multi-years through which small-scale trialling, modification and eventual adoption of the technologies takes place (Pannell *et al*., 2006). There are numerous constraints on the adoption CA by the resource-poor farmers of SSA, where it is needed most (Lal, 2007). McCarthy *et al.* (2011) reviewed the adoption of CA and concluded that CA adoption is subject to most traditional constraints found in literature.

Practices such as crop residue mulching are incompatible with the prevalent use of crop residue as a livestock fodder during winter (Aune *et al*., 2012). Rumley and Ong (2007), identified a significant obstacle to smallholder CA compliance as the requirement for continuous soil cover with crop residues as mulch. Numerous reports and studies have pointed to the problems of crop residue retention and the trade-offs between different uses in crop-livestock farming systems in southern Africa (Giller *et al*., 2011; Umar, Aune, Johnsen & Lungu, 2012; Rusinamhodzi *et al*., 2013). In smallholder settings where communal grazing lands provide the bulk of dry season feed, using crop residues for mulch in CA imposes an opportunity cost in the form of livestock feed (Akpalu & Ekbom, 2010; Nyathi *et al*., 2011; Valbuena *et al*., 2012). In most regions of SSA, free-range livestock are able to graze on crop residues, which become a communal resource after harvest. The communal grazing rights make it challenging to maintain permanent soil cover through a layer of mulch (Erenstein, 2003; Aagard, 2009). In general, small-scale mulching is likely to be agro-ecosystem specific, especially in semi-arid areas, where retention of crop residues contributes to termite prevalence and subsequent crop lodging contributes to yield losses (Nyathi *et al*., 2011).

The key challenge for crop rotation is the consideration of food security, as a result of which, farmers prefer growing maize a staple cereal (Haggblade &Tembo, 2003; Mazvimavi *et al*., 2008). Farmers are also hesitant to plant legumes in the permanent planting basins because of the recommended spacing (Baudron *et al*., 2007). In planting basin based CA systems, harvesting of legumes like groundnuts 'make it difficult to avoid soil disturbance as groundnuts have to be pulled out of the soil, which will compromise the CA principle of 'minimum soil disturbance'- to a certain extent (Thierfelder *et al*., 2013). Legume production is also likely to compromise the CA principle of permanent soil cover, as legume residues are often preferred animal feed or, when retained, disaggregate very quickly. Furthermore, rotating every third year with a legume is constrained by low prices for legumes and the unavailability of seed (Mazvimavi &Twomlow, 2009; Mutsamba *et al*., 2012). The difficulties in achieving soil fertility management through rotation and use of mulch, could have contributed to the inclusion of chemical fertilisers in the CA packages promoted in Zimbabwe.

Andersson and Giller (2012) viewed weeds as the "Achilles heel of CA", while Farooq *et al.* (2011), contend that weed management is the fourth principle of CA. Weed control becomes a challenge, especially when farming is done manually. One of the primary motivations for tillage is weed control because reduced tillage greatly increases weed pressure (Wall, 2007; Baudron *et al.*, 2007). Zambia's conservation farming unit (CFU), recommends weeding six times in order to manage the increased weed pressure, but farmers rarely achieve this (Baudron *et al.*, 2007). Controlling weeds is critical to avoid crop failure and increased labour for weed control with CA can be overcome with herbicides (Mashingaidze, 2013). Minimum tillage may require additional labour for land preparation and weeding, though under certain conditions these decrease after the first two or three seasons (Haggblade & Tembo, 2003; Mazvimavi, 2011). Conservation agriculture has a tendency to increase labour requirements for weeding and land preparation, at least in the first years and this serves as a major disincentive for CA adoption (Silici, Ndabe, Friedrich &Kassam, 2011; Mashingaidze, 2013, Anderssona, & D'Souza, 2014).

The suitability of CA for the majority of smallholder farmers in SSA has been questioned by a number of researchers (Giller *et al.*, 2009; Gowing & Palmer 2008; Baudron *et al.*, 2012), and the issue remains contentious among researchers and development practitioners. An increasing amount of evidence suggests that CA maybe less compatible with smallholder farming compared to large and mechanised farm holdings (Derpsch, 2008). Conservation agriculture techniques have been argued to be difficult to adopt by vulnerable households with inadequate draft power and labour (Twomlow *et al.*, 2008). Adaptation of CA in dry lands faces critical challenges linked to water scarcity and drought, low biomass production and acute competition between conflicting uses, including for soil cover, animal fodder, cooking/heating fuel and raw material for habitat (Grawboski, 2011). Despite the publicity claiming widespread adoption of CA, the available evidence suggests no virtual uptake of CA in most SSA countries (Giller *et al*., 2009). However, the suitability of CA for the majority of smallholder farmers in Africa is still contentious among researchers and development practitioners.

2.4 Historical developments of Conservation agriculture in Zimbabwe

Conservation techniques such as no-till tied ridging, mulch ripping, no-till strip cropping, clean ripping, hand-hoeing or zero till, tied furrows (for semiarid regions) and open plough furrow planting followed by mid-season tied ridging, have been actively promoted since the 1980s (Nyagumbo, 1998; Mupangwa, 2009; Twomlow *et al.*, 2006). However, these technologies have been modified over time and adapted to nearly all farm sizes, soil and crop types and climate zones. The pioneers of basin CA in Zimbabwe was the River of Life Church. The innovation was named “Operation Joseph”, built on the Hinton Estates outreach programme initiated by Oldrieve in the 1990s in Musana communal area. Farmers participating in the programme were able to increase yields and reduce erosion and this led to the components of reduced tillage and 30% mulch retention being promoted among smallholder farmers (Oldrieve, 1993).

The current manifestation of CA as defined by the FAO was initiated in Zimbabwe in 2003 after substantial donor funding targeting improved food security of vulnerable households (DFID, 2009). Initial efforts focused on the use of manual systems and left out the mechanised form of CA because the donor funding involved was for vulnerable communities. The target communities were mainly those considered vulnerable because of lack of access to draft power and labour and those affected by chronic illness including human immunodeficiency virus/acquired immunodeficiency syndrome (HIV/AIDS) (Mashingaidze & Mudhara, 2006). The need for coordination of CA activities emerged during these early stages, which resulted in the formation of the CA Task Force in 2003 at the request of donors to set up technical guidelines for implementing CA. The CA Task Force has been able to come up with implementation guidelines for CA activities, and monitors and disseminates information on

CA (ZCATF, 2009). Partnerships between the FAO, international research centres, NGOs and the government, mainly the Ministry of Agriculture, have improved the visibility of CA promotion in the country

There has been limited involvement of government at district and provincial level, which has resulted in major farming sectors being left out, save for smallholders from communal areas of Zimbabwe (MAMID, 2010). Moreover, participation of the private sector in CA programmes has been lacking, particularly in the development of CA machinery. These issues were addressed through a workshop that sought to harmonise all CA activities, as well as to ensure a more active role played by government, farmer unions and farmers for successful up-scaling of CA. The result of this workshop was the creation of a comprehensive CA implementing framework to guide CA implementation by the various stakeholders promoting CA in Zimbabwe. One of the immediate goals of the CA strategy was to institutionalise and vigorously promote CA. This was to be achieved through the implementation of CA principles by at least 500 000 farmers on 250 000 hectares and doubling the yields of conventional farming by 2015 on the CA fields (MAMID, 2012, Muchinapaya, 2012).

2.4.1 Promotion and uptake of Conservation agriculture in Zimbabwe

Promotion of CA to the smallholder farming sector in Zimbabwe was aimed at sustainably addressing the low productivity of farmers and improving their food security and overall cereal production. The CA option that has been mostly promoted in Zimbabwe is a manual system based on planting basins that act as planting stations for the crops (Twomlow *et al.,* 2006). This option was promoted mainly to address the draught power shortages in the communal farming sector, which delayed planting and consequently affected crop yields negatively. This technology of using planting basins is locally labelled 'conservation farming' to differentiate it from the other CA practices promoted in the region.

In recent years, there has been a rapid increase in the number of farmers practising CA technologies involving planting basins (Table 2.1). Because of the critical inaccessibility of inputs by smallholder farmers in the country during the past eight years (post-land reform period), CA promotion by different partners involved the supply of input packages (fertiliser and seed) to farmers who were willing to set up CA demonstration plots. However, findings from a study by Mazvimavi and Twomlow (2009) indicate that at household level, the area of land under CA has remained stagnant, mainly owing to labour constraints.

Table 2.1: Conservation agriculture trends in Zimbabwe, 2005-2011

Season	Number of households	Number of wards
2004/05	4700	22
2005/06	8900	30
2006/07	15900	50
2007/08	53100	117
2008/09	40500	118
2009/10	88262	223

Source: Marongwe et al., (2011).

Promotion of CA has been suggested as a key strategy to alleviate the negative impacts of drought and rainfall variability. However, under prevailing farming conditions and technology performance, partial, localised and sporadic adoption will remain the norm (Gowing & Palmer, 2008; Mazvimavi *et al.*, 2008). It is also known that dis-adoption of CA occurs because some organisations have barred farmers not adhering to CA principles from further input credit. Access to inputs on credit, otherwise not obtainable, may have stimulated some adoption. Whether use of CA will continue in the absence of project-provided inputs is an acid test of the technology. There are also cases where NGOs have stopped their promotion efforts after initial experimental years.

2.4.2 Current state of Conservation agriculture research in Zimbabwe

This section reviews the current state of CA studies in Zimbabwe, findings, important variables identified by the previous studies and methodological approaches used and their limitations. There is also an increasing body of knowledge from Zimbabwe and other southern Africa countries on the agronomic impacts of CA (Mupangwa, 2009; Nyamangara *et al.*, 2013; Rusinamhodzi *et al.*, 2011; Thierfelder & Wall, 2009; Mashingaidze, 2013). In their study Thierfelder and Wall (2010) report increased carbon and macro-fauna, as well as suppression of crop-specific pests, as noted plot-level benefits of rotation and associations of CA. Further, observations from long-term trials established in Zimbabwe reported soil quality indicators that are often overlooked but make rotation even more beneficial (Thierfelder *et al.*, 2013). Mupangwa (2009) assessed the influence of conservation tillage methods on soil regimes in semi-arid southern Zimbabwe and discovered that planting basin tillage methods gives a better control of water losses from the farmers' fields. This finding is supported by Thierfelder and Wall (2009), who conclude that CA systems maintain significantly higher water infiltration rates (by 24-38 mm h^{-1}) and retain more available soil moisture in seasonal dry spells. Mashingaidze (2013), conducted a series of investigations on a long-term CA experiment but failed to substantiate the view that weed infestation decreased within three years under recommended CA practices. This implies that weeds remain a major hindrance to the practice of CA and this has implications for the use of labour.

Few studies rigorously examine the private profitability of adoption of CA for farmers in Zimbabwe and its impact on yields obtained by adopters. The relationship CA and average yields remains unclear. A number of studies purport to show positive impacts on yield from adoption, when in fact the studies are subject to considerable selection bias, both overt and implicit, and placement bias (Mazvimavi, 2011; Rusinamhodzi *et al.*, 2013). A study by Mutiro *et al.* (2011) found that the return to fertiliser was $0.79 per dollar invested under CA compared with a return of $0.07 for conventional tillage systems. Returns to labour were equally high under CA systems, $10.4 and $15.7 for inexperienced and experienced farmers respectively compared with $9.8 under conventional farming. Findings by Twomlow *et al.* (2008) suggest that returns to labour of CA were twice that of conventional agriculture in Zimbabwe. Nevertheless, in the smallholder farming system the cash benefits per unit of land may not be an important measure compared to the labour productivity and risk reduction offered by CA.
In Zimbabwe, a growing number of studies are being undertaken to assess the key factors that influence the uptake of CA by smallholder farmers as well as challenges to CA adoption (Siziba, 2008; Chiputwa *et al.*, 2011; Makwara, 2010; Nhodo Gukurume & Mafongoya, 2011; Muchinapaya, 2012). Estimating the number of smallholder farmers practising CA has been difficult because of lack of clear criteria defining what constitutes adoption. The extent of CA adoption among smallholder farmers in Zimbabwe is not well documented, though it is estimated to be low. Most empirical studies on CA's contribution to income and livelihoods in Zimbabwe have however, concentrated on factors affecting adoption of CA. Not much work has been done on assessing the sustainability of CA.

Work by Mazvimavi and Twomlow (2009) showed that there had been a significant expansion in CA practices in Zimbabwe following promotional efforts by relief agencies aiming to improve food security among vulnerable farmers. Irrespective of earlier concern about the demand for labour, elderly farmers and households affected by HIV/AIDS are among the adopters of CA. In their analysis Mazvimavi and Twomlow (2009) only targeted farmers known to be practising CA and known to be targeted by NGOs as being vulnerable to food production shortages. Perhaps communal farmers participate in CA mainly because of the attached benefits, such as the much needed seed and fertilisers from supporting NGOs. In the same study, they note that relief programmes will continue to be an important intervention in support of CA technology uptake, working together with national extension services given the economic situation in Zimbabwe. A study by Nyagumbo (2002) on factors affecting the adoption of CA by smallholder farmers revealed that socio-economic and socio-cultural rather than technological attributes are more important in shaping adoption decisions among smallholder farmers in Zimbabwe. However, the study is silent on how CA can be sustained once adopted by the smallholder farmers

In two separate studies of CA in Zimbabwe, Chiputwa *et al*. (2011) and Mazvimavi *et al.* (2008) found that farmers tend to adopt the less risky components of the technology package first. Even though the full CA package is advised in order to reap the full benefits of the technology, farmers in Zimbabwe have not yet established the three principles since only a few use complete packages (Mazvimavi & Twomlow, 2009; Giller *et al*., 2009). The findings from Zimbabwe are in agreement with reports on adoption in Africa. Wall (2007) and Pedzisa *et al*. (2010) reviewed the empirical evidence on major constraints to adoption of CA by smallholders, while possible solutions to the constraints of this technology were explored by Mazvimavi *et al.* (2008); Thierfelder and Wall (2010) and Marongwe *et al.* (2011).

In Zimbabwe economic analyses of CA technologies as potentially risk-mitigating are relatively sparse. However, technology adoption studies found that crop losses were reduced in fields managed under CA (Mazvimavi, 2011; Thierfelder & Wall, 2009). A profitability analysis conducted by Mazvimavi and Twomlow (2009) used a partial budgeting approach to compare returns ha^{-1} for CA and conventional practices assuming low, normal and high rainfall periods. Based on partial budgeting exercises, it is often concluded that CA technologies are 'risk-reducing' based on superior net returns ha^{-1} compared to conventional tillage systems, without actually measuring risk at all. Few studies have accounted for risk in net return comparisons of CA/non-CA production systems in Zimbabwe. For example, using stochastic dominance analysis of partial budget results Siziba (2008), found that adoption of CA because of a combination of increased investment costs and low incremental yields, exposed farmers to higher risk of financial loss compared to their current practice particularly in dry areas.

Most previous adoption studies in Zimbabwe and elsewhere are limited in assessing the determinants of adoption versus non-adoption (Siziba, 2008; Chiputwa *et al.*, 2011; Muchinapaya, 2012). Very few studies have empirically assessed factors that influence the abandonment of earlier adopted CA practices in the Zimbabwean context. Most of the work on abandonment in Zimbabwe is based on simple descriptive analysis and assessment of farmers' views. Muchinapaya (2012), using cross-sectional data attempted to assess the determinants of abandonment of CA. However, this study was limited by the fact that it used a static analytical framework to measure dis-adoption, which requires more than one observation in time. So far no evaluations in Zimbabwe have been conducted on the extent of spontaneous adoption, where there is no material support from NGOs for having adopted CA.

2.5 Review of empirical studies on technology adoption

The importance of farmers' adoption of agricultural technology has long been of interest to agricultural economists. Several factors have been identified as influencing the adoption behaviour of farmers from qualitative and quantitative models for the exploration of the subject. Reviews by Pannell *et al. (*2006) and Knowler and Bradshaw (2007) collectively suggest that adoption of agricultural production technology depends on a range of socio-economic, agro-ecological, institutional, informational and psychological factors as well as perceived attributes. However, some scholars believe that this body of research may have reached its limit in contributing to a refined understanding, particularly in respect of uptake of sustainable agricultural practices (SAPs) (Knowler & Bradshaw, 2007). They argue that the current state of knowledge is not easily transposed with policy (Torborn, 2011).

When examining adoption of technology, several factors must be considered, such as managerial factors that influence farm operators' management capacity. These factors include those related to human capital, gender, age, education level and experience. Ersado *et al*. (2004) found that age has a significantly negative effect on the adoption of both productivity-enhancing and resource-conserving technologies. In their study in Zimbabwe, Chiputwa *et al.* (2011) found that the age of the farmer positively affects the use of contour ridging. This finding is consistent with those of Langyintuo *et al*. (2002) and Pandey and Mishra (2004) but is in contrast with the general belief that older farmers have shorter career horizons and hence are more reluctant to invest in technologies that take a long time before benefits are realised (Tizale, 2007; Marenya & Barrett, 2007). Similarly, Adesina and Zinnah (1993) noted that younger farmers are more amenable to change old practices than older farmers because they tend to be more aware and knowledgeable about new technologies. Further, Amsalu and Graaff, (2007) found a weakly significant positive relation between age and adoption of stone terraces in a study conducted in the Ethiopian highland watershed. These findings bring to the fore the inconsistency of the evidence about the relationship between age and innovativeness.

Jagger and Pender (2006) evaluated the effect of a programme for natural resource management of 451 households in Uganda and found no differences between male- and female-headed households in their adoption of the use of animal manure, mulching, and crop residue. Similarly, Amsalu and Graaff (2007) and Nkonya *et al.* (2008) did not find any significant effect of the gender of the household head on the adoption of conservation practices. However, Pender and Gebremedhin (2007) found that female heads of households in Ethiopia were not different from their male counterparts in the use of burning as a way to prepare fields, even though, women were less likely to use manure and composting to increase productivity. Kassie *et al.* (2009), indicated that male farmers often had greater access to and control over resources, especially in developing countries.

Characteristics of the household head, such as age and farming experience, imply farming knowledge gained over time and are important in evaluating technology information (Feder *et al.*, 1985). Experience has also been found to be positively correlated with adoption of CA (Adeogun *et. al*., 2008) or insignificant (Traore *et al.*, 1998) but was never found to be negatively correlated with adoption of these practices. The FAO, (2001) claims that age and farmers' experience are very difficult factors to link with the adoption of CA. Greater experience can lead to better assessment of investment. The educational level of the household head is hypothesised to be positively associated with the adoption of CA because it is a knowledge-intensive and complex technology (Wall, 2007). Higher education levels empower farmers with greater ability to manage new ideas and their associated risks and benefits (Knowler & Bradshaw, 2007). Farmers with higher levels of education are more likely to adopt crop rotation. This finding is consistent with that of Langyintuo and Mekuria (2005), who assert that educated farmers are better able to process information and search for appropriate technologies in the quest to alleviate their production limitations.

Labour plays a key role in farm management especially when the technology under study is labour intensive. Farmers with larger families benefit from greater labour availability and thus more likely to be better resource endowed than otherwise and hence more willing to try out new technologies. Therefore access to family labour is postulated to have a positive impact on adoption. This view is challenged by findings reported by Bekele and Drake (2003), whose study revealed that family size had a significant negative relation with certain adoption choices. Similarly, in a study conducted by Baudron *et al*., (2007) in Zambia, labour capacity was found to negatively and significantly affect the adoption and use intensity of the CA technology. The authors argued that farmers affected by the paucity of family labour will likely turn to technologies that save labour (such as reduced tillage systems) if they are accessible and affordable. Thus labour availability is likely to facilitate adoption, as additional labour can be hired from external sources to increase management capacity. However, this view is in contrast with the findings of Pandey and Mishra (2004) who found no association between adoption of zero tillage and the family's ability to access labour.

Ogunsumi and Ewuola (2005) reported that socio-economic status of farmers is positively and strongly related to adoption. In earlier studies, Meinzen -Dick *et al*. (2004) and Sheikh *et al.* (2003) emphasize the importance of resource endowment variables in shaping the adoption of 'no-tillage' technologies suggesting that lack of assets will limit technology adoption. In this context, a stronger fiscal capacity to make investment and afford any losses resulting from adoption is expressed as greater financial capital. According to CIMMYT (1993),Langyintuo and Mekuria (2005) and Marenya and Barrett (2007), disposable income significantly and positively affects technology adoption. These conditions are usually met by larger farms that benefit from the economies of scale, greater productivity and higher farm incomes. Zhang and Owiredu (2007) reported that the total amount of land owned and/or cultivated by farmers, has a significant positive influence on the adoption of plantation establishment in Ghana. As outlined in the work of Shiferaw and Holden (1998), livestock holdings may have an ambivalent effect on farmers' adoption decisions of technologies that protect environmental integrity of the soil. The authors also posit that lack of access to cash or credit may hamper smallholder farmers from adopting new technologies that require initial investments. On the other hand, when financial aptitude is bolstered, farmers have greater capacity to invest in and undertake the risk of practising CA.

The natural environment as captured through agro-ecological zones have a strong bearing on the performance of all agricultural technologies. Agro ecological zone is used to depict difference of natural resource quality across regions because it is not possible to capture all farm -specific characteristics (D' Emdem *et al.*, 2008). However, the agro -climate appears to be the most significant determinant of locational differences in adoption rates (Feder & Umali 1993). The effect of agro ecological zone upon adoption is indeterminate as it highly dependent on how the environmental challenges affect farmers in that zone. Tsegaye *et al.* (2008) found that the initial decision to adopt CA in Ethiopia is influenced by regional locational differences among other factors. Similarly, Mazvimavi and Twomlow (2009) found that farmers located in high rainfall regions, with better chances of increased crop production, tend to be less risk averse and are likely to try new cropping techniques. High rainfall areas, by virtue of high biomass production and limited competition for crop residues with livestock, are areas where CA is likely to be adopted. However, Haggblade and Tembo (2003) reported high adoption rates in low rainfall areas where benefits of CA could be realized from moisture conservation. These findings indicate that agro-ecological regions also play a significant role in adoption of CA.

Institutional factors such as number of extension contacts and membership of farmers' associations are also assumed to be positively related to adoption decisions. Several studies directly have included availability of information as an explanatory variable for adoption decisions and found a positive correlation (Traore *et al.*, 1998; Prokopy *et al.*, 2008). Other authors found a correlation between adoption and a specific source of information, such as visits from extension agents (Feder & Umali 1993), experience working with an NGO (Bandiera & Rasul 2007), or participation in field trials and workshops (Traore *et al.*, 1998). The importance of extension services in enhancing adoption of new technologies was also highlighted by Doss, (2006). This is because farmers get exposed to new information which reduces information asymmetry that characterize a new technology and hence farmers are more aware about it and more willing to take the risk of trying the new technology. Most governments or NGOs provide aid or subsidies when crop production fails. The expected sign on government support coefficient is positive. NGO and other institutional support will facilitate farmers' initial exposure to CA techniques (Chomba, 2004). The support can help farm households to smooth consumption and maintain productive capacity by reducing the need to liquidate assets that might otherwise occur without this support.

Many adoption studies have attempted to identify the drivers of adoption behaviour by exploiting cross-sectional variation in adoption rates with cross-sectional variation in village, household and plot characteristics (Bekele & Drake 2003; Gebremedhin & Scott 2003). However, it has been noted that such empirical models tend to have weak explanatory power (Abadi-Ghadim & Pannell 1999, Oostendorp & Zaal 2009). Therefore it is useful to exploit panel another type of variation namely variation across time.

2.5.1 Studies on technology dis-adoption

There are few empirical studies about abandonment of innovations in contrast to the numerous studies that have explored the domain of adoption of innovations (Carletto, Kirk, Winters, & Davis, 2007; Neill & Lee, 2001). Evidence that patterns of adoption and continuation of practices depend similarly on household wealth would provide more robust evidence than exists in the current literature as to the attractiveness of CA technologies for poorer smallholder farmers. Ex-post information on technology adoption, such as the actual profitability of the technology and its suitability for the existing farming practice, can be important determinants of continued use of the technology as well. Farmers can abandon technologies they previously adopted if the expected benefits from adoption are lower than the prevailing costs. The changing profitability of agricultural enterprises introduces the time dimension as a driver of adoption, since households may adopt technologies for some but not all periods.

The phenomenon of dis-adoption commonly reported in literature reveals that new technologies are replaced by conventional ones after being adopted in numerous cases owing to various factors, such as natural disasters, climate uncertainty and economic problems because of reductions in incomes (Kolawale, *et al.*, 2003; Oladele & Adekoya, 2006; Oladele, 2005). Neill and Lee (2001) investigated reasons for the high dis-adoption rate of a conservation practice called "maize-mucuna" which is considered labour-saving, yield-increasing and risk-reducing for rural households in the Honduras. The study findings indicate that farmers with higher dependence on and longer experience with maize production are likely to retain the technology. Similarly, seasonal labour bottlenecks have been reported as the cause of the abandonment of a labour-intensive low external input rice production system in Madagascar (Moser & Barrett 2003).

Oladele (2005), Amsalu and Graaff, (2007) and An (2008) have investigated the sparsely explored literature on factors leading to abandonment. Studies, which are mostly from the western hemisphere, have little to say about problems of active rejection in the context of rural Africa, where structural and institutional constraints are likely to hamper poor farmers' ability to continue using already adopted technology. Evidence from empirical studies in Africa confirms that farmers is SSA face a host of constraints, ranging from infrastructure to incentives and liquidity impeding the adoption and retention of agricultural technologies (Kijima *et al*., 2011; Marenya & Barrett, 2007; Poulton *et al*., 2006). Amsalu and Graaff (2007) analysed the relationship between adoption and continued use of stone terraces, a conservation practice to curtail soil erosion in Ethiopia, and found that continued use of the practice was affected negatively by the size of the family. However, there was no statistically significant relationship between family size and adoption of the practice, though factors relevant to the suitability of stone terraces, such as soil fertility and slope of land, were found important in both adoption and abandonment decisions. In another study, Walton *et al.* (2008) identified factors affecting adoption and abandonment of soil sampling techniques by US cotton farmers. Factors positively related with technology retention were age and longer experience with soil sampling technology. The authors concluded that factors influencing adoption and abandonment are not similar to one another.

Tura *et al*. (2009) indicated that dis-adoption is largely determined by the asset portfolio of farmers and by the structure of markets for credit, labour and seeds. As in the work of Neill and Lee 2001, off-farm income and the opportunity cost of land (in terms of distance to a main road) were found to be positively associated with abandonment. Barrett *et al*. (2006) concluded that households that suffer shocks that deplete their farm and non-farm cash earnings or critical labour, land and livestock assets (which require cash to replenish) become more likely to discontinue using the technologies with which they had previously experimented. Shocks thus lead to endogenous disinvestment, which reinforces the permanent income losses associated with the initial adverse shock. A study by Marenya and Barrett (2007) showed that households that are better educated, have larger farms and more livestock, and enjoy greater availability of household labour and non-farm cash income are considerably and statistically significantly less likely to discontinue their use of improved natural resource management practices.

Chomba (2004) used two-season data in Zambia and found that farmers who had access to agricultural support programmes were likely to dis-adopt the CA practices the following season. If farmers did not see the benefits of practices, removal of programme inducement could have resulted in discontinuing the CA practices. The study managed to track farmer's practices over two years but failed to establish whether discontinuation was likely to be temporary or not. The technology adoption choice is an inherently dynamic process that is best modelled as a repeated decision conditional on past decisions and the current/expected economic environment. Agricultural economists know far less about factors influencing technology retention or abandonment compared to the one time discrete decision on whether or not to adopt a technology. Some of the concerns raised by Feder *et al.* (1985) and Doss (2006) on the need to study the dynamic patterns of adoption remain unanswered. An important aspect of the dynamics of adoption is the study of dis-adoption. However, paucity of longitudinal data has led to few studies on dis-adoption patterns.

To analyse the decisions to retain or abandon previously adopted technologies, researchers need information not only on whether or not to adopt the technology, but also on whether the adopter chooses to retain or abandon the technology. The few recent studies that have properly tracked the dynamics of adoption yield important new insights into learning processes, farmers' experimentation with new technologies, the impact of changing profitability and social conformity effects (Conley & Udry, 2001; Moser & Barrett, 2003). Studies of dis-adoption require panel data, but the literature is based heavily on cross-sectional data that in general, bias estimates of the parameters that describe adoption processes if the data were collected during the process of technology diffusion (Besley & Case, 1993). The current study will fill this gap by making use of five-year panel data in trying to establish the determinants of abandonment of use of CA practices.

2.5.2 Methodological issues in technology adoption

Knowler and Bradshaw (2007), synthesised 23 published empirical studies on factors affecting adoption of CA technologies. In their paper, they outline the different analytical methods used to determine variables that were statistically significant in explaining adoption decisions. The commonly used methods include those that show bivariate associations, e.g. correlation coefficients and chi-square. Multivariate regression models such as OLS, limited dependent models and censored models are also common. Where the dependent variable is categorical, taking values of 0 or 1, the probit or logit models are used (Park and Lohr, 2005; Langyintuo *et al*., 2002). However, for a continuous dependent variable, a censored regression model is appropriate, as the probit or logit models fail to differentiate between limit (zero or censored) and non-limit (continuous or uncensored) observations, thus cannot handle the case of adoption choices that have a continuous value range (Langyintuo *et al*., 2002). This is the typical case for fertiliser adoption decisions where some farmers apply positive levels of fertiliser while others have zero application (non-adopters). Typically the Tobit (censored regression model), ordered multinomial logit or two stage Heckman models have been used in these situations.

Intensity of use is a very important aspect of technology adoption because it is not only the choice to use, but also how much to apply that is often more important. The Tobit model is used when the same independent variables influence both the probability and size of the dependent variable. However, the Tobit model attributes the censoring to a standard corner solution thereby imposing the assumption that non-adoption is attributable to economic factors alone (Cragg, 1971). A generalisation of the Tobit model overcomes this restrictive assumption by accounting for the possibility that non-adoption is due to non-economic factors as well. A major benefit of the Tobit model is that it allows for elasticities measured at the means to be decomposed into an elasticity of adoption and elasticity of effort when adoption occurs. In Zimbabwe a Tobit model has been used to analyse adoption intensity in terms of share of area under any one CA practice (Chiputwa *et al.*, (2011). On the other hand, Mazvimavi and Twomlow (2009) applied a Tobit model to measure adoption intensity of CA by smallholder farmers in Zimbabwe as the proportion of components of the CA package that a farmer used.

The ordered Tobit accounts for the dependent variable being truncated at either the upper or lower limits of its ranges by assuming the error term follows a truncated normal distribution. The ordered multinomial logit is used when the dependent variable is categorical, hierarchical and censored and when the same variables are assumed to influence both adoption and extent of adoption. Teklewold *et al*. (2013) applied the ordered probit to analyse adoption decisions of Ethiopian farm households facing multiple SAPs. When different explanatory variables are assumed to affect the decision to adopt and the extent or intensity of adoption, a two-stage Heckman model is more appropriate. Generally the first stage consists of either a logit or probit analysis of the probability of adoption. This is followed by an OLS regression of the extent of adoption incorporating the sample selection control function (the inverse Mills ratio) from the first equation (Greene 2008). In their work Caviglia and Kahn (2001), applied the Heckman model to analyse adoption of sustainable agriculture, including agroforestry systems, in Brazil.

The dependent variable “adoption/non-adoption” does not reflect adoption over time, since it fails to allow for farm households’ different waiting times. Sunding and Zilberman (2001) point out that a dynamic adoption model that adequately accounts for sunk costs and uncertainty in the adoption process can explain the reluctance of farmers to adopt CA technology. The influence of potential determinants of technology adoption within an appropriate dynamic econometric framework, namely duration analysis, has been used widely in labour economics. The main advantage of duration analysis over the logit, probit and Tobit methods is that it can deal with both cross-section and time series data. As a result, this kind of analysis can capture both cross-sectional and temporal changes in farm households’ characteristics, as well as incorporating the costs of adopting the innovation, output price, environmental characteristics and other explanatory variables. Although this technique has obvious advantages in the analysis of technology adoption there, is evident paucity of studies that have been conducted in the particular context of agricultural technology. Adoption and diffusion can, therefore be investigated together within a dynamic process.

Empirical studies are typically multilevel analyses and include variables that are measured at the plot, the household and the village (or even higher) level. Yet, despite their long lists of explanatory variables, it has been noted that these empirical models often lack explanatory power (Abadi Ghadim & Pannell 1999). Following their study on the adoption of soil and water conservation measures by farmers in Kenya, Oostendorp and Zaal (2009), concluded that the predictive accuracy of a fully specified logit model including multiple plot, household and village characteristics, was only somewhat higher than that achieved by a logit model with village dummies only (e.g. 78% versus 74% accuracy for the adoption of terraces). A possible reason for the lack of explanatory power is that the vast majority of studies aiming to explain innovation adoption are limited to cross-sectional data and analysis techniques that cannot accommodate time-dependent variables (D’Emden *et al*., 2006).

In practice the adoption decision was often made in the past depending on past circumstances and expectations, whereas cross-sectional studies analyse the relationship between currently observed farming techniques (which are the outcome of past adoption decisions) and current circumstances. Therefore dynamic analyses based on panel data or duration data can be expected to generate important additional insights into the actual adoption process. Studies focusing on the adoption and subsequent abandonment of farming technologies or processes often employ panel data. Walton (2008) constructs a model in which a farmer faces an initial discrete choice to adopt a technology based on preliminary estimates of cost versus profit and a successive choice to abandon after realising true costs and profits. Uematsu *et al.* (2010) expanded on this by estimating the probability of adoption, retention, and abandonment at a given point in time. In the same year, Läpple (2010) used a hazard function to model the likelihood of abandoning organic farming, given the length of survival time since adopting it and a set of parameters to account for differential characteristics. However, such comprehensive data sets are rarely available, as their creation requires substantial investment of time. Consequently, thus far only a few studies that use panel or duration data for rural environments in Africa have been conducted (Zaal & Oostendorp 2002; Gebremedhin & Scoot, 2003).

2.6 Theoretical models of adoption and dis-adoption

There are well-established theoretical models that explain factors that affect adoption of new technologies instead of one big theory explaining all aspects of technology adoption by farmers. The historical order of the development of adoption theories has been roughly in order of profitability (Griliches, 1957; Mansfield, 1961), farm size (Feder *et al*., 1985), risk and uncertainty (Feder *et al*., 1985; Sunding & Zilberman, 2001), information gathering (Feder & O'Mara, 1982; Feder & Slade, 1984), human capital (Huffman, 1974; Wozniak, 1994), labour supply (Huffman, 1980) and learning by doing and learning from others (Bandiera & Rasul, 2006). Theoretical models of adoption behaviour have looked into variables that may explain the decision to adopt or the intensity of adoption. Such factors include farm size, access to credit and information, personal traits of the decision-maker, tenure arrangement, etc. Theoretical models for the aggregate adoption complement individual adoption models. Alternative assumptions regarding individual adoption behaviour usually result in S-shaped curves. Cochrane's technological treadmill suggests diminishing gains over time in response to price declines following increased production due to adoption.

Early empirical studies of diffusion were conducted by sociologists such as Rogers (1983), who collected data on aggregate adoption of different technologies and found that diffusion was an S-shaped function of time, reflecting slow initial diffusion, then a period of take-off, and then an eventual tapering off. Since Rogers's classic work of 1960 on adoption, paradigms for explaining adoption decisions have revolved around three basic models: the innovation-diffusion model, the technology characteristics-user's context model, and the economic constraints model. The innovation diffusion model assumes that the appropriateness of the technology and access to information are the key factors in determining adoption decision (Adesina & Zinnah, 1993). The use of extension, the media and local opinion leaders thus play a key role in this model. The adoption behaviour of any agricultural technology would follow a normal distribution curve in a given social system (Rogers, 2003).The technology characteristics model assumes that the characteristics of a technology, such as the agro-ecological, socioeconomic and institutional contexts, play the central role in the adoption and diffusion processes. The participation of farmers and stakeholders in the technology development process is essential (Negatu & Parikh, 1999; Scoones & Thomson, 2009).

Rogers established the imitation model: assuming homogeneity among farmers, he was able to model the spread of a technological innovation as a process of imitation, which is similar to the spread of an epidemic.

In particular, if $P(t)$is the land share of the new technology over time, $P(t) = \frac{K}{1 + e^{-(a+bt)}}$, where K is the maximum diffusion rate, a is a measure of the initial rate of adoption and b is the measure of the speed of adoption. Griliches (1957) expanded the Rogers model by suggesting that the relative profitability of new technologies affects the speed of imitation. The more profitable the new technology, the faster the imitation, the steeper the slope of the S-shaped curve (higher b) and the larger the value of the maximum adoption, K. David (1975) and Feder *et al.* (1985) argued that the imitation model did not include an explicit economic decision-making model, and so they introduced the threshold model.

The threshold model incorporates three major components. First, farmers consider multiple factors in making economic decisions, including profit, utility, risk and other criteria. Second, it takes into consideration heterogeneity of farm size, human capital and/or land quality. Third, it is a dynamic model. Frequently, studies have assumed static profit maximisation or expected utility maximisation by the decision-maker. Recent studies have assumed dynamic optimisation, with the timing of adoption being determined by considering the trade-off of benefits from use in the present, with reduced prices as production expands in the future (McWilliams & Zilberman 1996). Sometimes, the dynamic processes that affect returns or costs are stochastic, such as additive and multiplicative random walk. In these cases, decision-makers are taking a real option approach; thus, timing of adoption is selected so that marginal benefit overcomes marginal cost plus the hurdle rates that increase with uncertainty (Khanna *et al*., 2000; Seo *et al*., 2009).

The threshold model emphasises the importance of the effective rollout of a technology, as well as its introduction in locations with the highest returns and willingness to experiment with the product. People who adopt the technology early are those who have the most favourable conditions. However, over time, a new technology may become more attractive because of learning by doing (i.e., knowledge acquisition from experience in production of a product), learning by using (i.e., learning through use of a technology) or network externalities, causing more adopters to join in. When there is partial adoption, increase in adoption over time may be within both the intensive and extensive margin. In the case of mechanical innovation, larger scale farmers will adopt it first, but as technology becomes cheaper and custom services are developed, smaller farmers will adopt the technology (Sunding & Zilberman 2001). The threshold model emphasises the importance of heterogeneity among farmers and has been applied using data on technology, as well as on land use choices at the plot or farm level.

The influence of economic thought on the adoption of innovations led Just and Zilberman (1983), to propose a theory of technology adoption under uncertainty using the expected utility framework. This model contends that economic constraints, such as access to capital or land, significantly affect the adoption decision. Thus, the decisions of the farmer are derived from the maximisation of expected utility (or profit) subject to his inputs (availability of land, labour and credit).The expected utility model is the most commonly used model for adoption studies of agriculture and agro forestry technologies (Mercer & Pattanayak, 2003; Negatu & Parikh, 1999).

Sociologists have traditionally focused on the characteristics of adopters, their perception of the innovation, adoption rates and communication channels in the decision process (Marra *et al*., 2003). The economics literature contains little theory on behavioural patterns of abandonment. Currently an important component of the innovation decision- making process that is receiving research attention is discontinued adoption behaviour, which is the decision to reject an innovation after having previously adopted it. Technology dis-adoption has not been analysed widely in the literature and there are no theoretical frameworks that analyses technology dis-adoption. Based on the theoretical discussion, this study will apply the concept of risk aversion, maximisation of utility and learning by doing as shown in the study theoretical framework.

Allan Low (1968) applied the household economics model to the case of smallholder farmers in southern Africa. He showed the importance of rural – urban interactions on decisions relating to technology adoption southern Africa. Low developed a model in which wage rates differed between household members especially male and female. Using the household model he found that specialisation takes place among members of the household in the form the absent male members earning cash income in urban or commercial rural areas while female members take responsibility for the farming activities. Farming households in southern Africa aimed at maximising household income not farm income, in the same vein, technology adoption must be understood in terms of broader household context. Households may use yield increasing technologies in a labour saving way for example using fertiliser to cultivate a smaller area to allow more time for other household activities like collecting water and firewood. The work of Low will inform this study to better understand factors shaping the abandonment of technological innovations.

2.7 Theoretical framework for the study

The subject of the adoption of agricultural practices has been heavily researched globally, in particular CA technology (Chomba, 2004). However, most of these studies related to adoption of CA have simply used farm and farmer characteristics to determine factors affecting the adoption of CA practices without providing the rationale for their inclusion based on theory (Feder *et al*., 1985).There have been several studies that have attempted to highlight the economic theory underlying farmer behaviour in decision making over CA. McConnell (1983) used production theory and assumed a farmer has an objective to maximise profit. Some farmers have adopted CA because they found that immediate yield benefits and profits were attractive. However studies such as Swinton and Quiroz (2003) and Marra *et al*. (2001) used a household model based on utility maximisation.

In order to determine factors that influence farmers to adopt CA technologies adequately, the focus of the adoption analysis needs to go beyond the characteristics of farmers and plots of land (CIMMYT, 1993). A farmer should be regarded as both a producer and a consumer (Sadoulet & De Janvry, 1995). This implies that a farmer takes into consideration current consumption and production and also policy and physical effects (CIMMYT, 1993; FAO 2001). A farmer may react in a number of ways towards a decline in production and/or variability in production that undermines consumption needs. Existing practices may be modified or altogether new ones may be adopted (FAO, 2001). Before investing in CA practices brought to a farmer's attention, the farmer looks at the monetary incentives, whether there is capacity to implement the practice and the constraints he faces (Reardon & Vosti (1997a).

Soil and water conservation practices have different waiting periods before a farmer can benefit from the investment. Their perceived returns may be slower than the immediate impact of inputs such as like fertilisers (Barlowe 1978; Reardon & Vosti (1997b). Most farmers in developing countries have high preferences rates for consumption rendering today's consumption of resources more valuable than the future consumption (Field, 2001). As a result, smallholder farmers in Zimbabwe are likely to have a great preferences for conservation practices that yield benefits in the shortest time possible. In addition, farmers tend to be conscious of uncertainties that may arise from both the physical environment and a new technology (Knox *et al.*, 1998). Farmers in such a situation may feel more comfortable to continue with current practices despite noticing a decline in soil productivity (Siachinji-Musiwa, 1999). They regard such behaviour as risk-reduction strategies.

In view of the above discussion, the study's approaches to the decision-making behaviour of Zimbabwean farmers in the adoption of practices under consideration are made based on the following assumptions:

- The farmer's primary objective is to be food secure.
- The farmer wants to generate farm revenues to meet household cash obligations.
- The farmers are risk-averse hence farmers living in geographical areas with erratic rains want to reduce risk as much as possible and CA practices that have a quick effect on productivity and reduce yield variability are more appealing to them.
- The farmers face constrained resources in land, labour, management skills and capital, hence activities and practices that ameliorate the pressure on these resources are more appealing to them.

This study considers farmer behaviour in the adoption of CA or any piece of the technology package within the theoretical framework discussed above and the incentive and capacity paradigm employed by Clay *et al.* (2002) and Reardon and Vosti (1997a). A farmer is regarded as a consumer and an investor hence an investment that yields utility over time to a farm household is employed. The conceptual model for investment in CA or any piece of the technology package highlights that the farmer pursues consumption and production ends depending on expected investment returns and other conditioning variables such as the availability of labour and input.

2.8: Summary

Although CA has the potential to address the problems of low productivity and soil degradation, adoption remains very low, especially in SSA. The current trend among most smallholder farmers is to adopt CA partially, by picking only those components that fit into their farming system. In addition, the waiting periods for CA benefits to manifest are too long for smallholder farmers, which then discourages them from adopting the practice. However proponents of CA posit that the benefits of CA can be realised even under partial adoption and in the short term. Furthermore, they attribute the problems of CA adoption to the complexity and packaged nature of the technology.

A review of literature shows that most adoption studies have considered single technology, yet CA is a packaged technology. Issues of dis-adoption are critical in addressing effective targeting and packaging of the CA technology. There are currently scanty information and few empirical studies on dis-adoption. The yield benefits attributable to CA, especially under smallholder conditions are difficult to establish, especially in the absence of a reasonable counterfactual situation. The literature reviewed current thinking on adoption of CA as the technology of focus. Partial adoption and dis-adoption have been acknowledged in contemporary literature, with limited empirical evidence.

CHAPTER 3

RESEARCH DESIGN AND METHODS

3.1 Introduction

Chapter three presents a detailed description of the research approach and data collection methods used for this study. This is followed by a description of the study area and the sample. The chapter is concludes with presentation of summary statistics on household variables and a description of the plot level data.

3.2 Research approach

The study employed a quantitative approach to address the research problem at hand which is seeking an understanding on why farmers are not keen to take up the CA package despite massive evidence of the yield enhancing effect of this technology. The analysis required a combination of inductive and deductive inquiry and quantitative research approaches was found to be most appropriate for the purposes. The quantitative research emphasised on breadth and representation of a survey sample with the intention of achieving the levels of confidence in conclusion regarding the significance of specific factors in driving outcomes. Regression results were used to shed light on the impacts of the factors. The quantitative research approach used in this study was in form of a household survey, however the surveys were of a panel nature. The key feature of panel studies is that they collect repeated measures from the same sample at different points in time. Most panel studies are designed for quantitative analysis and use structured survey data as is the case with this study.

3.2.1 Panel survey approach

A panel household survey provides repeated observations on a set of variables for the same households over time. Repeated observations are derived by following a sample of persons (a panel) over time and by collecting data from a sequence of interviews (waves). The interviews are fixed occasions and in most case are regularly spaced. A panel survey requires a more complicated design to remain representative across time for both individuals and households in which they reside. Panel studies provide the opportunity for more in depth analysis and are informative forms of research though they are costly to administer. Panel studies have been used extensively to monitor the dynamics of poverty, movements into and out of the labour market, and the process of demographic change. Longitudinal data generated from panel studies can be analysed to understand the short-term dynamics of change, including movements into and out of employment or transitions into and out of poverty. Longitudinal data sets tend to be more complex than surveys done in a cross-sectional context.

The advantage of panel surveys over cross-sectional surveys is that panel surveys allow changes to be studied at an individual or household level. Repeated surveys make it possible to control for individual heterogeneity, so that identifying cause-effect relationships is made easier. The availability of panel data makes it possible to control for individual household specific effects and plot specific effects which may potentially bias or make regression estimators inconsistent. For example, differences in plot characteristics, or any other unobservable or hard to measure characteristics can be controlled for with panel data. However, getting a good panel survey sample is difficult as people are reluctant to be interviewed several consecutive times. Attrition is a common as households from early rounds of the survey become unavailable. Long duration panel surveys can be affected by attrition whereby a panel respondent abandons the survey and there is loss of representation. Replacement of such households is not possible as the benefits of panel analysis rely on continuous representation of households across time periods.

3.2.2 ICRISAT panel survey

The Protracted Relief and Recovery Program (PRP) of 2004-2007 was a nation –wide program funded by DFID which worked to stabilize food security and protect livelihoods of vulnerable household. Under this program, NGOs facilitated the dissemination, testing and adoption of CA among smallholder farmers in Zimbabwe. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) as a technical partner provided training for extension agents and additional in-service support in the PRP (ICRISAT, 2009). In addition, ICRISAT was also involved in the monitoring of CA uptake and adoption patterns through the implementation of a panel survey which culminated in a database. The panel survey involved farm households that were first interviewed in 2007 and revisited in subsequent years until 2011. The initial sample size collected in 2006/7 season consisted of only 232 households who had been trained and had used CA for at least two years. The initial sample had been incentivized to participate in the CA program as part of the PRP targeted to vulnerable households who were facing serious food security challenges due to production constraints. In the subsequent years the sample size was expanded to include those farmers using CA but were not supported by NGOs with subsidised or free seed and fertiliser.

3.2.3 Sampling strategy for ICRISAT panel survey

Multi-stage sampling was employed in the ICRISAT panel survey. Purposive sampling was used to select the study districts and wards, and then random sampling was implemented choosing the villages and survey farmers. The districts in the sample study were already predetermined by virtue of their relative location in the agro ecological regions and presence of an NGO promoting CA. By construction, each of Zimbabwe's four agro ecologies was represented by at least two districts. The second stage involved purposeful selection of two wards in each district. The wards were selected based on the presence of donor organizations promoting CA in the area. Once the wards were ascertained, two villages were randomly selected from each ward. The last stage involved random selection of households from a list of farmers provided by NGOs operating in the specified areas.

3.2.4 Determination of the ICRISAT sample size

The targeted sample consists of farmers who have been trained and received technical and input assistance from NGOs. These farmers were specifically involved in manual CA commonly known as planting basin among practitioners in Zimbabwe. Thus the sample was representative of farmers who had experience with CA, but it is not necessarily representative of smallholder farmers in general. However the original survey sites were selected in 2006 when the panel survey was initiated. The original intention was to give a nationwide coverage to the CA up-scaling activities being promoted as part of the PRP.

The target was to interview 30 households from each of 15 districts giving a target sample size of 450 from 2007/8 season and thereafter. In the subsequent rounds of the panel survey the sample size was enlarged by increasing the number of participating districts and the number of farmers per ward. From each of the two wards in the district the number of interviewed farmers increased to 15 comprising of 10 households having received training and inputs from NGOs. The additional 5 households were identified as spontaneous adopters of CA. Spontaneous adopters are households that practiced the CA technology by copying from others, without receiving inputs and in some cases without formal technical support. Details about the sample size across all the rounds are shown in Table 3.1.

Table 3.1: Detailed sample for the ICRISAT five-year panel

Natural Region		District	Sample size per Season				
			[1]2006/07	2007/08	2008/09	2009/10	2010/11
II		Bindura	20	31	30	31	28
		Murehwa	20	29	29	32	26
		[2]Seke	-	30	29	30	30
III		Masvingo	22	28	32	28	28
		Chirumhanzu	16	23	30	28	29
		Mt Darwin	16	29	29	30	28
IV		Nyanga	20	32	30	30	28
		Nkayi	20	30	23	31	29
		Insiza	20	24	23	25	28
		Gokwe South	18	25	25	28	39
V		[2]Chipinge	-	29	30	29	28
		Chivi	20	29	30	29	28
		[2]Binga	-	29	23	30	26
		Hwange	20	27	28	31	29
		Mangwe	20	31	22	26	31
Total			**231**	**426**	**413**	**438**	**435**

3.3 Study area

The study area constitutes of 12 districts in Zimbabwe where CA had been actively promoted for two consecutive years since 2004 as shown in Fig 3.1. The survey households, selected through multi-stage sampling were representative of the smallholder farming community covering four natural farming regions to capture spatial variability in CA practices. Zimbabwe is divided into five agro-ecological regions also known as natural regions (NR) based on rainfall regime, soil quality and vegetation among other factors. The quality of the land resource and rainfall received declines from NR I through to NR V (Vincent & Thomas, 1960). Natural Region I and II receive the highest rainfall (at least 750 mm per annum) and are suitable for intensive farming. Natural Region III receives moderate rainfall (650–800 mm per annum), and Natural Regions IV and V, where most communal farmers reside have fairly low rainfall (450–650 mm per annum). Natural regions IV and V are classified as semi- arid area in Zimbabwe (Moyo *et al.*, 2012) and are too dry for successful crop production without irrigation but the farmers in these areas have a comparative advantage in the production of small grains. Semi- arid areas are characterised by extensive crop production with limited crop residue production. Livestock is an essential component of the farming system in the dry areas implying high demand for crop residues as feed.

[1] Round of survey not included in the study sample
[2] Districts not included the study sample

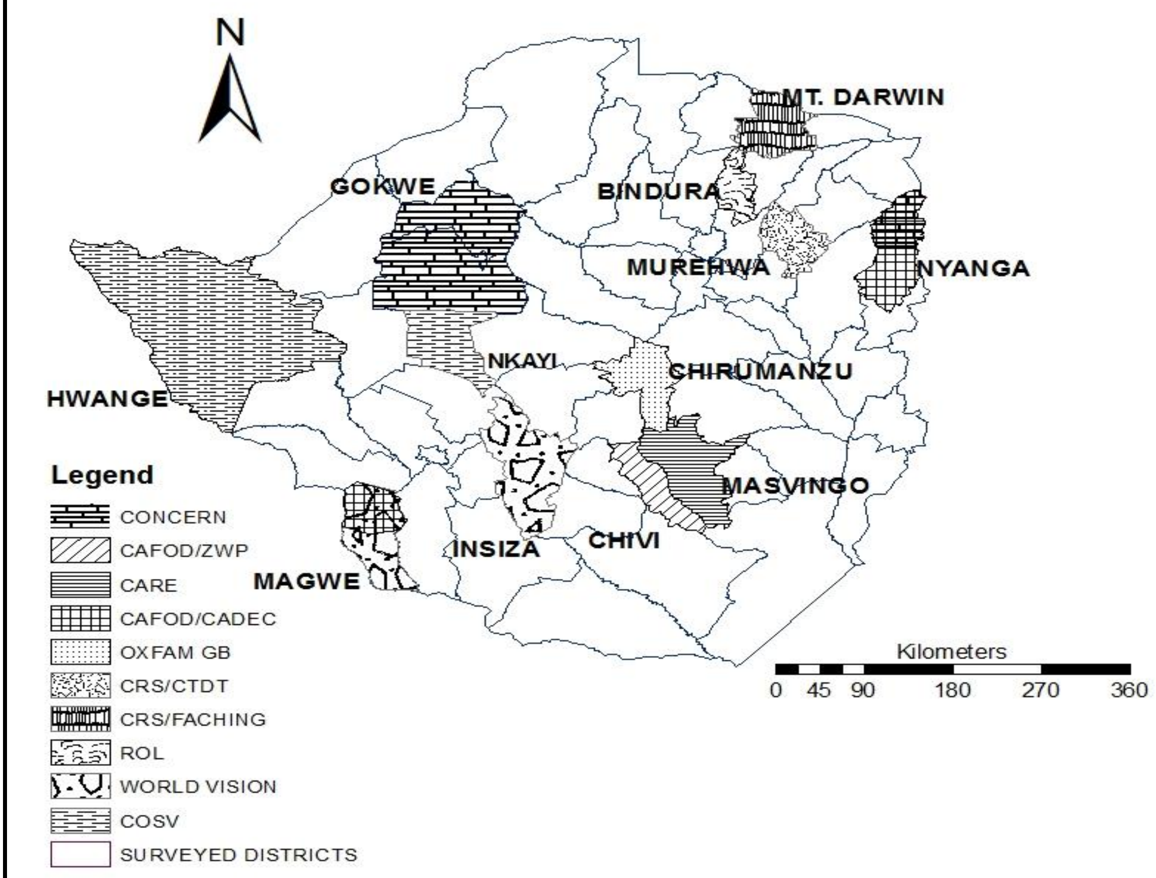

Figure 3.1: Map of ICRISAT CA panel survey districts in Zimbabwe

3.4 Data collection

The household data were collected using structured questionnaires designed in line with the broad objectives of the panel study. A farmer questionnaire was developed, field-tested and modified during enumerator training. The questions within the questionnaires have remained mostly unchanged over the course of the panel period. In each district, around 30 households were interviewed and a database was developed for continued monitoring in subsequent seasons.

Even though, focus group discussions (FGD) were conducted in 2006/07 and 2009/10 to complement the household surveys, they were not used as part of this study because they did not help to answer the research questions at hand. Trained enumerators repeatedly visited the sample households to collect both qualitative and quantitative survey data for five consecutive seasons. Upon their arrival in each district, the teams contacted the local NGO, Agricultural Research and Extension services (AGRITEX) and any other agencies that were involved in CA promotion. The household interviews took place with the key decision-maker on field crops, as well as any other members of the household who might be regarded as key informants, at the selected household's homestead. Farmers were asked about their current CA practices such as winter weeding, the management of crop residues, timely weeding and crop rotation. If farmers were not practising one of these management options they were asked why. Other questions related to weeding practices, labour allocation, planting times, crop rotation and residue management. During each interview, the team member visited the plots where the farmer was practising CA as well as plots where field crops were grown the conventional way.

All questionnaires had to be pre coded and checked for any missing data whilst in field. Post coding was done at the point of data entry and all collected data was entered into SPSS in preparation for data analysis. The data was cleaned and observations for the first years were dropped in order to maintain consistency. The data files were all merged in STATA giving two data samples, one for household level and another a plot level analysis.

3.4.1 Attrition

The level of attrition for this study was generally low and it was less than 10% in a year where attrition was highest. In this study, attrition was mainly due to absenteeism of previously interviewed households at the time of the survey and few cases of death and out - migration. Since not all respondents were available each year, there was some attrition over the successive rounds of the survey resulting in a panel that is unbalanced The panel study aimed at interviewing the same household's each year to capture heterogeneity across households over the years.

3.4.2 Study sample size

This study used four years of data out of a five year panel data set collected by ICRISAT to monitor adoption of basin CA by smallholder farmers in Zimbabwe. The panel survey provided a unique data set which covered an era of drastic economic and political changes in Zimbabwe. This thesis specifically makes use of four rounds of the panel survey that is 2008-2011 and data collected from 12 districts only. The sample sizes for the 12 districts was slightly varying each year since data was collected from 327 households in 2007/8, 331 in 2008/9, 347 in 2009/10 and 329 in the 2010/11 season. From these data a balanced panel of 195 households could be constructed in each of the 4 rounds for a sample of 780.

3.4.3 Crop production data

The information collected included detailed agronomic data such as farm operations, CA practices implemented at the plot level, inputs used including land allocation, quantity of seeds as planting materials in kg; quantity of fertiliser used in kg, crops grown and outputs on each of the household's plots. The use of a field map made it easier to identify plots using plot numbers. The plots were numbered in terms of relative location of plots to the homestead. For each plot on the map, information was collected about whether plot was CA or not, planting date and quantities and sources of key inputs used such as seed, basal fertiliser, manure and top dressing fertiliser. Detailed information was also collected for CA plots including a description of activities carried out which were the classified in terms of the CA package consisting of eight techniques. Manure quantities used per plot was collected but this variable not used because of variations in the local units of measure thus an indicator variable was used instead. Quantities of other inputs such as seed and fertilisers were captured in accordance to what the farmers reported and the source of each output was recorded at the plot level.

Plot sizes were determined through a combination of area estimation techniques which included the farmer self- reporting on the size of the plot according to his knowledge and a trained enumerator making a visual assessment of the plot and verifying the size using seed rates. Yield estimations based were based on farmer recall since farmers could harvest earlier than the survey in some instances. Local units of measure were used and these were standardised into kilograms after data entry.

The data collected showed that the most popular cereal grain grown by almost every farmer is maize with sorghum being equally popular in the drier areas. Millet is not commonly planted and is hardly grown in the wetter districts of NR II and NR III. Most of the sampled households allocated a small proportion of their land to cereal legumes like groundnuts, cowpeas and

Bambara nuts. However, analysis of this study was based on maize production because it offered the largest number of observations and the most important staple crop grown in Zimbabwe. The four seasons of data collection result in 1200 observations at household level and on agricultural activities with usable data on a total of 8500 plots. The plot level data forms the basis of the analysis in Chapter 4, which specifically evaluates the yield impact of CA compared to conventional farming.

3.4.4 Summary of household data

The household socio-economic data collected included information on characteristics of the household head such as age, sex, years spent in school and whether the farmer was a lead farmer or not. The household size information was broken down by age categories and sex. Information collected on the household included the time when the household started farming, livestock and assets owned including the number of contacts with extension agents. In line with the CA technology data was collected with regards to the time CA was introduced to the household, input assistance received from NGOs, training and extension advice received.

Data collected at the household level and aggregated across the household provides the basis of household level analysis presented in Chapter 5 and 6. Table 3.2 provides a summary of demographic data from the interviewed households aggregated by agro-ecology (NR) and district. The average age of the head of household range from 47 to 59. In Nyanga there were mostly younger farmers whereas the older farmers were from Bindura district. Most of the farmers had more than 20 years farming experience and at least five years of using CA. On average most of the households in the survey had spent on average six years in formal school which is basic primary education. Household heads in Hwange were least educated and household heads from Nyanga had spent more time in school. On average the household size is about six members which gives an indication of the amount of households labour available. Smaller households were prevalent in Bindura and Nyanga whereas Nkayi had larger household sizes of around eight. The households in sample are generally poor with TLU index ranging between 1.2 and 5.7. In terms of livestock ownership, farmers in Nyanga had very low values of tropical livestock units (TLU) index whereas Nkayi farmers had highest TLU index followed by Bindura.

Table 3.2: Household Characteristics

NR	District	Sample Size (n)	Household head			Experience in years		Household size	NGO support (%)	Livestock
			Male (%)	Age	Education	Farming	CA			
NR II	Bindura	105	52	58.9	5.21	33.44	8.46	5.02	52	4.46
	Murehwa	111	37	55.4	6.78	31.98	6.02	6.29	87	1.80
NR III	Masvingo	106	49	54.1	6.93	29.44	6.41	5.91	91	2.86
	Chirumhanzu	110	54	52.1	7.17	28.25	5.45	5.83	65	2.91
	Mt Darwin	117	61	50.2	6.48	24.35	5.87	6.20	49	2.28
NR IV	Nyanga	120	33	46.5	7.65	23.05	5.95	5.09	97	1.18
	Nkayi	113	58	58.0	6.67	28.71	5.19	7.85	70	5.64
	Insiza	98	46	55.6	6.01	23.39	5.46	6.67	63	3.12
	Gokwe South	110	70	54.9	5.86	31.83	5.70	7.08	86	1.86
NR V	Chivi	113	46	50.2	6.98	27.17	5.41	5.92	57	2.70
	Hwange	115	59	53.4	4.99	27.84	6.06	6.10	78	3.79
	Mangwe	109	31	53.8	6.32	23.62	6.17	6.07	75	3.34
ALL		1332	48	53.5	6.43	27.79	6.03	6.15	72	2.96

Source: ICRISAT, (2009)

Within the period of the survey, at the minimum, not less than half of the survey farmers received some form of input support from NGOs across all districts. Masvingo and Murehwa had the highest number of households receiving input support from NGOs while in Mt Darwin and Bindura there were fewer farmers receiving support from NGOs. NGOs provided inputs to farmers practising CA that were adequate to cover the CA plots. The inputs received consisted of seed, basal fertiliser and top-dressing fertiliser and herbicides for Bindura and Murehwa which fall in the high rainfall areas. Over time as the economic environment of the country improved the amount of inputs from NGOs was reduced and farmers had to source own inputs from the local retail shops. Training was given to all farmers especially in the initiation stages. Training was intensive if the farmer was selected as a lead farmer because they will be expected to teach other farmers or provide back-up technical advice.

3.5 Description of what constitute CA practices used in the study

This section outlines what constitutes CA practices in this study detailing the nature of CA as it used in this study. It also sets out to explain the differences between CA and conventional farming as the main basis of comparison in the subsequent chapters. The practice of CA involves planting crops directly into the land which is protected by mulch using minimum or no-tillage techniques and this is aimed at conserving soil and water. The CA package referred to as CAZim which was promoted under relief initiatives was developed Zimbabwe Conservation Agriculture Taskforce (ZCATF). The basic components of CAZim are eight as agreed by ZCATF and these included winter weeding, digging basins, application of crop residue mulching, application of manure, application of basal fertiliser, application of top dressing, timely weeding and crop rotation. Table 3.3 gives a detailed comparison of CA and conventional farming methods as used in this study.

Table 3.3: Comparison of Conservation and Conventional agriculture practices in Zimbabwe

Practice	**Conservation agriculture**	**Conventional agriculture**
Land preparation	Digging of planting basins to allow for planting at the onset of rains	Use ox-drawn mold board ploughs for total inversion of the soil
Crop rotation	Cereal/ legume rotations practised enable nitrogen fixation by legumes Allows for a break in pest and disease cycles. Ensure that different nutrients are extracted from soil as crop is changed	Maize typically grown in pure stand as a staple food crop annually If there is rotation it is with other cereals such as rapoko, millet and sorghum which require same nutrients and associated with same pests and diseases as maize.
Crop residues management	Stored away and used as mulch for the crops. Mulch protect the soil against the direct impact of raindrops, regulates soil temperature and eventually rot and add to the soil organic matter	Gathered and burnt as a way of pest control. Grazed upon by communal livestock during the off season months
Weed management		
Winter weeding	Weeding done before planting to reduce weed pressure	Weeds are overturned into the soil during ploughing
Timely weeding	Timely and multiple weeding during the post planting period if herbicides are not used	Weeding done two to three times throughout the season
Fertility management		
Manure	Placement of a handful of manure in the basin at planting	Broadcasting to the soil which will likely result in poor seed – soil contact, wasted fertility and ultimately lowered yields
Basal fertiliser	Placement of one level beer bottle cap of basal fertiliser in the basin at planting allows for efficient use of nutrients by plants. Minimum application rate is 80kg/ha of compound D	Basal fertiliser usually applied at crop emergence – plant fails to take advantage of the nutrients necessary for root development Banding can be used to apply fertiliser at a recommended rate of 250kg/ha
Top dressing fertiliser	Precise placement of small doses (one level beer bottle cap) of top dressing fertiliser. A minimum of 80kg/ha of ammonium nitrate Apply at 6 leaves and just before flowering stage	Broadcast or banding used at the recommended rate of 300kg/ha of ammonium nitrate. Staggered Apply as per need

Source: Author's compilation, 2014

When applying CA, farmers do not plough but, instead, hand dig basins 15x15x15 cm in size for planting seed. The permanent basins allow for improving the soil in small pockets rather than improving the soil of the entire field. However, weeds grow faster in the undisturbed soil, requiring more effort to keep the fields clean and farmers must .gather the stalks and leaves left in the field after harvest to use as mulch, which protects the soil from erosion and holds in moisture. Crop rotation calls for farmers to alternate legumes with their maize crops in order to improve soil fertility, but they are often averse to giving up field space where they normally grow their major crops. On the other hand, traditional crop farming referred to in this thesis as conventional farming is characterised by frequent soil tillage and this entails turning of the soil using a plough. Waste crop material is usually removed from the fields by livestock grazing or burning and in many cases mono cropping is practised.

CHAPTER 4

THE YIELD IMPACT OF CONSERVATION AGRICULTURE: AN ASSESSMENT OF SMALLHOLDER FARMERS IN ZIMBABWE

4.1 Introduction

Yields in smallholder farming systems of southern Africa have remained appallingly low despite technological innovations such as fertilisers and improved seeds (Baudron *et al*., 2012). In many cases farmers cannot guarantee food security from their own production and very few smallholders are able to sell surplus harvest to generate income (Marongwe *et al*., 2011). Many causes of agricultural stagnation have been suggested, with some observers emphasizing the Malthusian link between rapid population growth, low agricultural productivity, and resource degradation (Knowler & Bradshaw, 2007; Rockstrom *et al*., 2009; Mazvimavi, 2011); others emphasising market, government and institutional failures (DFID, 2004; Diagana, 2003) or bio-physical factors such as climate and soils (DFID, 2004; FAO, 2011). Despite the debate regarding the causes, there is consensus about the need to devise strategies to improve food production in order to address food insecurity in the twenty-first century in Africa (Conceição *et al*., 2011). Increases in food production in Africa must come through increased productivity based on the adoption of new technologies. Agricultural intensification is necessary because many regions of SSA are no longer land abundant (Mwangi, 1996). It is also imperative to involve smallholders in the intensification efforts so as to enhance access to food for vulnerable people.

Conservation agriculture strives to achieve acceptable farm profits with high and sustained production levels while concurrently conserving the environment (Steiner & Bwalya, 2003). Adoption of CA by farmers in several African countries has shown potential to improve rural livelihoods through sustainable and intensified production (Silici *et al*., 2011). Conservation agriculture is being promoted in response to low agricultural productivity, chronic household food insecurity and environmental degradation linked to conventional tillage and nutrient mining. This innovation constitutes a package of agronomic practices characterised by three principles that are linked to one another namely: a) reduced or eliminated mechanical soil disturbance, b) better use of production inputs and therefore greater cover with crop residues; and c) diversification of crop species grown in sequences and /or associations (FAO, 2008).

Worldwide experience of CA over the past four decades has demonstrated how the simultaneous application of a set of practices of minimal mechanical soil disturbance, organic soil cover and diversified cropping can lead to greater and stable yields (Kassim & Friedrich, 2010). Land preparation and cropping methods in CA also enable efficient use of rainwater which considerably reduces the risk of crop failure due to drought and make the soil a better environment for the development and functioning of plant roots (Reicosky, 2008). Twomlow *et al*., 2006; Nyagumbo, 1999, Fowler & Rockstrom, 2001, explained the advantages of CA compared with traditional cultivation practices as being its ability to diversify production, increase social capital through farmer groups and decrease dependence on food aid.

When practised correctly, CA stabilises crop yields, thereby increasing household food security and economic and social wellbeing (Solís *et al*., 2009). Grain yield of maize, teff and wheat have been reported to double under CA-based practises compared to conventional farming in Ethiopia, Ghana, Tanzania and Malawi (Ito *et al.*,2007), Kenya (Rockstrom *et al.*,2009) and Mozambique (Nkala *et al.*,2011; Grabowski, 2011). Haggblade and Tembo (2003) reported that early CA adopters increased crop productivity by 30 to 70% in Zambia. These findings were also observed by Mashingaidze and Mudhara (2006), who reported that crop yields for maize increased by up to 3.5 tons per hectare in Zimbabwe for farmers practising CA. Hassane *et al.* (2000) evaluated the impact of planting basin, and use of fertiliser and manure on millet crops in Niger and found that over a five year period, farmers experienced yield gains of up to 511%. Yield differences ranged between 20 to 120% higher for CA-managed fields compared with conventionally managed fields in Latin America, Asia and Africa (Pretty *et al*., 2006; Landers, 2007; Erenstein *et al*., 2012; FAO, 2008; Hengxin *et al*., 2008; Rockstrom *et al*., 2009). The ability of CA technology to yield higher productivity than existing practices was the main reason why farmers decided to adopt the new innovative technology (Twomlow *et al*., 2008; Muchinapaya, 2012). While there is evidence of CA gains in the literature, there are also studies that present a sharply contrasting assessment of the impact of CA. Giller *et al*. (2009) suggests that empirical evidence is not clear and consistent on CA contributions to yield gains. Their study notes concerns that include decreasing yield in CA. This chapter addresses methodological problems in other studies to provide more definitive measurements of yield impact of CA as practised by Zimbabwe´s smallholders.

4.1.1 Background

The type of CA under study is called the planting basin method, which was initiated in Zimbabwe by Brian Odrieve in the 1990s (Muchinapaya, 2012). This method involves planting crops directly into the land which is protected by mulch using minimum or no-tillage techniques and this is aimed at conserving soil and water. Crop rotation is an essential component which calls for farmers to alternate legumes with their maize crops in order to improve soil fertility, but they are often averse to giving up field space where they normally grow their major crops. Mazvimavi *et al.* (2008) and Marongwe *et al.* (2011), reported that basin CA was introduced in Zimbabwe on a large scale in the 2003/04 season. This was implemented primarily through programmes aimed at improving the livelihood and food security status of smallholder farmers in Zimbabwe. A comprehensive package of CA has been promoted by NGOs and national agricultural research and extension departments throughout Zimbabwe. It consists of several key practices, namely dry-season land preparation using minimum tillage systems (for example basin planting), crop residue retention, nitrogen fixing crop rotations and precise fertiliser application. CA has been promoted by different partners and involved in the supply of input packages (fertiliser and seed) to farmers who were willing to set up CA demonstration plots. Yield gains from demonstration trials were attributable to multiple factors such as, timely planting of CA fields, availability and precision placement of fertilisers and better moisture conservation (Nyagumbo *et al*., 2009; Marongwe *et al*., 2011).

Yield benefits from CA-managed trials encouraged diffusion of CA to other farmers. However, farmers tended to practise CA on relatively smaller portions of their land holdings because of the extra labour required for weeding, and the challenge of retaining crop residues on fields because of communal grazing pressure (ICRISAT, 2009). The Food and Agriculture Organisation estimated that area under CA in Zimbabwe was 139 300 ha, constituting about 9% of area under cereals in 2012 (FAO, 2012). Empirical studies that have been carried out to assess the impact of CA in Zimbabwe use various methods and analytical approaches, ranging from on-station and on-farm agronomic experiments to broader household surveys (Nyagumbo, 1999; Siziba, 2008; Mupangwa, 2009, Musara *et al*., 2012; Nyamangara *et al*., 2013; Ndlovu *et al*., 2013). Most of the impact studies tend to attribute all yield and welfare differences to CA. However, this can be faulty in the absence of robust quantitative approaches capable of isolating effects of other exogenous factors. Ascribing causality of change in yield to CA without first establishing a counterfactual situation could be oversimplification of a complex process. This poses a serious challenge especially when a study makes use of cross-sectional data and does not have a longitudinal (time) dimension. In such analyses the measured impact of CA on yield can be biased by unmeasured or unobservable variation in household conditions. Studies that use longitudinal data focus on agronomic impacts such as yield and soil properties, but generally fail to control for household-level covariates that may have important interactions in the production process. This evaluation however, takes advantage of the longitudinal nature of the data set to control for unobservable household-level factors.

By observing the same farmers in successive seasons of CA practice in a non-experimental setting, it is possible to compare CA with alternative conventional farming practices within the same households (*i.e* households practising both technologies). The primary interest is on the impact of CA on maize production, since it is a staple crop grown by more than 80% of the sample farmers. The purpose of the study is to estimate the yield impact of applying CA practices. This is achieved by using a unique data set that captures, at the plot level, maize production under CA and alternative conventional farming practices across different agro-ecological regions.

The main hypothesis of the study is that applying CA has a positive and significant impact on yield across agro-ecologies. By testing this hypothesis, the study seeks to justify the use of CA by smallholder farmers. Econometric approaches that capture OLS and household fixed effects were employed in order to determine the impact of CA adoption on maize yield.

4.2 Analytical framework

The yield impact of practicing CA is measured through Cobb-Douglas production function estimation. Cobb-Douglas production function, estimates the quantitative effect of two or more inputs on output (maize yield in this case). The estimation uses various specifications in both ordinary least squares (OLS) and household fixed effects frameworks.

The estimated maize yield equation is:

$$\ln Y_{pt} = a + b\ \mathrm{In}X_{pt} + cZt + dCA_{pt} + eT + \varepsilon, \qquad (1)$$

Where Y_{pt} is yield of maize on plot p, in year t. X_{pt} represents the production inputs such as seed fertiliser on plot p, in year t. The amount of seed, basal fertiliser and top dressing fertiliser are the logs of the positive mounts of these inputs applied to the plot in question. The natural log of the yield of maize is regressed as a function of the natural logs of positive quantities of inputs such as seed, area, basal and top- dressing fertiliser. Total cropped area is log of the sum of all plots which have been cultivated by a household measured in square meters (m^2). Z represents various household, plot, and regional factors affecting yield. T is the year indicator representing the year and also round of the survey and ε is the error term which is normally distributed.

CA is an indicator variable for a plot (or household) on which CA is practised in a particular round of the survey. For a plot to be coded as 1, the farmer identified the plot to be a CA plot. CA plot are thus defined in terms of the land preparation in which case it will be digging basins. Digging planting basins is what distinguishes CA plots from non-CA plots. In terms of the practices reported by the farmer, these vary in accordance with the intensity of adoption. Due to a number of farmer specific constraints, the range of practices is from one to eight however, digging of basins is a requirement for a plot to be coded as 1.The dummy variable for CA =1 means that at least one part of the CAzim package (basin land preparation) has been applied to a plot. When the land preparation does not involve digging of planting basins then the plot is coded as 0.

Five model specifications of the yield function were estimated using OLS with indicator variables for round and natural region (NR)

Specification A

Xpt in equation 1 refers to seed only. Specification A is the general function whereby yield is expressed as a function of seed and CA technology is used as a dummy. This specification captures the impact of basic CA. Basic CA is merely digging basins however, it may or not include all the three principles of CA on some of the plots. Many farmers who use this CA method will use other technologies and practices as well. As these practices and technologies like top dressing fertiliser, basal fertiliser, manure and multiple weeding are not included in the regression, some of their effect will be reflected in the CA coefficient. Thus this specification gives an estimate of the upper end of the CA impact.

Specification B

Xpt in equation 1 refers to seed, fertiliser (both basal and top dressing), manure and weeding (Lower end of CA effects). The full CA package includes basic CA i.e the three principle of

CA plus additional components which are included in the CA package promoted in Zimbabwe. The yield function is similar to that specified in Specification A but the difference is in that, weed frequency and fertility management are included in the specification. Though CA is used as an indicator variable, practices that enhance the effect of CA such as manure application and weeding frequency, are also specified. Specifically including these practices will reduce the estimated coefficient on CA in Specification B compared to Specification A, because any positive effects of fertilizer, manure and weeding will be captured separately, rather than being pooled with the CA indicator. Specification B gives a yield function with positive quantities of inputs such as seed, basal and top-dressing fertilisers, weeding frequency gives the lower end in terms of CA impact on yield. The impact of CAzim would be the sum of the effects captured in the coefficients on CA, weeding, and fertilizers.

Specification C

Specification C is similar to Specification B but for the CA technology variable: a detailed variable that captures the depth of the technology use (number of techniques applied) is used instead of an indicator variable. CA_{pt} in equation 1 refers to the number of CA techniques applied to a plot in a particular year. The CA variable is not captured as an indicator variable (0; 1) but represented by a count (1;8) since they are 8 distinctive techniques defining CAzim. Zero implies that the plot is non-CA 8 means all techniques were applied.

Specification D

Specification D attempts to capture the impact of labour by excluding weeding frequency in the specification. The impact of labour on yield is captured by disaggregating the household size into various age groups. The yield function includes the dummy variables for use of top-dressing and basal fertiliser, as well as year dummies to capture shift in weather and policy.

Zpt in equation 1 refers to the disaggregated household size into various age groups and exclude weeding frequency

Xpt in equation 1 captures quantity of inputs used except for basal and top dressing fertiliser where an indicator variable is used instead.

Lag variable of CA is defined as dCAp (t-1) and captures the history of CA application in a given plot. The lag of CA is an indicator variable implying CA was applied to the plot in the previous season. The greater the number of years CA was practiced in the plot the more the benefits, if the lag is t-1 it means CA was implemented on the plot the previous year whereas t-2 implies CA was implemented on the plots two seasons prior to the current.

Specification E

$LnY_{pt}= a +b LnX_{pt} + cZt + dCA_{pt} + eT+ + f2009CAp+ gFemaleCAp + hDryCAp + iTopdressngCAp + \varepsilon$ (2)

Specification E includes the addition of interactions to the basic model given in equation 1. This estimates maize yield in the presence of the interaction between year 2009 and CA the interaction of CA with the female headed households. There is particular reference to the year 2009 because it marked a period of major policy shift which marked the end of the era of hyperinflation and the beginning of positive economic growth in Zimbabwe.

f2009CAp in (2) refer to the interaction of CA technology and year 2009 which capture shift in weather and policy over the years

gFemaleCAp in (2) refers to the interaction of CA technology and female headed households

hDryCAp in (2) is the interaction of CA technology and dry agro ecological regions (NR IV and V)

iTopdressngCAp in (2) is the interaction term of CA technology and topdressing fertiliser dummy

The household fixed effects model controls for observable and unobservable household characteristics which do not change with time. For the purposes of this study, the fixed effects model is operationalized by including a dummy variable for each household in the panel. This procedure effectively accounts for the effects of all time-invariant household factors that might affect the yield. If some unmeasured or unobservable factor, such as farmer initiative, affects both the yield and the practice of CA, there could be a bias in the ordinary least squares (OLS) results. This bias will not emerge in the fixed effects model. While the fixed effects model can be expected to yield more defensible estimates of the yield impact of CA, the approach blends all time invariant factors into a categorical variable for the household. As a result one cannot measure the effect of household level variables of interest that do not vary with time, such as gender. Some variables included in the OLS regression, like age, household size, and farming and CA experience and education level cannot be included in the household fixed effects analysis. However, this model implicitly corrects for many household factors that could not be included in the OLS regression but which might be introducing bias into the results.

Three specifications of the maize yield are specified under the household fixed effects model. The estimation results will be used to validate the yield impact measured through OLS. Specification F is a basic maize yield function similar to specification B, and it also specifies if seed and fertiliser was provided NGOs. Specification G, used the basic maize yield function which is similar Specification D where the CA variable is measured in term of the number of techniques applied to the plot and not as an indicator variable. Specification H is similar to specification E given in the OLS, it gives a basic yield function which includes interaction terms for CA.

4.2.1 Data

This chapter specifically makes use of plot level data from four rounds of the survey (2008-2011) to determine the maize yield impact of CA compared to conventional farming. The analyses considers only plots dedicated to maize production, which is the most popular crop in Zimbabwe and in the sample. Useful data are available for 800 maize plots over four rounds of the survey for a total 3200 observations. Harvest data in terms of crop output was determined for each plot from farmer interviews using the most common unit of measure used in the particular area. Maize yields were then computed based on the quantity of output realised from a particular plot as well the plot sizes. Enumerators collecting the data we trained to estimate plot sizes using visual assessment or inferring from the amount of seed used during planting.

4.2.2 Description of yield function variables

Tables 4.5 gives a description and summary statistics of the variables used to estimate the yield regressions. Total cropped area is log of the sum of all plots which have been cultivated by a household measured in square meters (m^2). The amount of seed, basal fertiliser and top dressing fertiliser are the logs of the positive amounts of these inputs applied to the plot in question. Indicator variables on whether or not manure, basal and top dressing fertiliser were included in some specifications through a yes or no dummy variable. The lag of CA is an indicator variable implying CA was applied to the plot in the previous season. Ecological zones in Zimbabwe are classified as NR I through V. The most humid NR is I while Natural Regions IV and V are semi-arid to arid. The rest of the variables are measured as explained in Table 4.5, including the expected signs on the explanatory variables of the yield function.

Table 4.1: Definition of variables and summary statistics

Variable	Description	Expected sign	Obs. (n)	Mean	Std. Dev.	Min	Max
Yield	Log of yield from a maize plot (kg/ha)	Dependent variable	3180	5.95	2.30	0	8.78
CA	Used CA technology on maize plot (1=yes; 0 otherwise)	+	3516	0.38	0.49	0	1
Numtech	Number of CA techniques applied to the pot	+	3143	5.46	1.63	0	8
Seed	Log of seed planted to a maize plot (kg)	+	3507	1.90	0.70	0	4.33
Basal fertiliser	Log of basal fertiliser applied to a maize plot (kg)	+	3383	1.10	1.53	0	5.02
Top dressing	Log of top dressing fertiliser applied to a maize plot(kg)	+	3422	1.71	1.56	0	5.30
D basal	Applied basal to plot (1=yes;0 otherwise	+	3267	0.624	0.485	0	1
D top	Applied top to plot (1=yes;0 otherwise	+	3230	0.387	0.487	0	1
NGO seed	Log of seed planted to a maize plot that came from NGOs	+	3335	0.306	0.466	0	1
NGO basal	Log of basal fertiliser applied to a maize plot that came from NGOs (kg)	+	3335	0.18	0.484	0	1
NGO top	Log of top dressing fertiliser applied to a maize plot that came from NGOs(kg)	+	3335	0.318	0.487	0	1
Total cropped area	Log of total cropped area (m2)	-	3516	7.66	1.04	3.04	10.82
Manure	Applied manure to the plot (1=yes; 0 otherwise	+	3192	0.34	0.47	0	1
Weeding	Number of weeding on the plot for the season	+	3298	2.26	0.62	0	6
Pdate	Planting date in days (increases daily from the onset of effective rains > 2.5 mm)	+	3516	18.73	2.82	1	31
Pdate2	Square of planting date	-	3516	358.59	110.31	1	961
Total livestock units	Tropical livestock unit (Relative value of all livestock)	+	3516	3.24	4.09	0	40.20
Age	Age of household head (years)	-	3516	53.06	13.97	4	99
Education	Years of schooling of household head (years)	+	3516	6.94	3.81	0	14
Female head	Household head is male (1=yes; 0 otherwise)	+	3516	0.51	0.50	0	1
Farming experience	Years since household started farming (years)	+	3508	28.20	13.84	1	90
CA experience	Years of using CA since first training (years)	+	3516	5.88	1.81	1	25
Lead farmer	Household head selected as lead farmer (1= yes; 0 otherwise)	+	3311	0.27	0.44	0	1
Household size	Number of persons in the household	+	3516	6.38	2.79	1	24
No. of children	Children(< 5 years)	-	3516	1.08	1.21	0	9
No. of youths	Youth members (5- 18 years)	+	3326	2.305	1.696	0	13
No. of adult	Adult members of households (19-64years)	+	3516	2.38	1.41	1	12

No. of Elderly	Elderly members of household (>65years)	+	3326	0.609	0.776	0	5
NR III	Plot in Natural region III (1=yes;0 otherwise	-	3516	0.29	0.46	0	1
NR IV	Plot in Natural region IV (1=yes;0 otherwise	-	3516	0.33	0.47	0	1
NR V	Plot in Natural region V (1=yes;0 otherwise	-	3516	0.22	0.42	0	1
2009	2009 round of survey 1= yes;0 otherwise	+/-	3516	0.24	0.42	0	1
2010	2010 round of survey 1= yes;0 otherwise	+/-	3516	0.28	0.45	0	1
2011	2011 round of survey 1= yes;0 otherwise	+/-	3516	0.26	0.44	0	1

Source: Author Data Analysis, 2014

For the production inputs, the quantities applied to a particular plot where calculated based of farmer recall. The amount of manure applied could not be measured accurately due to variations in the units of measure, an indicator variable is generated to show whether or not manure was applied to a particular plot. There were challenges with collecting the rainfall data throughout the season and as a result this important variable was not captured. Based on the eight CA techniques which the farmers were taught, they had to give a detailed account of the techniques which were applied to the CA plots. Tropical livestock units (TLU) captures the value of all livestock (on four legs only) owned by a household and the computation of this index is explained in Chapter 3. TLU provides a convenient method for quantifying a wide range of different livestock types and sizes in a standardized manner. All the socioeconomic variables were derived from the questionnaire.

4.2.3 Expected impact of explanatory variables on yield

All production inputs such as seed, fertiliser (both top dressing and basal), manure and the number of times weeding was carried out (are expected to) have a positive influence on yield (Foster & Rosenzweig, 2010). The amount of land is expected to have a negative influence on yield because yield based on well-documented inverse relationship between and farm area in developing countries (Feder *et al.*, 1985). Household size which is a proxy for labour is expected to have a positive effect because it is an input to the production function (Ndlovu *et al.*, 2013). However a breakdown of the household according to its composition will show that, it is the number of adults which contribute to labour and hence have a positive effect of yield.

CA technology is expected to have a positive influence on yield, and this is supported by Nyamangara *et al.*, 2003 and Haggablade & Tembo 2003. The number of CA techniques used disaggregates the technology into its various components and the greater the number of techniques, the greater the yield impact. The number of CA techniques used disaggregates the technology into its various components and the greater the number of techniques, the greater the impact on yield. The lag variable of CA is expected to have a positive influence because the effects of CA are cumulative. Farmers who are selected to be lead farmers, lead other farmers in their neighbourhood on implementation of CA though visits, field demonstrations and training. Being a lead farmer is expected to have a positive influence on yield (Mazvimai *et al*., 2008). The variables NGO seed, basal and top where measured by adding the quantities of each input used from NGO sources. The contribution of NGO inputs to the production of maize is important in highlighting how NGO support has affected productivity especially in situations where the inputs can only be sourced though NGOs due to absence of input market.

According to Chiputwa *et al*., 2013, the level of education of household head is expected to have a positive effect on yield, and the same applies to farming experience. However age is expected to have a negative influence of yield since older farmers do not have as much energy as the young. This has been disputed by Ekbom *et al*., 2012 who found that older farmers with better accumulated experience are more efficient than young farmers. Male headed households have more access to land and other productive resources and this will have a positive influence on yield. The number of livestock owned is a proxy of wealth, which is expected to positively influence yield by providing liquidity for better management (Shumet, 2012). However, it is hypothesised that high TLU index indicates more competition for crop residue between CA and livestock feed.

Agro-ecology has a strong influence of yield because it captures the natural environment, the soils and locational factors. The drier regions of NRV, IV and III are expected to have a negative influence on yield, relative to the wetter region of NR II. The semi-arid regions have more production constraints and this negatively impacts on yield. The time dummies which capture changes in policy or season rainfall have variable influence on yield depending on the prevailing conditions.

4.3 Results and discussion

4.3.1 Comparative analysis: Area cultivated

Table 4.2 presents the total cropped area and the area dedicated to maize production for both CA and conventional farming across the four agro-ecological regions and over time. Total cropped area per household increases from high potential regions to the semi-arid regions of NR IV and V. Farmers in NR IV and V have bigger fields, which is indicative of the extensive nature of crop production in these dry areas. The total cropped area of NR V areas is almost double (2.04 ha) that of areas in NR II (1.24 ha). During the whole period of the survey, the proportion of cropping area allocated to CA was lowest (15.4%) in NR V and highest in NR II (41.3%).

The sample farmers were those who had practised minimum tillage (such as digging basins) for at least two years (2005 and 2006). Consequently it was to be expected that the highest use rates of CA occurred during in the initial years of the survey. The proportion of land allocated to CA was highest in 2008 (32%) and declined to 18% in 2011. Exposure to the technique is expected to result in both repeated use and improved application if it is seen as useful to farmers or dis- adoption if the practices are not attractive, given the specific conditions of a farmer who experimented with CA.

Table 4.2: Comparison of Total cropped area and area under CA

Agro-ecology/ Year	Observations (plots) N	Total cropped area (ha) per household	% cultivated area under CA per household
NR II	529	1.241	41.3
NR III	1034	1.565	28.16
NR IV	1167	2.023	20.93
NR V	786	2.036	15.38
2008	765	2.011	32.11
2009	828	1.701	31.23
2010	998	1.823	17.90
2011	925	1.574	18.57
ALL	**3516**	**1.778**	**24.86**

Source: Author Data Analysis, 2014

On average plots under conventional farming are significantly larger (0.4 ha) compared with CA plots (0.24 ha) for all the years and across agro-ecological regions (Table 4.3). The largest CA plots were recorded in the high rainfall areas of NR II while the smallest CA plots are located in the arid areas of NR V. Mazvimavi and Twomlow (2009) found that CA is generally implemented on smaller tracts of land and suggested that labour and mineral fertiliser constraints limited the CA plots´ sizes.

Table 4.3: Comparison of plots sizes under maize crop

Agro-ecology/ Year	Area under maize crop		t-value
	CA area (ha)	Non CA area (ha)	
NR II	0.283	0.327	1.84*
NR III	0.221	0.361	6.92***
NR IV	0.239	0.470	8.65***
NR V	0.202	0.393	7.41***
2008	0.260	0.585	9.99***
2009	0.240	0.407	5.81***
2010	0.209	0.351	7.03***
2011	0.234	0.328	5.36***
ALL	0.236	0.401	13.24***

*Significance at the 10%, 5 %, and 1% levels are indicated by *, ** and *** respectively. Source: Author Data Analysis, 2014*

4.3.2 Comparative analysis: Maize yield

Table 4.4 shows that average maize yields under CA are consistently higher than yields from conventional plots. With or without CA, yields are much higher in high potential natural regions than in drier zones, but the percentage difference in yield with and without CA is similar across natural regions, with average yield under CA about double those in non-CA plots. It appears that there are limiting factors that CA does not address in the semi- arid areas. High yields were realized in 2009 and 2011 which were generally good seasons in terms of rainfall (Table 4.4). In 2008 and 2010, the yields were low due to poor season quality and farmers practicing CA had a yield advantage because CA has the ability to conserve moisture when compared to conventional farming.

Table 4.4: Comparison of mean maize yield from CA and Non CA plots across agro ecological zones

Year	Agro-ecology	CA plots		Non CA plots		Differences in yield
		Mean Yield (kg/ha)	Co-efficient of variation (%)	Mean Yield (kg/ha)	Co-efficient of variation (%)	Difference in mean yield for CA and Non CA (%)
2008	NR II	2401.70	92.9	888.17	138.7	63.0***
	NR III	2603.20	98.6	579.50	162.0	77.7***
	NR IV	1192.39	104.2	598.37	198.5	49.8***
	NR V	988.03	142.3	239.61	147.3	75.7***
2009	NR II	1944.6	82.6	1537.48	104.7	20.9
	NR III	2484.35	76.6	1146.85	100.3	53.8***
	NR IV	1791.71	92.3	1063.00	140.1	40.7***
	NR V	1780.31	103.3	1053.47	103.3	40.8***

2010	NR II	2196.21	61.6	1577.78	104.7	28.2**
	NR III	2017.26	116.9	936.67	157.5	53.6***
	NR IV	2239.09	101.5	1098.53	143.6	50.9***
	NR V	1706.01	195.7	851.57	195.6	50.1***
2011	NR II	2321.48	64.9	1445.58	61.7	37.7***
	NR III	1850.80	103.8	960.07	103.8	48.1***
	NR IV	1905.94	79.2	1023.02	113.1	46.3***
	NR V	1210.43	131.5	581.74	131.5	51.9***
2008-2011 (Pooled)	NR II	2183.61	76.4	1382.03	95.5	36.7***
	NR III	2355.17	93.4	949.22	126.8	59.7***
	NR IV	1783.05	96.4	984.62	140.5	44.8***
	NR V	1437.31	163.7	703.89	163.7	51.0***

*Significance at the 10%, 5 %, and 1% levels are indicated by *, ** and *** respectively.*
Source: Author Data Analysis, 2014

There is greater variation in maize yield under conventional plots compared with the CA plots and this situation is peculiar to Zimbabwe. Studies in Zambia tend to point to the fact that CA has greater yield impact in the drier areas compared to the wetter areas (Ngoma *et al*, 2015). It is however acknowledged by (Gatere *et al*., 2014) that CA failed to increase yield because of insufficient weeding and late planting. Study findings show greater variation for maize yield under conventional plots compared with the CA plots. The result tends to imply that CA technology has the ability to increase and stabilise maize yield. Greater variation of maize yield is realized in the drier regions of NR IV and NR V compared to the high potential regions of NR II and NR III. In addition yield of CA decreased most likely because of water logging in the high rainfall (>1000 mm) areas of Zambia (Gatere *et al*., 2014). However, the average yield reported in Table 4.4 may mask the effect of other factors other than CA practices which cause plots farmed with CA to have higher than average yields. Multivariate regression analysis is needed to help identify effect of CA on these yield outcomes.

4.3.3 Comparative analysis: Planting dates

Table 4.5 shows that CA plots are consistently planted earlier than conventional plots, regardless of agro-ecology and season. One of the most acclaimed benefits of CA is the fact that it allows farmers to plant soon after the first rains, even if they do not have draft power. Early planting is possible for CA farmers because basin preparation is done well before the rains start. Early planting enables farmers to take advantage of nitrogen flushes in the early days of the season (Mazvimavi, 2011). Thus, crops planted early tend to have a yield advantage compared to crops planted late. Planting dates vary on a year-to-year basis depending of the seasonal rainfall pattern. However, CA plots were planted about one week earlier than conventional plots in each year of the survey.

Table 4. 5: Comparison of planting dates for maize across the agro ecological zones and seasons

Season	**Planting date (weeks after 1 October of any season)**							
	Agro ecology							
	NR II		**NR III**		**NR IV**		**NR V**	
	CA	Non CA	CA	Non CA	CA	Non CA	CA	Non CA
2008	17.53	18.97	16.86	18.24	18.07	19.06	17.81	18.00
2009	18.52	19.84	19.12	19.69	18.17	19.85	19.06	19.65
2010	17.73	19.26	18.31	18.99	17.85	19.32	18.01	19.67
2011	17.33	19.32	18.54	19.42	18.63	18.63	17.48	19.39
Pooled	17.84	19.33	18.28	19.16	18.18	19.17	18.23	19.26

Source: Author Data Analysis, 2014

4.3.5 Ordinary least squares (OLS) Results

Estimation results show that the use of CA technology has a positive and statistically significant impact on yield (Table 4.6). Across the four specifications that treat CA as a dichotomous variable, the practice of CA appears to raise maize yield by 48% up to 179%. The highest estimated impact emerges in Specification E which has interaction terms of CA with female headed households, dry agro-ecologies, year 2009 as well as top dressing fertiliser. Specification A has an equally high CA impact on yield as it tries to capture the full impact of basic CA. Basic CA comprises of only the three principles of CA at the exclusion of additional practices which are normally included in the CA package promoted in Zimbabwe. The additional practices include manure application, targeted application of basal and top dressing fertilisers and these were excluded from the yield function. To enhance the measured impact of CA on yield (increasing the CA coefficient), planting date has been removed from specification A, B and E because early planting is one of the benefits of CA.

The CA package promoted in Zimbabwe includes some practices which are specified in the yield regression of Specification B. The CA package which is referred to as full CA consist of additional practices not normally included in the CA definition and these include use of soil fertility amendments (manure, basal and top dressing fertilisers) and weed management (weeding frequency). Coefficients on those practices can be considered as additional positive effects for users of CA or full effects of the practice for farmers who apply it outside of the context of CA. Each of the practices was added to yield function in Specification A one at the time. The change in yield impact in Specification B from 47.5% to 105.4% in Specification A is as a result of other practices which constitute CA. The change comprise of 26.3 % due to use of top dressing fertiliser + 6 % basal fertiliser + 36% manure use + 31 % weed management (Table 4.6). Application of basic CA only with nothing else added enhances yield by 47.5%. When fertilisers use is captured as dummy variable the impact on yield is estimated at 34.7 and 98.2% for basal and top dressing respectively. However, when basal fertiliser is measured in natural logs of kg of basal fertiliser there is only a 6.1% increase in yield is significant at 99% level of confidence.

In specification C where CA is captured as the number of techniques applied, the impact is 11.6 % implying that increasing the number of techniques by one, would result in a yield increase of about 12%. The impact of fertiliser is moderated when the variable for actual quantities of fertiliser used is used in the specifications compared to using an indicator variable. Basal fertiliser is only significant at 5% and 10% level when the variable for actual quantities are used is used. The basal effect is not as strong as the top dressing effect because there is a substitute for basal fertiliser in form of manure. For all the model specifications, manure use has a positive and significant impact on yield of between 15.5 to 37.5%. Similarly the amount of maize seed used on a plot has a positive and significant effect on yield (16-28%) whereas the effect of the total cropped area is significantly negative (34-50.5%) across all the model specifications.

Agronomic experiments reported in literature indicates that nitrogen fertiliser has a larger influence on rain-fed maize yield under CA (Rusinamhodzi *et al.*, 2011; Nyamangara *et al.*, 2013). It has been argued by Huggins and Reganold (2008) that CA demands extra nitrogen fertiliser to meet the nutritional requirements of maize crops because increasing organic matter at the surface immobilises nutrients. Top dressing fertiliser which provided the bulk of the nitrogen to plants, has a positive and significant effect on yield (23-27%). Rusinamhodzi *et al.*, 2011 reported that maize yields were increased more by N mineralisation than tillage in the semi- arid regions.

Weeding frequency has a positive and significant effect of yield and this has been supported by (Akter *et al*., 2013, Idris *et al*, 2012, Naim & Ahmed, 2010). Increasing the number of weeding by one unit will result in a yield increase of 30-38% across all model specifications. However, CA plots have more weed pressure as evidenced by (Mashingaidze, 2013) and it is a requirement that the plots are weeded more than the conventionally tilled plots. Weeding tends to take up most of the household labour supply. Under CA the weeding frequency increases and this has implications on labour demand (Mazvimavi & Twomlow, 2009, Ngwira *et al*., 2012). Thus including weeding frequency reduces the measured (residual) impact of CA in the specification.

The effect of labour on maize yield is captured in Specification D whereby weeding frequency is excluded as an explanatory variable.The number of household members gives a proxy for labour availability, since most smallholder farmers rely on family labour and there are few opportunities for hiring labour. In all specifications, family labour that is captured as household size does not seem to have an impact on yield, but in the absence of weeding and using disaggregated household composition, labour has an impact on yield. The analyses point to the fact that the number of children (under five years old) has a negative impact on yield because children require divert labour away from the field to child care and other domestic chores. Youths (those between 5 and18 years) have no effect on yield, implying that this age group may not be contributing to weeding labour. This could be explained by the fact that, most family members in this age group spend most on of their time at school rather than on farming activities. Most of the weeding labour is supplied by mainly the elderly (37.5%) and to some extent adults members the family. The positive coefficient on the number of adults and the elderly, coupled with the negative coefficient on the number of children, suggests that labour constraints may affect yields negatively. The lag variable of CA is expected to have a positive influence because the effects of CA are cumulative. However, the insignificance of lag variable for CA in Specification D implies that time of CA practice is not long enough to accumulate meaningful improvements in soil quality.

A planting date that is either too early or too late can affect yields adversely because it is dependent on the onset of rainfall. To account for this, the planting date (days after the onset of the first effective rain (2.5mm) for the season) is entered in a quadratic form in the estimation. When planting date is in the regression, the CA coefficient does not include the planting date effect on yield thus planting date has been removed in some specifications to enhance the CA coefficient. TLU has a positive and significant impact on maize yield because the presence of livestock increases access to manure, which is used to enhance soil fertility and also boost yields. Livestock ownership can be used as a wealth indicator: this can be converted into cash to acquire purchased inputs such as fertiliser. The impact of the TLU index is small, a unit increase in TLU index when other things are held constant will increase maize yield by only 4.8% up to 5.8%.

Table 4.6: Maize Yield regressions: OLS for different model specifications

Variable	Specification A	Specification B	Specification C	Specification D	Specification E
Observations (n)	2969	2749	2419	1777	2749
Adjusted R^2	0.205	0.250	0.273	0.264	0.265
CA	1.056***	0.474***		0.551***	1.786***
Numtech			0.124***		
Total cropped area	-0.491***	-0.492***	-0.560***	-0.419***	-0.474***
LCA				-0.039	
Seed	0.308***	0.193**	0.196*	0.288**	0.303**
Basal fertiliser		0.067**	0.061*		
Top dressing fertiliser		0.264***	0.224***		
Pdate2			0.018***	0.018***	
Pdate			-0.624***	-0.600***	
Basal dummy				0.359***	0.397***
Top dressing dummy				0.882***	1.060***
Manure		0.372***	0.344***	0.159	0.242**
Weeding frequency		0.310***	0.369***		0.355***
Total livestock units	0.058***	.048***	0.050***	0.042***	0.049***
Education	-0.0002	-0.005	-0.021	0.036*	-0.006
Age	-0.021***	-.019***	-0.022***	-0.039***	-0.018***
Farming experience	0.014***	0.014***	0.010**	0.022***	0.014***
CA experience	0.061*	0.053**	0.045	0.068**	0.063**
Lead farmer	0.363***	0.276***	0.115	0.198*	0.230***
Female head	0.248***	0.269**	0.234**	0.358***	0.456***
Household size	0.0002	0.005	0.011		0.010
No. of child				-0.132**.	
No. of youth				0.033	
No. of adult				0.071**	
No. of elderly				0.386***	
NR III	-0.886***	-0.658***	0.526***	-0.821***	-0.649***
NR IV	-0.994***	-0.690***	0.605***	-0.724***	-0.612***
NR V	-1.700***	-1.239***	-0.910***	-1.335***	-1.152***
2009	1.078***	0.994***	1.209***	1.602***	1.342***
2010	-0.043	0.027	0.433***	-0.478	-0.020
2011	0.417***	0.143*	0.387**	0.665	0.194
CA*female					-0.503***
CA*dry					-0.195
CA*2009					-0.478***
CA*topdressing					-0.693***
Constant	9.458***	8.169***	3.194***	3.332***	8.225***

*Significance at the 10%, 5 %, and 1% levels are indicated by *, ** and *** respectively. Source: Author Data Analysis, 2014*

The effect of farming experience is consistently positive and significant across all model specifications which is a result of learning by doing. CA experience has a moderated effect on yield across the different specification. This result points to a stronger learning by doing effect and build-up of the benefits of CA which have a positive impact on yield. Age has a negative influence on yield. Being a lead farmer is associated with more knowledge on CA as well as access to farming inputs targeted for the CA plot. Lead farmer status thus has a positive and significant effect on maize yield. Education level seems to have no effect on yield because the sample farmers have achieved some primary education and they all received similar extension messages and CA training.

Specification E uses various interaction terms to capture the yield impact of CA. The time dummies have a positive influence on yield relative to 2008, the base year. In 2009 there was a major policy shift in the Zimbabwean economy in terms of dollarisation and the revamping of markets, especially the agricultural inputs market. In 2009, the economy of the country experienced positive growth in GDP after a decade of negative growth and hyperinflation and this particular year has a positive influence on yield. 2010 was not a very good year in terms of season quality and the impact on yield though positive was not significant. 2011 had a positive and significant impact on yield because it was a good year in terms of weather.

Agro-ecological zones tend to have a big influence on yield because they captures the production potential through the natural environment. The impact on yield is significant and negative as one moves from the NRII, which is a high-potential area to NR IV and V. In the semi-arid regions the impact on maize yield is negative because of the presence of more production constraints. The semi-arid areas cited in this study, get less than 450mm of rainfall per annum which cannot support maize production. This indicates that maize is not suitable and resilient enough in the conditions of the semi-arid areas though this has been disputed by Rurinda *et al*., 2014 who alluded to the superiority of maize over finger millet and sorghum. Using an interaction term of CA and dry NRs, shows that maize yields under CA are lower in the dry agro-ecological regions compared to the wetter regions. The incremental effect of maize yield on CA plots is lower though the impact is not significant. There are less benefit realised from using CA in the dry areas compared to the high rainfall areas even though the net incremental effect on yield is above 100%.This is in sharp contrasts with findings from Zambia whereby positive yield effects are experienced in the lower rainfall agro-ecological zones (Haggablade & Tembo, 2003, Gatere *et al*., 2014). Rockstrom *et al*., support the finding that CA can perform well even under low rainfall conditions, however, erratic rainfall confounds its virtues and the performance of CA is largely hamstrung by adverse agro-ecological conditions.

Plots which are managed by female headed households have a positive and significant impact on yield. The incremental effect on yield ranges from 23% to 46 % depending on the model specification. However, the interaction of female headed households and CA is significant and negative implying that the incremental effect of yield on CA plots which are managed by women is reduced compared to the effect on the plots managed by their male counterparts. The base effect of CA impact is 1.786 and the impact of CA and female headed household's interaction is -0.693. Therefore the net effect on yield of having CA plots managed by women is reduced to 93%.

4.3.6 Household fixed effects model results

The impact of CA is positive and significant across the three model specifications (Table 4.7) of the household fixed effects. The OLS results are confirmed by the household fixed effects model thus confirming their credibility. Similarly cropped area, weeding frequency and seed have a positive and significant impact on yield. Planting dates have been removed from Specification G to improve the CA coefficient.

Basal fertiliser has an impact only when it is captured as an indicator variable not the actual quantities used. The use of manure tends to moderate the effect of basal fertiliser since they serve the same purpose. Input support from NGOs such as basal fertiliser input and seed do not have an impact on yield. This can be explained by the fact that farmers tend to replace basal fertiliser with manure and also use of other sources of seed other than that provided by NGOs. Farmers received mostly open pollinated variety (OPV) seed from NGOs to enable them re-cycle for at least two seasons, though this seed performed better than farmers retained seed, the yield impact was not significant. The only input support that has an impact on yield is top-dressing fertiliser. This implies that investing in nitrogen fertiliser will produce a larger impact compared to other inputs.

When CA is captured as an indicator variable the measured impact of CA is around 22.5% when there are no CA interactions captured in the model specification. Considering the number of CA techniques practised, the result shows an increase in yield of 7.6% per technique, with a maximum of eight techniques possible. These measured effects are slightly lower than those found in OLS regression, suggesting that unobserved variables led to an overestimation of impacts in the OLS model. However, the statistical and practical significance of the impact of CA on yield remains substantial in the household fixed effects model.

Mwalwanda *et al*. (2011) suggested that in general, maize grain yield was higher for male farmers than female farmers. This may be because of resource entitlement disparities between male and female farmers where generally male farmers dominate in controlling both financial resources and land, which directly influence production abilities. Both the OLS and the fixed effects model give a negative and significant coefficient on the interaction term between female head and CA implying that female headed households get a smaller positive effect from using CA than male headed households. This is despite the fact that female-headed households tend to be more vulnerable and with limited resources and as a result they are targeted to receive more support which is logically should improve the efficacy of CA. There virtually no benefit in terms of yield to female headed household applying CA, the net effect is (0.215-0.326) -11.1%. Therefore there are gender specific constraints which makes it difficult for women farmers using CA to realise a higher yield impact.

Top-dressing fertiliser has a large and positive impact in all the model specifications. Gatere *et al*, 2014 confirmed that CA with higher levels of fertiliser than conventional maize production has the potential to raise yields, though cash constraints are a barrier to widespread fertiliser use. The interaction of CA and topdressing fertiliser is negative and significant for both OLS and fixed effect model. This implies that the use of top dressing fertiliser is less critical under CA than conventional agriculture because other practices in CA (mulching and rotation) are reducing the need for fertilisers in poor soils. Incremental benefits of using fertiliser are much lower when one uses CA compared to conventional farming because fertility management is enhanced through the use of mulch and rotation which are part of the CA package promoted in Zimbabwe.

The interaction term of CA and dry areas is not statistically significant, which implies that the percentage impact of CA on yield is similar across natural regions. This suggests that lower adoption rates of CA in the dry areas than in the higher potential areas may be due to factors other than the natural environment. The net incremental effect of using top dressing fertiliser in CA plots is much lower compared to if it was used on the conventionally managed plots.

Table 4. 7: Household fixed effects for three model specifications

Variable	Specification F	Specification G	Specification H
Observations (n)	2876	2523	2876
Adjusted R^2	0.387	0.379	0.389
CA	0.313**		1.220***
Numtech		0.076**	
Total cropped area	-0.518***	-0.524***	-0.508***
Seed	0.285***	0.290***	0.368***
Basal fertiliser	0.030		
Top dressing fertiliser	0.211***		
Pdate2		-0.010***	
Pdate		0.320***	
Basal dummy		0.169*	0.229**
Top dress dummy		0.664***	1.013***
NGO seed	-0.042		
NGO basal	-0.056		
NGO top	0.220**		
Manure	0.697***	0.826***	0.668***
Weeding frequency	0.386***	0.463***	0.390***
CA*female			-0.326**
CA*2009			.112
CA*dry			-.253
CA*top dress fertiliser			-0.942***
Constant	5.912***	5.108**	7.530***

*Significance at the 10%, 5 %, and 1% levels are indicated by *, ** and *** respectively. Source: Author Data Analysis, 2014*

The OLS results are confirmed by the household fixed effects model thus confirming their credibility. The OLS is only important in relation to measuring the impact of time-invariant variables, which cancel out in the household fixed effects model. The measured effects are slightly lower than those found in the OLS regression, suggesting that unobserved variables led to an overestimation of impacts in the OLS model. However, the statistical and practical significance of the impact of CA on yield remain substantial in the household fixed effects model.

4. 4 Conclusion

Based on evidence from the four year panel (2008-2011) yields from the CA plots are higher than those from non-CA plots. The evaluation shows that CA plots are generally smaller compared to conventional plots this could be a results of the high labour demand of CA.

Multicollinerity was tested for all variables used in the yield regression model and the test was negative. Though the CA plots are generally smaller, this has no bearing on the negative relation between farm size and yield. It can however be acknowledged that the methods used to estimate area cold have resulted in some measurement error but the error had no statistical significance. It has been observed that even the smaller CA plots have the potential to contribute to household food security because even in a poor season the yields are higher.

One of the main advantages of CA is the ability to plant early especially at the onset of rains hence planting date is the key pathway for CA to have impact. The study revealed that CA plots are generally planted early compared to non – CA plots. It is interesting to note that planting date has a quadratic effect on yield; early planted crops will have a positive yield effect whereas the effect is reduced and becomes negative for the late planted crops. The water conserving properties of CA have not been realised through yield gain in Zimbabwe. Farmers in the semi-arid areas of NR IV and V experience some negative yield impacts relative to the wetter areas of NR II however, the effect is not statistically significant. The yield benefit of practising CA in the dry areas is not pronounced and this could be a result of the assessments which are based on maize cropping whose suitability in the semi-arid areas is questionable.

The simplest OLS estimation of the yield effect suggested that households merely practicing basic CA can increase their yields by 105%. This factor is considered a high end estimate as it may confound some of the effects of other practices, such as fertiliser use. This high impact of CA can point to the fact that CA is relevant to the smallholder farmers. There is a considerable decline in the estimate of the yield impact in the fixed effects model compared to the OLS. This confirms the fact that the OLS tend to overestimate the yield impact of CA by failing to correct for time invariant unobservable variables that might be correlated to both yield and practice of CA. The fixed effects model implies that farmers practising CA can increase their yield by 50.7% on average. A 50.7 % yield improvement is of practical significance but it might be too small for farmers to discern or think is worth the effort. The lower yield impact after controlling for households fixed effects may go a long way to explain limited adoption. This low average yield may mask wide variation in impacts. There is very a very large impact when an interaction term is included suggesting that some farmers get big yield impacts and others do not.

Female household heads tend to have a positive impact on yield compared to their male counterparts in this study. This can be explained by the fact that female headed households are targeted as recipients of subsidised farm input. However, female headed households who practice CA tend to get less benefits on yield compared to their male counterparts. When interaction terms are used to extract the impact on yield among female headed households there is a large negative effect. Thus male farmers seem to have significantly higher positive yield effects from CA than women. Even after correcting for the unobservable factors, the female farmers tend to get lesser from applying CA and this puts to question the suitability of CA for the vulnerable in the face of other constraints such as labour.

Top-dressing fertiliser is the only purchased input with no substitutes and has the greatest positive agronomic impact on yield. There are higher returns on top dressing investment compared to other inputs under the CA technology. Policy-makers should address the issue of the availability top-dressing fertiliser through markets or subsidised input schemes as a way of boosting smallholder productivity. In term of the inputs provided by NGOs, top dressing fertiliser in the only NGO input with a significantly positive effect of yield. This points to the fact that NGO support for farmers is best channelled to top dressing fertiliser. There are higher returns to top dressing investment compared to other inputs provide by NGOs.

However the unambiguous finding of this study is the positive significant impact of CA technology on maize yield which is consistent.

CHAPTER 5

FACTORS AFFECTING ADOPTION INTENSITY OF CONSERVATION AGRICULTURE AMONG SMALLHOLDER FARMERS IN ZIMBABWE

5.1 Introduction

Conservation agriculture (CA), which is based on the principles of providing permanent soil cover, minimising soil disturbance and rotating crops, is now considered an important contributor to sustainable agriculture (FAO, 2008; Hobbs *et al.*, 2008) and is seen as a way to address major causes of food insecurity while protecting natural resources and the environment. Conservation agriculture must be adapted to local conditions, such as soil type, climate and socio-economic settings (Erenstein *et al.*, 2008), but it can be used in all parts of Africa, except where it is too dry to grow crops at all. Because of local adaptations, CA may thus look different from place to place, but must conform to the principles stated above. CA has the potential to reduce water stress in crops, which is critically important as southern Africa braces for the hotter and drier weather predicted by climate change models (Lobell *et al.*, 2008). The benefits of CA have been validated empirically through various studies around the world such as those of (Cavalieri *et al.*, 2009; Affholder *et al.*, 2010; Marongwe *et al.*, 2011; Mazvimavi, 2011). As a result, many institutions have invested in efforts to transfer this technology to smallholder farmers, particularly those of Sub Saharan Africa (SSA). Despite this enthusiasm for CA, empirical evidence on CA adoption remains fragmentary (Knowler & Bradshaw 2007): available studies suggest that adoption of CA practices in Africa remains spotty and adoption rates are generally low (Rockström *et al.*, 2009; Giller *et al.*, 2009; Arslan *et al.*, 2014; Andersson & D'Souza 2014). This has prompted some international experts to question the potential of widespread adoption of CA in Africa openly (Giller *et al.*, 2009).

Full CA, however, is today rarely practised outside South America (Ekboir, 2003; Derpsch, 2008; Bollinger *et al.*, 2006) and is indeed difficult to achieve right from the onset. Farmers who are willing to follow the path to more sustainable agriculture usually embark on a long journey consisting of consecutive phases, each characterised by the use of specific practices that increasingly incorporate practice and mastery of the three principles of CA (Triomphe *et al.*, 2007). Adapting CA to the local environment usually results in partial adoption. The researcher has to distinguish between CA in theory (as promoters of CA would like it to be implemented) and CA in practice (as farmers are eventually able, or willing, to implement it). Some farmers attribute their deviations from the recommended practices to labour shortages. Partial adoption driven by labour shortages may imply lower returns from the CA practices used and ultimately discourage use of any CA components. However, overall uptake of CA as a package in Africa has been disappointing (Friedrich *et al.*, 2012; Giller *et al.*, 2009) because of the substantial challenges associated with targeting, adapting and adopting CA, particularly for smallholder farmers (Erenstein *et al.*, 2012).

The nature of CA practices implemented by a farmer depends on the environmental, socio-economic, institutional and political circumstances and constraints (Giller *et al.*, 2011). Some of the determinants are factors and conditions that clearly relate to the characteristics, preferences and experiences of individual farmers and farms such as the capital available for investing in equipment and inputs, the choice of cover crops, the soil conditions prevailing at the time CA is introduced, the care with which a farmer applies inputs or controls weeds, or the ability to learn new practices and take risks (Erenstein, 2003; Siziba, 2008). Others, however, relate more to the local or regional environment of the farm: ease of access to equipment, inputs and relevant knowledge, links to markets and the existence of policies favouring (or discouraging) the adoption of CA practices (Chiputwa *et al.*, 2011).

5.1.1 Background

In Zimbabwe promotion of CA is part of an agricultural relief programme aimed at improving the livelihood and food security status of smallholder farmers (Gukurume *et al.*, 2010). Despite all promotional efforts by donor agencies in Zimbabwe adoption rates by smallholder farmers have been disappointing (Derpsch *et al.*, 2010; Marongwe *et al.*, 2011; Andersson & Giller, 2012). In practice, smallholder farmers have modified the package and generally adopted some components of the technology, such as digging planting basins, while leaving out others, such as mulching and crop rotation (Giller *et al*., 2009; Mazvimavi & Twomlow, 2009; Pedzisa *et al*., 2010). Gowing and Palmer (2008) assert that adoption of CA by small-scale farmers is likely to be partial as opposed to full adoption.

The majority of smallholder farmers reported to be practising CA in southern Africa are in fact practising minimum tillage (Baudron *et al.*, 2007; Mazvimavi, 2011) because of mulch constraints and planting legumes for crop rotation. According to Mazvimavi (2011), more than

80% of the farmers practise maize mono-cropping on fields that are reported to be under CA in Zimbabwe. Chiputwa *et al.* (2011) suggest that different households tend to select and adopt different components of the CA package conveniently, owing to the heterogeneity of the farmer's socio- economic profiles, perceptions and livelihood objectives. The finding that labour intensity diminishes adoption of some CA practices supports earlier findings elsewhere that scarcity of labour is one of the main reasons why some farmers would not adopt CA (Haggblade & Tembo, 2003, Baudron *et al*., 2007). Risk aversion may contribute to piecemeal adoption because smallholder farmers in Zimbabwe have weak mechanisms to absorb risk and are inclined to adopt the less risky components of the CA technology package first. However, by adopting only parts of the technical package, smallholders diminish the benefits of the technology (FAO, 2001; Ito *et al*., 2007). There are indications of gradual intensification of adoption (in terms of number of components) over time (Mazvimavi & Nyamangara, 2012; Arslan *et al.*, 2014).

To understand farmers' adoption decisions concerning portfolios of practices is a break from past research, which simply looked at individual farming practices in a stand-alone formulation. This study is similar to that of Mazvimavi and Twomlow (2009), in that it is derived from the same data set: it also assesses adoption intensity in terms of the number of component used by a practising farmer. However, the current study differs in a number of ways, such as the use of panel data instead of a cross-section. The main assumption underlying the current methodology is the fact that all components of the CA package are considered equally important, whereas Mazvimavi and Twomlow (2009), allocated subjective scores to the different components.

Informed by literature and current practices of CA in the smallholder sector of Zimbabwe, the following hypotheses were suggested as explanations for partial adoption of the CA package:

1. Being in the drier agro-ecological regions makes it difficult for farmers to use more CA components, especially mulch.
2. Having less labour as measured by household size makes it harder to use more components such as weeding and digging basins.
3. Farmers who receive inputs and training from NGOs, technical advice from extension services and those who are lead farmers use more components.
4. Farmers with more CA experience are likely to use more components as they learn from doing.

5. The number of components used in the previous season has a positive influence on the number of components to be used in the current season.

Table 5.1 shows the eight components of CA as defined by the Zimbabwe Conservation Agriculture Taskforce (ZCAT, 2009) in its guidelines to NGOs promoting the technology as a standardised package. The components of CA are complementary in that, under certain conditions, the benefits increase dramatically if more components are used (Gama & Thierfelder, 2011). This complementarity explains why CA is usually promoted as a package. Since CA is most effective when adopted as a package, the challenge is to ensure that farmers take up the whole package, not just portions of it. One factor inhibiting CA adoption is that the technology presents a set of practices rather than a discrete input. Thus adoption of CA is knowledge-intensive and complex (Wall, 2007). The complexity of the elements of CA technology contributes to low adoption rates (Giller *et al.*, 2009).

Table 5.1: Eight standard practices which make up the CA technology package in Zimbabwe

Technique	Description	Importance
Winter Weeding	Removal of all weeds soon after harvesting- there should be little disturbance of the soil	Ensures plot is weed-free at basin preparation and prevent dispersal of weed seeds
Digging planting basins	Holes dug into which a crop is planted -	Enhance the capture of water from the first rains and enable targeted application of soil nutrients
Application of crop residues	Mulch is applied on the soil surface to provide at least 30% soil cover	Cushion soil against traffic , suppress weeds through shading and improves soil fertility
Application of manure	A handful of manure or compost is applied into the planting basin	Boosting soil fertility through organic nutrients
Basal fertiliser	One level beer bottle cap is applied per planting basin before the onset of rains	Enhancing soil fertility through inorganic nutrients
Top dressing fertiliser	One level beer bottle cap of Nitrogen fertiliser is applied per planting basin	Precision application ensures that the nutrients are available where they are needed.
Timely weeding	Weed when weeds are still small, which prevents them from setting Seed	In combination with mulch leads to effective weed control
Crop rotation	Key principle of CA. Cereal/legume rotations ensure there is optimum plant nutrient use by synergy between different crop types.	Improves soil fertility, controlling weeds, pests and diseases, and producing different types of outputs, which reduce the risk of total crop failure in cases of drought and disease outbreaks.

Source: Author's compilation, 2014

There is general consensus that CA should be defined as a management system based on three principles that should be applied in a mutually reinforcing manner: minimum physical soil disturbance, crop diversification in space and time (e.g., crop rotation, cover crops or intercrops) and permanent soil cover with live or dead plant material such as crop residue mulches (Wall et al, 2013). However recent publications including this study have used the term conservation agriculture to include a diversity of other practices that add on, complement or replace one or more of these principles (Lahmar *et al*., 2012; Garrity et al., 2010). The aim of arriving at a consensual CA definition was to distinguish CA systems from pre-existing technologies, such as resource conserving technologies, water harvesting, soil and water conservation, agroforestry, etc. The rather strict definition of CA has been the strength but also somehow the weaknesses of CA and in some cases this has led to polarised debates of what is and what is not CA? There is general consensus among researchers that strategies for using CA in SSA in SSA must integrate a fourth principle which is appropriate use of fertiliser to increase likelihood of benefits for smallholder farmers. This study uses the broader concept of CA, it goes beyond the three principles and uses the eight component package developed by ZCATF.

For the purposes of this study each component is assessed as a discrete technique, and these will be the basis for measuring the intensity of CA adoption. Intensity of adoption is modelled given the fact that most farmers adopt CA only partially and variables that may increase the intensity of adoption are relevant for policy-makers. The intensity of adoption is usually defined as the proportion of total cultivated land that is under CA practices and is bounded by the [0, 1] interval. Although most applied literature on CA tends to define adoption as a binary outcome (e.g. having some area under minimum tillage), it has been accepted that adoption is not binary and the adoption process and tends to be partial and incremental. However, in this chapter, adoption intensity is the number of CA components applied out of the possible eight from the full package.

5.2 Analytical framework

In this study, the number of CA practices adopted by a farmer is a function of a set of independent variables ($\mathbf{X}_{it}$):

$$In\ (Y_{it}) = \alpha_0 + \beta' X_{it}\ , \qquad (1)$$

Where ln (Y_{it}) is the natural log of Y_{it}, which is the observed number of CA practices for the *i*th farmer in time t. Y_{it} is assumed to be independent and may be over or under dispersed. The parameter β is dependent on a set of explanatory variables (X_{it}) which are hypothesised to affect the number of CA technologies used by a farmer at any time t.

Assuming a Poisson distribution

$$E[Y_{it}] = exp^{(\beta X it)} \quad (i=1, ..., n)\ (t=2008 ....., T=2011) \qquad (2)$$

where $E[Y_{it}]$ is the expected value of the dependent variable for the *i*th observation, exp is the exponential function, β is a 1 by k vector of parameters, X_l is a k by 1 vector with the values of the k independent variables in the *i*th observation and n is the number of observations. Equation (2) can be used to predict the expected level of adoption given the value taken by the vector of independent variables Xit. Two broad types of explanatory variables are often included in technology adoption studies: qualitative, modelled through dichotomous (dummy) variables, and quantitative, integer or non-integer valued. Their relative impact on the dependent variable is calculated differently. Note that equation (2) can also be expressed as:

$$E[Y_{it}] = exp^{(\beta 1X1it)}\, exp^{(\beta 2X2it)} \ldots .exp^{(\beta iXkit)} = exp^{(\beta jXjit)}\, Cj(i=1, \ldots, n), \qquad (3)$$

where j can take any one value from 1 to k and identifies a specific explanatory variable and C, is a constant representing the product of the remaining exponential terms in (2). For dichotomous explanatory variables, if X_{jt}, = 0,

$$E[Y_{it}] = C_{jt}, \text{ and when } X_{jt}, = 1, E[Y_i] = exp^{(\beta jXjit)}\, Cj.$$

Therefore:

$$100\ X\ (exp\beta jt - 1), \qquad (4)$$

calculates the percentage change on E [Y] when X_{jt} goes from zero to one, for all observations (i). In general, for independent variables that take several integer values, the percentage change in the expected level of adoption when X_{jt} goes from X_{j1t} to X_{j2t} can be calculated as:

$$100\ X\ (exp^{(\beta jXj2t)}) - exp^{(\beta jXj1t)}/exp^{(\beta jXj1t)}. \qquad (5)$$

For quantitative explanatory variables the elasticity estimate at X_{jit} is given by:

$$\partial\epsilon[Yit]/\partial\epsilon[Xijt](Xjit/E[Yti]) = \beta jXjit. \qquad (6)$$

Count data regression analysis was employed in the estimation of the farmers' decision on how many CA practices to adopt. Quantifying the impact of each independent variable on the level of adoption is also straightforward. The greater the number of practices, the higher the adoption level because CA is a full package consisting of eight standard practices and each component is equally important. If a farmer implements all eight, the benefits will be greater. The restriction of equality of the mean and variance in the Poisson distribution is often not realistic and it has been found that the conditional variance tends to exceed the mean, resulting in an over-dispersion problem (Winkelmann, 2000; Cameron & Trivedi, 2009) is still consistent, though the standard errors of β are biased downwards. In such cases an estimation based on a negative binomial distribution can be applied.

5.2.1 Data

Data used to determine the factors that predict the number of CA practices a farmer adopts were part of a five year panel dataset (2007-2011) collected to monitor adoption patterns of CA by smallholder farmers in Zimbabwe. Only data from four rounds (2008-2011) were used in the analysis. The list of eight technologies employed by smallholder farmers in Zimbabwe and the proportion of sample farmers using each technique are presented in Table 5.2.

Table 5.2: Uptake of conservation agricultural techniques among Zimbabwe smallholder farmers

CA practice employed	**Proportion of farmers applying a specific technique (%)**				
	2007/08	2008/09	2009/10	2010/11	Pooled 2008-11
Winter Weeding	68.7	62.4	48.1	38.3	54.3
Mulch Application	31.7	38.3	32.8	26.52	32.5
Digging Basin	94.1	80.5	80.1	72.5	81.9
Spot application of manure	80.9	78.8	62.8	62.8	73.2
Application of basal fertiliser	69.7	39.3	46.2	42.1	49.3
Micro – dosing of nitrogen fertiliser	78.3	59.7	62.8	73.2	68.5
Timely Weeding	87.9	82.4	56.4	53.7	70.1
Crop Rotation	24.7	21.61	20.9	22.9.	22.5.

Source: Author Data Analysis, 2014

The use of practices such as digging basins and timely weeding is relatively high. As might be expected, digging basins is the most popular CA technique because it determines whether a farmer applies CA or will resort to conventional tillage. Planting basins are used as a basis for determining CA adoption in Zimbabwe. Less prevalent practices include crop rotation (22.5%) and crop residue mulching (32.5%). The precise reason for adoption is an empirical question, but it seems reasonable to assume that farmers will choose options that generate additional private benefit in the short run ahead of those that do not. There was an increase in the uptake of CA components up to 2009; and this observation is supported by findings by Mazvimavi *et al*. (2008). However, there was a gradual decline after 2009. The period after 2009 represents the post crisis period which has been characterised by a positive growth in the economy, pulling out of most NGOs and the dollarization of the economy. This economic growth resulted in the dwindling of donor support, despite the fact that most smallholder farmers relied on subsidised inputs (seed and fertiliser) for their CA plots. A greater proportion of farmers applied nitrogen fertiliser compared to basal fertiliser. Nitrogen was shown to have a higher yield impact (Mazvimavi & Nyamangara, 2012). In addition, farmers could use manure as a substitute for basal fertiliser as a way of reducing cash expenditure. Few farmers could afford to invest in fertiliser despite the impressive yield gains associated with CA.

5.3 Results and discussion

Table 5.3 shows how the uptake of specific CA components changed across the agro-ecologies. There were no specific trends and patterns in use techniques such as basin digging, timely weeding and crop rotation. However, for most the practices, inclusive of winter weeding and application of mulch, manure, and chemical fertilisers, there was a decline is use as one moved to the drier regions. Fertilisers might not be readily available in the dry regions of Zimbabwe and low levels of biomass production could explain the limited use of crop residues for mulching.

Table 5.3: Uptake of conservation agricultural techniques across agro-ecologies for 2008-2011

CA practice employed	Proportion of farmers applying a specific technique (%)			
	NR II	NR III	NR IV	NR V
Winter Weeding	75.22	61.05	65.25	56.68
Mulch Application	41.58	38.63	31.73	26.52
Digging Basin	99.08	95.04	92.30	93.50
Spot application of manure	92.20	81.51	90.19	73.64
Application of basal fertiliser	76.60	62.37	48.01	47.65
Micro – dosing of nitrogen fertiliser	97.24	76.89	80.01	65.70
Timely Weeding	90.36	77.56	81.17	76.17
Crop Rotation	29.02	25.08	19.89	21.29

Source: Author Data Analysis, 2014

Across the four years of the panel study, smallholder farmers commonly used between four and seven CA components, with a mean of five and median of six components (Table 5.4). On average, 7.4% of farmers used all eight techniques in any given year, whereas 16.6% did not apply any of the components in any given year, as the farmers reverted to the plough. The proportion of farmers using the full package declined after 2009 in line with the reduction in donor support. Indications of a high-intensity level of adoption are that more than half of the farmers used more than five components in any given year. Few of the farmers (23%) used fewer than three techniques, which is indicative of low-intensity levels of adoption.

Table 5.4: Proportion of farmers using number of CA techniques in a given year

Year	Sample Size (n)	Proportion of farmers using CA techniques (%)								
		Number of techniques used								
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
2008	327	0.9	0.6	1.5	7.9	12.7	15.9	21.6	17.5	13.8
2009	331	7.1	0.3	0.6	2.9	11.2	19.9	26.1	19.9	8.1
2010	349	12.9	0.3	0.6	1.7	17.6	19.1	20.1	17.6	7.7
2011	335	19.4	1.2	4.5	7.2	19.2	29.5	27.4	8.9	2.6
Pooled (2008-11)	1358	16.6	0.6	1.8	4.9	12.0	17.6	21.6	17.5	7.4

Source: Author Data Analysis, 2014

Maize yield increases with higher intensity of use of CA technology. Farmers using all eight techniques reported yields almost six times the yield of those using only one technique (Table 5.5). Farmers using fewer than three techniques had maize yields of less than 1000 kg/ha, whereas using at least four techniques would shift the yield of maize to well above 1200 kg/ha. Mean maize yield for farmers who used three techniques were quite above expectation because of the large variation in mean yields as indicated by an unequivocally large standard deviation. While this pattern could be driven by some other factors correlated to both adoption intensity and yield, the trend suggests that intensity of CA adoption could play an important role in its productivity effects.

Table 5.5: Number of CA techniques and maize productivity

Number of techniques	Observations (n)	Maize yield over 4 years (kg/ha)	
		Mean	Standard deviation
1	10	366.67	404.15
2	17	582.12	1065.30
3	54	1579.57	5527.70
4	136	1300.36	1448.51
5	241	1458.47	2613.78
6	258	1688.12	1628.41
7	214	1864.47	2059.67
8	90	2522.18	3802.63

Source: Author Data Analysis, 2014

5.3.1 Description of adoption intensity variables

Table 5.6 provides definitions, the expected signs and summary statistics for the variables used in the empirical model. The average smallholder farmer in the sample is 52 years old, has at least seven years of schooling, approximately 27 years of farming experience and had used CA for more than five years. Approximately 41% of the farmer respondents were male. On overage the number of oxen owned by a household was 0.7, with a household size of six. The average number of CA practices used was 5. Almost 74% of the sample farmers had received some form of input support from NGOs and 23% of the sample farmers had been selected as lead farmers meaning those farmers who would technically assist others with the implementation of CA. On average, the total area of CA plots per household was 0.32 ha. On average the proportion of farmers located in NR III was 23%, 30% in NR IV and 29% in NR V, and the remainder in NR II. The significance of NR II is that it cannot be classified as semi-arid; it is a high potential area unlike the other three regions.

Table 5.6: Definition of variables, expected signs and summary statistics

Variable	Definition	Expected sign	Mean	Min	Max	Standard Deviation
Numtech	Number of CA techniques applied by the household	Dependent variable	5.34	0	8	1.97
NGO support	Received inputs from NGOA (1=yes; 0 otherwise)	+	0.740	0	1	0.439
Total livestock holdings	Total livestock by household in tropical livestock units (TLU)	+	622.86	0	40.2	3.884
Total value of assets	Total value of household assets in US$	+	2.975	0	30121	1083.98
Total cropped area	Log of total land under cropping for the season (m^2)	+	3132.6	0	30118	374
Household size	Number of individuals in the household	+	6.298	1	23	3.010
Male head	Head of household is male (1=yes; 0 otherwise)	+	0.413	0	1	0.492
NR III	Household in Natural region III (1=yes; 0 otherwise)	-	0.237	0	1	0.425
NR IV	Household in Natural region IV (1=yes; 0 otherwise)	_	0.309	0	1	0.462
NR V	Household in Natural region V (1=yes; 0 otherwise)	_	0.295	0	1	0.456
2009	2009 round of survey 1=yes; 0 otherwise)	+-	0.200	0	1	0.400
2010	2010 round of survey 1=yes; 0 otherwise)	+-	0.194	0	1	0.395
2011	2011 round of survey 1=yes; 0 otherwise)	+-	0.196	0	1	0.395
CA experience	Years of using CA since first training (Years)	+	5.84	3	12	1.861
Farming experience	Years since household started farming (Years)	+	27.72	4	76	14.50
Education	Years of schooling of household head (Years)	+	6.73	0	14	3.81
Age	Age of household head	_	53.06	21	92	14.36
Lead farmer	Selected to assist other farmers with CA (1=yes; 0 otherwise)	+	0.235	0	1	0.424
Extension visits	Frequency of extension contacts within a season	+	2.432	0	24	3.653
Lnumtech	Number of CA techniques used by the household in the previous season.	+	4.91	0	8	2.64

Source: Author Data Analysis, 2014

5.3.2 Correlation analysis of components of the CA package

Table 5.7 shows the pair-wise correlation coefficient, which depicts whether any pairs of techniques are complementary, are substitutes or do not affect each other in their adoption patterns. For the sample of smallholder farmers using CA, all the correlation coefficients are less than 0.5 (i.e. r <0.5). Sharma *et al*. (2011) interpret a correlation coefficient greater than 0.5 (i.e. r >0.5) as high. Thus, in general the estimated correlations among smallholder farmers' selection of CA technologies are not high. Defining correlation coefficients less than 0.25 as low, Table 5.7 suggests that manure application is weakly correlated with basal fertiliser (r = 0.110), crop rotation (r = 0.127) and mulching (0.153). Also, mulching is weakly correlated with digging basins (r = 0.221) and manure application(r = 0.217), while top-dressing application and winter weeding are weakly correlated (r = 0.203). It might be important to point out that digging basins, which is used by most of the smallholder farmers (91.5%), is moderately correlated with the other CA practices.

Table 5.7: Pair wise correlation of CA techniques

	Winter Weeding	Mulch	Digging basin	Manure	Basal fertiliser	Top dressing	Timely weeding	Crop Rotation
Winter Weeding	1.000							
Mulch Application	0.417	1.000						
Digging Basin	0.296	0.221	1.000					
Manure	0.251	0.218	0.426	1.000				
Basal Fertiliser	0.149	0.153	0.259	0.110	1.000			
Top Dressing	0.203	0.256	0.433	0.260	0.460	1.000		
Timely Weeding	0.392	0.310	0.440	0.287	0.220	0.366	1.000	
Crop rotation	0.091	0.175	0.138	0.127	0.128	0.163	0.079	1.000

Source: Author Data Analysis, 2014

5.3.3 Factors affecting the number of CA techniques used by smallholder farmers

Regression results are presented for the Poisson model in Table 5.8 and for the negative binomial model in Table 5.9. The coefficients represent rate ratios and the impact of each explanatory variable of intensity of adoption is captured through the marginal effects. These results were used to test the study hypotheses stated earlier. The alpha coefficient for the negative binomial was found to be significant, indicating over-dispersion and therefore the negative binomial was selected over the Poisson model. At the 1 percent level of significance, the negative binomial is the suitable model for describing smallholder farmers' intensity of adoption of CA. Nonetheless, results from the two estimations are similar and both sets of results are presented.

Adoption of CA practices appears to be driven primarily by agronomic and climatic factors, with high adoption intensity in NR II compared to the other drier regions. Being in the semi-arid areas of NR III, IV and V is associated with low adoption intensity, as farmers face more crop production constraints relative to those in NR II, which is a high- potential area. In the semi-arid regions, the use of crop residues as mulch is constrained by low biomass production and competing use of crop residues with livestock. Table 5.3 shows how the practice of mulching decline and falls out in the drier areas of NR IV and V.

Table 5.8: Poisson model results

Variable	**Specification 1**			**Specification 2**		
	Coefficient	Standard Error	Marginal Effect	Coefficient	Standard Error	Marginal Effect
NGO support	0.180***	0.034	0.912	0.134***	0.034	0.691
Total Livestock value	0.009	0.004	0.009	0.004	0.009	0.024
Total cropped area	0.00001***	2.86e-06	0.0001	0.00002***	3..22e-06	0.014
Household size	-0.010**	0.005	-0.049	-0.010*	0.005	-0.054
Female head	0.015	0.029	0.090	-0.017	0.029	-0.088
NR III	-.186***	0.041	-0.998	-0.132***	0.041	-0.682
NR IV	-.172***	0.040	-0.990	-0.125***	0.041	-0.652
NR V	-0.249***	0.042	-1.401	0.208***	0.043	-1.051
2009	-0.139***	0.035	-0.688			
2010	-0.198***	0.038	-0.999			
2011	-0.186***	0.039	-0.948			
CA experience	0.004	0.010	0.021	-0.006	0.010	-0.029
Farming experience	0.004	0.002	0.019	0.003	0.002	0.016
Education	0.009*	0.005	0.038	0.006	0.005	0.034
Age	-0.001	0.002	-0.004	-0.001	0.002	-0.005
Lead farmer	0.089***	0.031	0.491	0.070**	0.034	0.382
Extension visits	-0.002	0.004	-0.013	-0.003	0.004	-0.0001
Lnumtech				0.042***	0.007	0.222
Constant	1.734***	0.118		1.559***	0.123	
Pseudo R-squared	0.0407			0.041		
Wald Chi-squared	194.39			185.87		

*Significance at the 10%, 5 %, and 1% levels are indicated by *, ** and *** respectively. Source: Author Data Analysis, 2014*

The CA practice under study involves a lot of drudgery associated with manual digging of basins and has a tendency to increase labour requirements at least in the first years (Affholder *et al*, 2010; Mashingaidze, 2013). Results indicate that household size as a measure of family labour has a negative impact on adoption intensity contrary to expectation. This could be a result of using a crude measurement of labour not adequately captured by family size. There is some evidence that the area under CA has a positive and significant impact on the number of techniques adopted. The larger the area under CA, the more components are adopted.

Receiving NGO input support is positively related to the number of technologies adopted as hypothesised. NGO inputs would include basal fertiliser and nitrogen fertiliser, which are components of the CA package. When NGO support is removed from an area, smallholder farmers may be unable to implement CA owing to lack of the required critical inputs. Lead farmers are trained so that they can teach and monitor other farmers in their locality. Lead farmers tend to apply more CA components than their counterparts, presumably because they are more knowledgeable and better informed about CA. It is also possible that individuals chosen to be lead farmers are more likely to respond to training owing to factors that are not observed in these data.

Table 5.9: Negative Binomial model results

Variable	**Specification 1**			**Specification 2**		
	Coefficient	Standard Error	Marginal Effect	Coefficient	Standard Error	Marginal Effect
NGO support	0.180***	0.034	0.912	0.140***	0.035	0.691
Total Livestock value	0.009	0.004	0.049	0.004	0.009	0.024
Total cropped area	0.0001***	3.21e-06	0.0001	0.0002***	3.22e-06	0.0001
Household size	-0.013**	0.005	-0.070	-0.012*	0.005	-0.054
Male head	0.017	0.029	0.090	-0.018	0.028	-0.088
NR III	-.187***	0.041	-0.958	-0.132***	0.041	-0.682
NR IV	-.183***	0.040	-0.943	-0.125***	0.041	-0.652
NR V	-0.270***	0.042	-1.338	-0.208***	0.044	-1.051
2009	-0.139***	0.035	-0.687			
2010	-0.198***	0.038	-0.999			
2011	-0.186***	0.039	-0.948			
CA experience	0.001	0.010	0.007	0.007	0.010	0.029
Farming experience	0.003	0.002	0.016	0.003	0.002	0.016
Education	0.007*	0.005	0.038	0.004	0.005	0.034
Age	-0.001	0.002	-0.004	-0.001	0.002	-0.005
Lead farmer	0.086***	0.033	0.496	0.070**	0.031	0.382
Extension visits	-0.002	0.004	-0.013	-0.003	0.004	-0.014
Lnumtech				0.042***	0.008	0.222
Constant	1.734***	0.118		1.559***	0.123	
Lnalpha	-22.570			-22.606		
Alpha	1.57e-10			1.52e-10		
Pseudo R-squared	0.0407			0.0408		
Wald Chi-squared	194.39			185.83		

*Significance at the 10%, 5 %, and 1% levels are indicated by *, ** and *** respectively. Source: Author Data Analysis, 2014*

Time has a negative and significant coefficient, indicating that a farmer is likely to adopt fewer techniques in subsequent years from the base year of 2008. This strongly suggests that the nature of adoption is stepwise, though results strongly indicate abandonment. A risk-averse farmer would use more techniques as he/she gains confidence in the technology; however, in this study, farmers evaluate the performance of the technology each season and subsequently reduce the intensity of use. The sequence of adoption would vary from farmer to farmer, depending on the constraints and what could be considered an easy practice.

5.4 Conclusion

This study contributes to the literature by using a count data estimation procedure to examine the impact of various factors on the number of CA components adopted by smallholder farmers. A suitable econometric method to examine the data has been employed. Several key determinants of the intensity of CA technologies were identified.

The complementarity of the components of CA might either support or discourage adoption. If poor performance with only partial adoption discourages farmers, then use of CA is unlikely to take hold. If partial adoption leads to sufficiently good results that farmers are inclined to adopt more CA techniques over time, the benefits of adoption and the rate of adoption can be expected to magnify over time. It is important to identify the constraints to more intensive adoption so that once these barriers are overcome, and farmers can use more techniques to realise greater yield impact. An additional technique from the year before only leads to less than one additional technique today, implying that there is a slowdown in the decrease in adoption.

Being in the drier agro-ecological regions makes it difficult for farmers to use more CA components, especially mulch and fertiliser, while farmers in high-potential areas of NR II employ a larger number of CA technologies. It becomes difficult to use more components of CA as one moves to the drier regions because of the adverse agro-ecological conditions and production constraints are more limiting. Smaller households with limited family labour find it easier to use more components of CA relative to their counterparts from larger families. This finding is contrary to the expectation that labour constraints make it difficult to use more components such as weeding and digging basins. The smaller families could have resolved the issues of labour constraints by pooling village labour to form CA labour clubs.

Farmers who received some form of NGO input support adopted more components than those who did not receive any inputs. There appears to be a need to assist individuals or vulnerable households with inputs so that they increase their production through the introduction and adoption of CA. In addition, fertiliser should be made available at local input markets so that farmers can adopt micro-fertilisation to improve yield. The finding that the lagged number of practices applied positively affects adoption intensity suggests that there could be a lingering effect of NGO promotion on future use of CA practices.

Research should be directed towards adapting the CA package in light of the constraints to the adoption of current components. The most adopted components are digging basins and those techniques like application of soil amendments such as manure, basal fertiliser and top dressing. For those farmers who are most likely to adopt the technology incrementally, mulching and crop rotation would be adopted last. To facilitate adoption of the whole package, it is useful to identify and alleviate the barriers to adoption for the less-utilised techniques, such as ensuring access to fertiliser and legume seed. The emphasis should be on ensuring that the whole package is eventually adopted to maximise environmental and productivity gains.

CHAPTER 6

ABANDONMENT OF CONSERVATION AGRICULTURE BY SMALLHOLDER FARMERS IN ZIMBABWE

6.1 Introduction

Following repeated bouts of severe food insecurity in Africa, several development agencies prescribed conservation agriculture (CA) as a promising response to declining yields that was suitable for drought-prone communities (Hobbs, 2007; Shaxson, 2006). The objective of CA is to manage agro-ecosystems and improve productivity, while preserving the soil. Conservation agriculture rests on the three interlinked principles of minimal soil disturbance, permanent soil cover and crop rotation (FAO, 2013). Proponents of CA have emphasised its potential to provide resilience against drought and sustainably increase crop productivity (FAO, 2001). The research studied continued adoption of manual CA, which involves farmers preparing planting basins using hand hoes. The emphasis on digging basins is central to the definition of CA among smallholders in Zimbabwe because it facilitates increased soil moisture, concentrates soil nutrients and minimises the need for tillage, thus reducing erosion from soil disturbance. Because soils in much of Zimbabwe are badly depleted, basin tillage is usually combined with use of chemical fertilisers to achieve productivity improvement. Though CA is generally purported to address the problem of intensive labour requirements in smallholder agriculture (Giller *et al.*, 2009), basin-tillage CA requires high labour input during land preparation and weeding. By allowing land preparation ahead of the onset of rains, CA does relieve a labour bottleneck at planting time.

Most studies of CA in Sub-Saharan Africa and elsewhere are limited to assessing the determinants of adoption versus non- adoption (Bekele & Drake 2003; Doss, 2006; Tura *et al.*, 2010). Abandonment is part of the adoption cycle that has historically been overlooked, despite the fact that technologies that are abandoned are as ineffective as technologies that are not adopted (Jones, 2005). In contrast to the vast number of empirical studies on technology adoption, little empirical evidence exists on the post-adoption behaviour of farmers (Oladele, 2005). The paucity of such studies may be attributed to data requirements because the analysis of decisions to retain or abandon previously adopted technologies requires information on multiple decisions over an extended period, rather than one decision at one point in time

(Uematsu *et al.*, 2010). Technology adoption decisions are inherently dynamic because farmers' decisions in one period critically depend on the decisions made in previous periods. For example, farmers do not simply decide whether to permanently adopt an improved variety permanently, but instead they make a series of decisions about whether or not to continue to using the technology (Neill& Lee, 2001). Farmer's adoption decisions need to be followed over a time period because ex-post information of technology adoption such as its continued profitability are important determinants of continued use of technology (Uematsu *et al.*, 2010). Further, understanding who continues to use the technology may indicate who benefits most from its continued use. Examination of dis-adoption and continued use can yield insights into the constraints on the spread of a technology and guide efforts to make technologies more suitable or create conditions that support their use. This study examines dis-adoption in Zimbabwe and identifies institutional and technical factors that could lead to greater continued use of the technology.

6.1.1 Background

In Zimbabwe CA programmes have been championed and supported by the United Kingdom's Department for International Development and the European Commission Humanitarian Aid Office. While CA can take many different forms, in Zimbabwe digging basins distinguishes CA from conventional farming and is potentially consistent with minimum soil disturbance, permanent soil cover, crop rotation and improved productivity. Basins also allow for concentrating the benefits of supplemental fertilisers which are required to restore the fertility of widely depleted soils. The donor community through the Protracted Relief and Recovery Program implemented CA programmes in the context of short-term, ad hoc emergency relief and subsidised safety nets, including free input deliveries and input subsidies (Anseeuw, Kapuya & Saruchera, 2012).

In Zimbabwe, CA has been promoted as a solution to the production problems facing smallholder farming families (Mazvimavi & Twomlow, 2009; Makwara, 2010). The focus of CA projects has been on the formulation of technological prescriptions for resource-poor farmers, though these prescriptions were largely developed and tested in researcher-managed trials, with only limited consideration of the problems and priorities of smallholder farmers (Stoop & Kassam, 2005; Freidrich & Kassam, 2009). The oft-asserted attractiveness and appropriateness of CA as a sustainable farming method for the poor is not reflected in patterns of uptake and continued use (Marenya & Barret, 2007; Mazvimavi & Nyamangara, 2012). Critics of CA programmes have noted that the projects have had only limited success in addressing the production constraints of smallholder farmers. Nhodo *et al.* (2011), argue that CA projects have fostered and entrenched a dependency syndrome through reliance on subsidised inputs.

Early predictions that CA would transform smallholder agriculture in Zimbabwe have been sharply contradicted by sluggish adoption despite substantial initial support from non-governmental organisations (NGOs) (Gukurume *et al.*, 2010). Adoption of CA practices in Zimbabwe was encouraged through promotion and technical support provided by both NGOs and government (Mazvimavi et al., 2008). The critical inaccessibility of inputs immediately following Zimbabwe's Fast Track Land Reform of 2000 may have made farmers particularly responsive to CA promotion that provided fertiliser and seed on the condition that recipients establish CA demonstration plots with basin tillage (Twomlow *et al*., 2008). Linking CA with inputs for vulnerable households spurred initial adoption, but continues to confound objective evaluation of CA technology. Even though promotion increased the number of farmers practising CA, expansion in the CA area has been more modest (Marongwe *et al.*, 2011). Moreover, most farmers have only adopted a subset of CA practices and more and more farmers are choosing to discontinue their use (Giller *et al.* 2009; Gowing & Palmer 2008).

This study seeks to understand factors affecting abandonment of basin CA, which was promoted in the context of emergency and relief projects in Zimbabwe. The role of NGO input support has often been assumed to be critical in the initial uptake of CA. In addition, promotion of CA has often been associated with the poor and vulnerable and more often CA is said to be a climate change adaptation strategy as well as a productivity-enhancing technology. Given these assumptions and attributes of CA, this study was therefore informed by the following hypotheses:

1. Households with greater access to NGO input and extension support are less likely to abandon CA.
2. The poor and vulnerable are more likely to continue with CA.
3. Households in the dry agro ecological zones are less likely to abandon CA
4. The greater the farming experience, the greater the likelihood of continuation.

5. Farmers who quit CA are most likely to have received less maize yields from the CA plots compared to those who persisted with the technology.

By testing these hypotheses, the researcher intends to understand the patterns of abandonment and reveal constraints on adoption and continued use. Results are expected to indicate institutional and technical interventions to make CA more suitable for smallholder farmers.

6.2 Analytical framework

The basis of the econometric model and estimation strategy is informed by farmers' utility maximisation. This framework assumes that abandonment is the optimal choice if utility from discontinuing the technology is higher than the alternative. The household decides to discontinue the use of CA in a particular year if reducing the area planted with CA to zero increases utility (Carletto *et al.*, 2007). Saha, Alan and Robert (1994) showed that adoption will be an optimal choice if the expected net marginal benefit of adoption exceeds zero. The abandonment of CA practices is treated as a binary variable equalling one in any given year when the area treated with CA practices (digging basins) is reduced to nothing and zero otherwise (Neill & Lee, 2001). Adoption and dis-adoption are not associated with high fixed costs, so it is relatively easy to adopt and abandon basin tillage. Since dis-adoption is treated as a categorical variable, logit and probit methods can be used to study the farmers' decision. In this study, the logit model will be used to model abandonment, which is a mirror reflection of adoption decisions. The probit model will be estimated as an alternative and for comparison purposes. (In practice estimations are made using STATA. The xtlogit and xtprobit commands are used as they are appropriate for panel data estimation.)

6.2.1 Data

This chapter paper uses data collected from 12 districts in four rounds of the panel survey from 2008 through to 2011. The 12 districts were located throughout the country covering high rainfall, medium rainfall, semi-arid and very arid areas. The balanced panel used in the analysis consists of 780 observations collected across four years from 195 households. Based on data from the 2007 survey round, farmers who dropped out of the survey are not different from those who continued with the panel. The level of attrition and the characteristics of the drop-outs are unlikely to introduce bias in the results.

Table 6.1 shows the number of farmers who stopped practising CA through each round of the survey. The number of farmers dropping out of CA increased steadily from 2008 to 2011. The largest drop occurred from 2009 to 2010 when there were major policy shifts in the Zimbabwean economy, such as the introduction of multiple currencies that put a halt to hyperinflation, resulting in a positive growth in gross domestic product. A number of donor-supported input distribution projects ended at this point which may have contributed to reduced adoption.

Table 6.1: Classification of farmers into persistent users and dis-adopters of CA

Season	Observations (n)	Owns CA plot (Continued user)	Dis-adoption rate (%)	Re-adoption rate (%)
2008/09	195	186	4.6	-
2009/10	195	171	12.3	3.1
2010/11	195	144	26.1	3.6.
2011/12	195	138	**29.3**	11.8

Source: Author Data Analysis, 2014

The decision to abandon CA in any given season can be reversed in subsequent years if the conditions that deter the farmer from practising CA are reversed. Farmers could have reversed the dis-adoption because of a return of some favourable conditions, such as receiving NGO input support in later years. However one only observes a few cases of re-adoption in the data.

6.2.2 Empirical model estimation

The latent variable approach is used to model the decision of a farmer to stop or continue using CA. The latent variable, utility, is unobserved, but one can observe use of CA. If a farmer chooses to dis-adopt CA, one can conclude that the incremental utility CA offers is less than zero. Thus, dis-adoption of CA is an indicator variable for utility derived from CA versus the next best alternative.

Let the latent variable C^{*}_{it} be defined as

$$C^{*}_{it} = X_{it}\beta + U_{it} + \alpha_i + \mu_t \qquad (1)$$

for farm *i* in time *t*. The variable X_{it} is a 1 x K vector (with first element equal to unity), β is a K x 1 vector of parameters. U_{it} is the normally distributed error term independent of X_{it}. α_i are time-invariant unobserved effects and μ_t is a time varying error term (Wooldridge, 2002). What is observed is an indicator variable C_{it} that represents farmer *i*'s decision at time *t* to stop practising CA:

$$C_{it} = 1[C^{*}_{it} > 0] \tag{2}$$

The distribution of C_{it} given X_{it} and the unobserved effect α_i, can be expressed as follows:

$$P\,(C_{it} = 1 \mid X_{it}, \alpha_i) = \varphi\,(X_{it}\beta + \alpha_i),\; t = 1\ldots,\, T. \tag{3}$$

The parameters of interest will be estimated using the traditional random effects logit model, which requires an assumption that V_i and X_i are independent and that α_i has a standard logistic distribution, i.e.:

$$\alpha_i / X_i \sim N\,(0, \pi^2/3). \tag{4}$$

The partial effects of the elements of X_t on the probability at the average value of α_i ($\alpha_i = 0$) are estimated using a conditional maximum likelihood approach. Maximum likelihood estimates are obtained by taking the derivative of the log-likelihood with respect to the coefficients and correlation term. This approach is used to model abandonment decisions on an already adopted technology.

The variables that are hypothesised to influence abandonment are summarised in Table 6.2, as well as the expected signs in the abandonment equations. Most of the expected signs follow from the previous literature and the author's familiarity with agriculture in Zimbabwe.

Dis-adoption is measured as a dummy variable equal to one in any year a farmer has no plot under basin-tillage CA and equal to zero if he/she has some land under CA. The NGO support variable attempts to capture access to CA education and relevant inputs. NGO support is measured as a proportion of households in a given ward that receive NGO support in any given year. Input support was mainly delivered in response to lack of farming inputs because of the deteriorating macroeconomic environment and drought prevailing in the country. Tropical livestock units (TLU) captures the value of all livestock (on four legs only) owned by a household. Each class of livestock is given a subjective value, depending on its relative importance to the household, with very high values allocated to cattle and the smallest allocated to goats and sheep. The total value of assets is measured by aggregating the value of all assets owned by the household based on 2011 prices at the village level. The total cropped area is the log of the sum of all plots cultivated by a household measured in square metres (m^2). The lag of maize yield is the average maize yield of the household, whether from conventional or CA plots, from the previous season. Ecological zones in Zimbabwe are classified as natural regions (NR) numbered I to V. The most humid NR is I while NR IV and V are semi-arid to arid. The rest of the variables are measured as explained in Table 6.2.

The model is specified based on the assumption that dis-adoption is likely to be impacted by many of the same factors that influenced adoption. These factors can be classified as human capital (e.g. education, age), farm assets endowments and institutional and policy variables that are external to the household (Wendland & Sills, 2008). Institutional factors such as extension visits and access to NGO input support are expected to influence the adoption of CA practices. Extension provides farmers with information on the availability and properties of the new technology and technical skills for using it (Wozniak, 1994). Fertiliser donations are often linked to digging basins hence farmers with more access to free fertiliser are likely to use basin tillage. However, the sustainability of such incentivised adoption is questionable, as observed by abandonment of CA once project support is ceased.

Table 6.2: Definition of variable used in the model and their expected signs

Variable	Definition	Expected sign
Dis-adopt	Household without a CA plot (0= continued use, 1= dis-adopt)	Dependent variable
NGO support	Availability of NGO support (% of households receiving NGO support per ward)	-
Total livestock holdings	Total livestock by household in tropical livestock units (TLU)	+
Total value of assets	Total value of household assets in US$	+
Total cropped area	Log of total land under cropping for the season (m^2)	-
Total no. of plots	Number of plots used by the household in any season	-
Household size	Number of individuals in the household	-
Male head	Head of household is male (1=yes; 0 otherwise)	-/+
NR III	Household in Natural region III (1=yes; 0 otherwise)	-
NR IV	Household in Natural region IV (1=yes; 0 otherwise)	-
NR V	Household in Natural region V (1=yes; 0 otherwise)	-
2009	2009 round of survey 1=yes; 0 otherwise)	+
2010	2010 round of survey 1=yes; 0 otherwise)	+
2011	2011 round of survey 1=yes; 0 otherwise)	+
CA experience	Years of using CA since first training (Years)	-/+
Farming experience	Years since household started farming (Years)	-/+
Education	Years of schooling of household head (Years)	-/+
Age	Age of household head	-/+
Lead farmer	Selected to assist other farmers with CA (1=yes; 0 otherwise)	-
Extension visits	Frequency of extension contacts within a season	-
Lag maize yield	Previous year's maize yield for the household (kg/ha)	-

Source: Author Data Analysis, 2014

Lack of access to farm assets such as land or livestock, is also expected to limit the use of modern technologies. Nega and Sanders (2006) found that ownership of livestock promotes adoption and continued use of improved maize seed, since it generates income to finance the inputs associated with technology and reduces the risks arising from crop failure. The technology under the current analysis does not require much land. Ndlovu *et al. (*2013) and Mazvimavi *et al*. (2008), assert that CA is practiced on smaller plot compared to conventionally tilled plots, thus land is not a binding constraint to CA adoption. Digging basins is meant to enable farmers with no access to draft power to plant early so that ownership of cattle may diminish the appeal of the practice of digging basins. Given the characteristics of the technology under investigation, it is expected that continued use will be prevalent among the poor, who face constraints such as limited land and livestock.

Human capital endowments, usually captured by age, experience and education, are the main factors treated in decisions of the household. Education increases the ability of farmers to obtain, process and use information relevant to the technology leading to greater use and sustainability of new technologies (Wozniak, 1994). Literate household heads are more likely to make informed decisions and apply a combination of practices effectively. Haggblade and Tembo (2003) note that the level of education and experience influences farmers´ ability to manage the technology. However, it is difficult to hypothesise *a priori* on the impact of experience on dis-adoption. More experience may allow learning by doing, which can make a new technology more profitable. On the other hand experience, might confirm that the technology is inappropriate.

The study hypothesise that households with greater access to household labour support continued use of CA, while smaller households have a higher likelihood of dis-adopting because labour constraints may inhibit the use of CA. This hypothesis is supported by observations made by Grabowski (2011), that adoption of basin CA is constrained by increased labour requirements for land preparation and weeding. Sustained adoption is more likely in labour-abundant households. Female-headed households typically have less access to labour and other productive resources, leading to low levels of adoption and high levels of dis-adoption (Croppenstedt *et al.*, 2003). However programmes promoting CA targeted resource-constrained smallholder farmers, including female-headed households. Because female-headed households were targets for training, they may be unlikely to dis-adopt, but labour shortages and other gender-specific constraints might encourage dis-adoption in these households.

Agro ecology has a strong effect on yield and is a major factor influencing adoption and sustained use of CA practices. Chapter 4 of this thesis, provided evidence that using CA in the drier areas has a negative yield impact. This implies that farmers in the dry areas of NR IV and V are more likely to dis- adopt because they get less benefits from using CA compared to their counterparts in the wetter agro-ecological zones.

6.3 Results and Discussion

6.3.1 Categorisation of CA users: Descriptive statistics

Sample households were classified as dis-adopters if they stopped using CA in any given season and continued users if they had any fields under CA. Table 6.3 gives the descriptive statistics for the variables used in the abandonment model and compares the characteristics of continued users and dis-adopters of CA. Approximately 72% of the sample farmers had access to input support from NGOs. The average age for the household head was 53, had six years of formal education with average farming experience of 27 years of which five years were years of CA experience. A quarter of the sample farmers were lead farmers. An average household owned assets to the value of US $648 and livestock amounting to 2.89 TLU and had six members. Among the sample households, the poorest did not own any assets or livestock. The distribution of farmers according to agro ecological zones (NRII, III, IV and V) was 23.1%, 24.4 %, 32.2% and 20.6%, respectively.

There were significant differences between the dis-adopters and other farmers in terms of access to NGO input support and based on the value of household assets (in US dollars), size of cropped land (in square metres), number of plots cultivated, household size, CA experience, being a lead farmer and being located in NR II or NR V, a high and low- potential farming region respectively. Female headed households are more likely to continue with the CA technology compared to their male counterparts. A male headed household is likely to abandon CA because of more livelihood options and better access to resources and off- farm work. This is supported by Low (1968) who found that favourable off farm opportunities had a negative impact on agriculture. Similarly for this study, the availability of off farm employment opportunities has resulted in male headed households quitting CA unlike their female counterparts with limited options. There were more households getting input support from NGOs among continued users compared to abandoners of CA. However, those who abandoned were wealthier compared to persistent users indicating that the poor persisted with CA.

To assess how performance of the technology affects farmer's planning decisions, the lag of the average maize yield was used to compare if there were any differences between those who continued with the technology and those who quit. The results show that on average the two group of farmers received more or less similar amounts of maize yield in the previous season. However for technology specific results, maize yields from CA plots is higher for the continued users of CA compared to the abandoners at the 10% level of significance. This finding supports the hypothesis that farmers who are likely to quit CA would have experienced a poor performance of CA in previous seasons compared to those who continued. Similarly maize yield under conventional agriculture is higher among abandoners compared to the continued users though the difference is not significant. However, the difference in the average yield of maize under CA and conventional agriculture is almost twice as large for the continued users compared to those who quit the CA practice. The difference between the two groups is not statistically significant but the magnitude of the difference is according to expectation.

Table 6.3: Comparison of characteristics of continued users and dis-adopters

Variable	Full sample (n=780)	Continued user (n=639)	Dis-adopter (n=141)	Difference between continued users and abandoners
NGO input support	0.72	0.74	0.64	0.1***
Total livestock value	2.89	2.81	3.26	-0.45
Total value of assets	648.58	592.49	902.78	-310.29**
Total cropped area	9.48	9.30	9.52	-0.22**
Total no of plots	5.70	5.98	4.42	0.54***
Household size	6.34	6.43	5.89	0.54*
Female head	0.50	0.49	0.55	-0.06
NR II	0.23	0.25	0.14	0.11**
NR III	0.24	0.23	0.28	0.05
NR IV	0.32	0.33	0.30	0.03
NR V	0.21	0.20	0.28	0.08**
2009	0.25	0.27	0.17	0.1**
2010	0.25	0.23	0.36	0.13***
2011	0.25	0.22	0.40	-0.18****
CA experience	4.74	4.61	5.36	-0.75***
Farming experience	26.66	26.91	25.54	1.37
Education	6.41	6.43	6.33	0.1
Age	53.12	52.77	54.70	-0.2
Lead farmer	0.25	0.26	0.19	0.6*
Lmaizeyield	1326.40	1415.03	1012.66	403.37*
LCA maize yield	1753.40	1813.20	1415.89	327.49
LNonCA maize yield	798.32	778.98	800.31	21.33
Difference Lmaizeyield (CA- Non CA)	964.08	1082.97.	537.63	545.34

*Significance at the 10%, 5 %, and 1% levels are indicated by *, ** and *** respectively* .Source: *Author Data Analysis, 2014*

6.3.2 Determinants of abandonment: Econometric estimation

Table 6.4 presents the estimates of the abandonment model among CA beneficiaries. The dependent variable equals one if there is no area under CA and zero otherwise. Therefore, a positive coefficient indicates that the corresponding explanatory variable is positively associated with abandonment. Three model specifications have been estimated for the random effects logistic model. Model 1 represents a generalised estimation of the logit model, while Model 2 is the same as Model 1, except that it has various interaction terms added. Model 3 replicates Model 1 but it includes the lag of maize yield as an explanatory variable. The use of lagged measures of yield is meant to address the potential endogeneity of key farm-level adoption determinants that arise when using cross-sectional data (Barham, Smith & Moon, 2002). The null hypothesis that all coefficients are simultaneously zero is rejected consistently at the 99% significance level, while the percentages of the correctly predicted positive outcome (dis-adoption) are between five and 12% for all model specifications.

Overall, access to NGO support, farming experience and household size significantly reduce the probability of abandoning CA. In turn, wealth indicators such as value of household assets owned by the household, including number of plots cultivated by a household as well as the year dummies and drier agro-ecology, significantly increase the probability of dis-adoption of CA. Probit model results presented in Table 6.5 are similar to those in Table 6.4 and are largely consistent with expected results in Table 6.2.

Access to NGO input support can help to overcome the challenges and constraints of adopting CA. Study results indicate that if a ward has a higher level of NGO support, households in that ward are likely to continue using CA. This variable is highly significant across the three model specifications. Female-headed households that have greater access to NGO input support are even more likely to persist with CA, as indicated by a 10% level of significance of the interaction of NGO support and female-headed households. Female- headed households are therefore particularly responsive to NGO support and are likely to persist with CA as a livelihood option and food security strategy when support is offered. The interaction of NGO support and livestock ownership is positive and significant at 5% level, implying that households with more livestock assets are less influenced by NGO promotion than others. Overall, greater livestock assets correspond to greater likelihood of dis-adoption and a lower impact from NGOs. Given that livestock increases the availability of manure, the fertiliser provided by the NGOs may provide less of an incentive to adopt CA. Further, easier access to livestock implies that a household has fewer incentives to use basin-tillage for land preparation.

The total cropped area has no effect on the decision to abandon CA, but the number of plots cultivated has implications for dis-adoption decisions. Households with more fragmented plots persist with CA, presumably because they have more experimental options and a greater capacity to spread risk over several fields than if they had fewer plots. Wealthier households, indicated by possession of asset of higher value, are more likely to abandon CA than poor households. Wealthier households have a larger resource base and are likely to pursue other off-farm livelihood strategies and conventional tillage, since CA is promoted as a technology for the poor. Female-headed households are likely to persist with CA, unlike their male counterparts.

A larger household size implies greater access to labour leading to a higher probability of continuing with CA compared to households with smaller families. Larger families are less labour-constrained and are likely to persist with digging basins because they pool their labour resources. Experienced farmers tend to persist with CA, suggesting that acquired experience and knowledge increases the return to using CA. Since CA is a knowledge-intensive technology, learning by doing may come into play, resulting in experienced farmers most likely to continue using this technology.

Basin digging is enhanced by fertiliser application which is why the form of CA promoted in Zimbabwe is associated with small doses of nitrogen fertiliser and less emphasis on mulching (Nyamangara *et al.,* 2014). Though CA is expected to overcome the constraint of rain water under dry-land farming, results indicate that farmers in the dry areas of NR V are more likely to stop practising CA, compared to those in the wetter areas of NR II. Locational factors have an impact on adoption and dis-adoption decisions. In Zambia, farmers in the drier regions adopted CA because of its water-conserving properties (Haggablade &Tembo, 2003, Chomba, 2004). However, this study found that farmers in the drier areas are likely to quit CA. This result may be due to differences in the cropping systems, with maize dominating in NR II and NR III, but small grains (sorghum and millet) becoming more common in NR IV and V.

Table 6.4: Logit estimates of abandonment of CA

Variable	Model 1 Coefficient	Model 1 Marginal Effect	Model 2 Coefficient	Model 2 Marginal Effect	Model 3 Coefficient	Model 3 Marginal Effect
NGO support	-2.364*** (0.710)	-0.125**	-2.449** (1.024)	-0.117**	-2.295*** (0.615)	-0.238***
Total cropped area	0.057 (0.218)	0.027	0.049 (0.223)	0.002	-0.030 (0.228)	-0.003
Total no of plots	-0.510*** (0.087)	0.033***	-0.512*** (0.089)	0.024***	-0.330*** (0.079)	-0.034***
Total value of assets	0.0003* (0.0002)	0.0002*	0.0003* (0.0002)	0.00002*	0.0004* (0.0002)	0.00004*
Total livestock value	0.057 (0.050)	0.003	-0.224 (0.140)	0.011	0.031 (0.059)	0.003
Education	0.014 (0.057)	0.001	0.003 (0.060)	0.0001	-0.040 (0.057)	-0.004
Age	0.033* (0.019)	0.002*	0.033* (0.020)	0.002*	0.037* (0.020)	0.004*
Farming experience	-0.036** (0.017)	-0.002**	-0.039** (0.018)	0.002**	-0.044** (0.018)	-0.005
Household size	-0.098* (0.057)	0.005*	-0.114** (0.059)	0.005*	-0.089 (0.060)	-0.010
*Female head	-0.620* (0.379)	0.033*	0.924 (0.912)	0.045	0.088 (0.367)	0.010
*NR III	1.179** (0.557)	0.084*	1.053* (0.584)	0.066	0.769 (0.540)	0.093
*NR IV	1.380*** (0.544)	0.094**	1.389** (0.571)	0.087*	0.991* (0.531)	0.117*
*NR V	1.948*** (0.570)	0.178**	2.016*** (0.598)	0.173**	1.389** (0.566)	0.198**
*2009	1.466*** (0.508)	0.111**	1.627*** (0.531)	0.118**		
*2010	3.880*** (0.561)	0.499***	4.108*** (0.594)	0.516***		
*2011	2.982*** (0.548)	0.329***	3.142*** (0.576)	0.334***		
Lead farmer	-0.143 (0.407)	-0.007	0.061 (0.424)	0.003	-0.353 (0.413)	-0.034
Lmaize _yield					-0.0003 (0.0001)	-0.00001
NGO*female			-2.279* (1.190)	.-0.109*		
NGO*livestock			0.421** (0.189)	0.020**		
Constant	-2.283 (2.298)		-2.112 (2.382)		0.811 (2.338)	
Observations	780		780		564	
Log likelihood	-265.202		-261.414		-240.997	
Predicted likelihood for dis-adoption (%)	5.6		5.0		11.7	
AIC	568.895		564.827		515.994	
BIC	657.421		662.672		589.659	

Standard errors in parentheses. *Significance at the 10%, 5 %, and 1% levels are indicated by *, ** and *** respectively.* (*) *dy/dx is for discrete change of dummy variable from 0 to 1.Source: Author Data analysis, 2014*

The level of education and being a lead farmer do not affect abandonment decisions. Performance indicators such as previous maize yield do not seem to have an impact on the current decision to abandon CA, as had been hypothesised. The test for robustness was carried out by dropping re-adopters in all model specifications of abandonment. The household size variable, total asset and livestock variable and female headed household variable were not robust. Their significance diminished across all the model specifications. However, the results for the number of plots and access to NGO support were robust across all specifications.

Table 6.4 and 6.5 also displays marginal effects, which measure the percentage change in the probability of adoption owing to a one-unit change in an explanatory variable. Marginal effects for the continuous variables in the logit models are equal to:

$$ME = \beta P\,(1-P), \qquad (5)$$

and in the probit model are equal to:

$$ME = \phi\,(\beta \mathbf{X})\,\beta^{-1}, \qquad (6)$$

where ϕ is the event probability at the chosen setting of X and X is the vector of exogenous variables and β are the estimated parameters for X (Madalla, 1983). The marginal effects are measured at the mean value of the repressors. Marginal effects for the dummy variables are measured by taking the difference between the value of the prediction when the dummy equals one and when it equals zero, holding all other variables at their respective means (STATA, 2003).

Support from NGOs has the largest marginal effect in all model specifications for CA abandonment, followed by the year and natural region dummies. The number of plots cultivated by the farmer also has a strong marginal effect. Increasing the percentage of households receiving NGO support in the ward by 1% in any given year reduces the probability of dis-adopting CA by 12%. Among female-headed households this effect is almost twice as great. Meanwhile, an adding a plot to the household fields reduces the same probability by about 8%.

Table 6.5: Probit estimates of abandonment of CA

Variable	Model 1		Model 2		Model 3	
	Coefficient	Marginal Effect	Coefficient	Coefficient	Marginal Effect	Coefficient
NGO support	-1.291*** (0.393)	-0.148**	-1.352** (0.567)	-0.142**	-0.148**	-1.352** (0.567)
Total cropped area	0.045 (0.121)	0.005	0.0410 (.123)	0.004	0.005	0.0410 (.123)
Total no of plots	-0.288*** (0.048)	0.033***	-0.287*** (0.048)	0.030***	0.033***	-0.287*** (0.048)
Total value of assets	0.0002* (0.0001)	0.0002*	0.0002* (0.0001)	0.00002*	0.0002*	0.0002* (0.0001)
Total livestock value	0.032 (0.028)	0.004	-0.124 (0.079)	0.013	0.004	-0.124 (0.079)
Education	0.010 (0.032)	0.001	0.004 (0.032)	0.0004	0.001	0.004 (0.032)
Age	0.018* (0.011)	0.002*	0.018* (0.011)	0.002	0.002*	0.018* (0.011)
Farming experience	-0.020** (0.010)	-0.002**	-0.022** (0.010)	0.002**	-0.002**	-0.022** (0.010)
Household size	-0.058* (0.032)	0.007*	-0.066** (0.033)	0.007*	0.007*	-0.066** (0.033)
*Female head	-0.360* (0.210)	0.042*	0.474 (0.506)	0.050	0.042*	0.474 (0.506)
*NR III	0.661** (0.316)	0.100*	0.590* (0.318)	0.080	0.100*	0.590* (0.318)
*NR IV	0.770*** (0.315)	0.111**	0.771** (0.312)	0.103*	0.111**	0.771** (0.312)
*NR V	1.078*** (0.323)	0.198**	1.108*** (0.327)	0.193**		
*2009	0.788*** (0.276)	0.124**	0.876*** (0.286)	0.132**		
*2010	2.128*** (0.314)	0.490***	2.247*** (0.314)	0.506***		
*2011	1.638*** (0.322)	0.340***	1.720*** (0.306)	0.346***		
Lead farmer	-0.028 (0.223)	-0.003	0.010 (0.231)	0.001	-0.194 (0.233)	-0.038
Lmaize _yield					-0.00002 (0.00004)	-0.00001
NGO*female			-1.222* (0.656)	.-0.128*		
NGO*livestock			0.234** (0.106)	0.025**		
Constant	-1.354 (1.298)		-1.262 (1.318)		0.511 (1.325)	
Observations	780		780		564	
Log likelihood	-265.447		-261.760		-240.912	
Predicted likelihood for dis-adoption (%)	5.7		5.1		12.4	
AIC	568.895		565.510		515.824	
BIC	657.421		663.365		589.490	

*Standard errors in parentheses. Significance at the 10%, 5 %, and 1% levels are indicated by *, ** and *** respectively. (*) dy/dx is for discrete change of dummy variable from 0 to 1.Source: Author Data analysis, 2014*

An additional year of farming experience reduces the probability of abandoning CA by 1.9% whereas an additional year added to the age of the household head increases the probability by 1.7%. The marginal effect of the total value of assets is 0.03%. The year dummies and agro-ecology are positively related to abandonment of CA. As one would suspect, households were more likely to have abandoned CA in 2010 when NGO activity declined compared to 2008. The probability of quitting CA increased by 50% in 2010, then dropped to 32 % in 2011 and finally 10% in 2009. Households in the drier areas of NR V and NR IV were respectively 19% and 11% more likely to stop using CA.

The logit model has lower AIC and BIC values compared to the probit model indicating a better fit.

6.4 Conclusion

This chapter contributes to the literature on agricultural technology adoption generally and specifically on CA adoption in the context of Zimbabwe. In particular, this study represents one step towards understanding the post-adoption behaviour of farm households. Technology adoption requires close monitoring to determine whether households continue to use the practice and to use it appropriately. Equally important, understanding why farmers dis-adopt technology can inform efforts to develop more appropriate technical innovations or support services. The chapter provides insights into the key factors associated with dis-adoption of CA. The results reveal that human capital, asset endowment and institutional variables all affect dis-adoption decisions. Abandonment is evident despite the fact that this technology has been supported through the provision of technical knowledge and inputs and has been tested by farmers. Results point to a need for continued institutional support to enable CA practices and room for technical adaptations to CA to make is more feasible for smallholders.

The observed relationship between the loss of NGO support and abandonment of CA suggests that understanding the importance of subsidised input provision is essential to design future programmes for CA promotion. Continued incentives and support services may be necessary to ensure that farmers continue to use CA. As practised in Zimbabwe, CA is most effective if it includes the use of chemical fertilisers. If these fertilisers are unavailable, CA is unlikely to be practised. In the past fertiliser distribution was closely linked to NGO programmes. While it is clear that loss of those programmes has contributed to the abandonment of CA, it is not clear whether commercial fertiliser has been available in the absence of NGO programmes. As a result, it is difficult to discern whether private sector distribution of fertiliser could support CA practices in the absence of NGO services. Research to understand the role of the private sector in distributing fertiliser and thereby facilitating CA might yield insights into alternative mechanisms to encourage the practice sustainably.

In addition to institutions to ensure access to inputs needed to make CA profitable, results indicate that institutions to help farmers learn to use CA could be important. CA is a complicated and labour intensive technology. Farmers who have practiced CA over a protracted period persist with the practice. The use of CA seems to be enhanced through learning by doing, since it takes time to appreciate and understand how the technology works. The use of demonstration plots and effective technical backstopping support may be useful when designing CA promotional programmes and continued advisory services may support continued CA practice. The performance of the technology and its profitability are key determinants in the acceptability of any technology by farmers.

These findings suggest that poor, vulnerable households are more likely to persist with CA than wealthier households. This result confirms that CA is accessible to the poor, who are the target group for this technology. Institutional innovations could support expanded use by the poor, but some households appear to be less suited to the technology because of technical rather than institutional factors.

A strong tendency towards dis-adoption in semi-arid and arid regions such NR V raises the question about the suitability of CA in those regions. However, it is unclear whether the weak persistence of CA in those marginal regions is due to ecological or institutional factors. That the areas where dis-adoption is most common are also areas better suited to millet and sorghum than maize, suggests that there may be room to adapt CA better to settings where maize is a secondary rather than primary crop.

The observation that increased household size reduces the probability of dis-adoption suggests that labour constraints may prohibit some households from practising CA. Technical innovations to reduce labour demands, as well as effective extension to facilitate learning, could contribute to more persistent use of CA.

The analysis clearly indicates that better screening of agro-ecological and socio-economic constraints and incentives for adoption of CA are needed in order to achieve effective and durable adoption of CA in Zimbabwe. The CA policy should be aimed at supporting poor and vulnerable farmers with inputs and extension advice so that they sustainably adopt this pro-poor technology. However, defining the appropriate system for ensuring delivery of inputs and services remains a challenge.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

7.1 Introduction

This chapter summarises the major findings and presents conclusions and recommendations based on the empirical results of this study. The chapter also gives an overview of policy implications of the findings in the study. The chapter begins by reconsidering the study objectives that guided this study and a summary of insights and recommendations for policy. Lastly the chapter makes suggestions on the areas that merit further research.

7.2 Summary findings

Farmers practising CA across Africa have provided feedback and reported significant positive impact on their incomes, livelihood, and well-being and on the empowerment of women farmers. As a result many governments in Africa have realised the need to channel massive investment of resources towards the promotion of CA and creating an environment conducive for its adoption. However, scientists have been cautioned against promoting CA as a panacea to agricultural challenges associated with poor performance in SSA and it has been pointed out that there has been no critical analysis of CA's potential in the region (Giller *et al.*, 2009). It is therefore necessary to test, tailor and target the relevant components of CA across the diverse agro-ecological and socio-economic conditions of different countries in pursuit of food-security goals.

This study specifically sort to:

1. Assess the yield impact of CA,
2. Investigate the determinants of adoption intensity and
3. Evaluate the determinants of abandonment of CA

The first stage analysed the impact of CA adoption on maize yield. Yield was measured through the Cobb-Douglas production function estimation. Based on evidence from the four- year panel (2008-2011), the OLS and household fixed effects estimation provide undisputed evidence of a positive and significant impact of the CA technology on yield.

The second stage of analysis applied the Poisson and a negative binomial regression models were applied in the estimation of the farmers' decision on how many CA techniques they adopted. The greater the number of practices employed the higher the adoption intensity and productivity level. High productivity is observed under high intensity levels of use because CA components have a complementary effect on each other.The analysis shows that agro ecology, NGO support, learning from doing effect, education, draft power and labour have a significant impact on the number of CA components adopted.

Lastly, in assessing the determinants of abandonment, a random effect logit and probit models were employed. The analysis concluded that access to NGO support, farming experience and household size significantly reduce the probability of abandoning CA. In turn, wealth indicators such as value of household assets owned by the household, including number of plots cultivated by a household as well as the year dummies and drier agro-ecology, significantly increase the probability of dis-adoption of CA. Abandonment is evident regardless of the fact that this technology is supported through provision of technical knowledge and inputs.

7.3 Conclusions

Using the three analytical approaches to answer the research questions set, this study has drawn a number of conclusions based on key variables such as CA experience, female headed households, household size, agro-ecology, number of CA components used and NGO support.

Farmers who have practiced CA over a protracted period persist with the practice. In addition, experienced farmers apply more CA techniques and CA experience has a positive impact on yield. The use of CA seems to be enhanced through learning by doing, since it takes time to appreciate and understand how the technology works. It can be concluded that training and education are important in enhancing adoption intensity, improving yields and encouraging persistent adoption. The use of demonstration plots and effective technical backstopping support may be useful when designing CA promotional programmes and continued advisory services may support continued and high intensity CA practices.

Female-headed households tend to be more vulnerable and have more limited resources and as a result they tend to receive more support which improves the efficacy of CA. Female headed households show significantly higher yields than their male counterpart in this study because they are more responsive to NGO support. More so, female headed households persist with CA even with no inputs. However, female headed household who practise CA tend to get less out of adopting CA than their male counterparts. Therefore there is need to address gender specific constraints which affect the performance of CA such as limited supply of household labour.

Smaller households with limited family labour tend to use more component of the CA package and this in turn translates to high levels of productivity. Effectively labour does not impair the intensity of adoption but persistent use of CA. The observation that increased household size reduces the probability of dis-adoption suggests that labour constraints may prohibit some households from practising CA. Higher weeding frequency has a positive impact on yield and CA plots are weeded more frequently than conventionally tilled plots. The increased weeding frequency coupled with the drudgery of digging basins has implications for labour demand of CA. Technical innovations to reduce labour demands, as well as effective extension to facilitate learning, could contribute to more persistent use of CA. Though labour is an important limiting factor in the implementation of CA but has not been captured accurately for the purposes of this study.

The techniques used in the previous year have a positive effect on the number of practices used in the current season. This implies that CA is becoming more intensively practised in a relatively endogenous manner. The complementarity of CA components tend to support farmers because performance with only partial adoption encourage farmers to use CA. This is supported by the finding that yield increases by 7.6% per each additional CA technique applied, the more techniques applied the greater the yield impact. Application of basic CA with no fertiliser added can increase yield by almost 100%. This implies that even the poor and vulnerable with no access to draft power and soil fertility enhancing inputs can capture this yield gain by applying CA. Therefore, the accessibility of CA to the poor is thus confirmed. This is further reinforced by the finding that wealthier households in term of assets and livestock had a higher likelihood of abandoning CA in pursuit of conventional agriculture. Institutional innovations could support expanded use of CA by the poor, but some households appear to be less suited to the technology because of technical rather than institutional factors.

Farmers in drier areas tend to employ fewer components of the CA package because production constraints and adverse agro-ecological conditions are more limiting. In the semi-arid regions, the use of crop residues as mulch is constrained by low biomass production and competing use of crop residues with livestock. However, adverse agro-ecological conditions of the semi-arid areas do not affect the impact of CA on yield which is positive and significant. This suggests that lower adoption rates of CA in dry areas than in higher potential areas may be due to factors other than the natural environment. A strong tendency towards dis-adoption in semi-arid and arid regions like NR V raises the question about the suitability of CA in those regions. However, it is unclear whether the weak persistence of CA in those marginal regions is due to ecological or institutional factors.

As practised in Zimbabwe, CA is most effective if it includes the use of chemical fertilisers. Fertiliser enhances the efficacy of digging basins, especially in the semi-arid regions. Top-dressing fertiliser is the only form of input from NGOs that has a significant impact on yield. Therefore, investing in nitrogen fertiliser produces a larger impact compared to other inputs. Farmers who received some form of NGO input support, adopted more components than those who did not receive any inputs. In addition, there is a very strong and robust relationship between NGO support and abandonment of CA. This finding suggest that incentives are necessary to ensure that farmers continue to use CA as a productivity boosting and sustainable farming method. The finding that the lagged number of practices applied positively affects adoption intensity suggests that there could be a lingering effect of NGO promotion on future use of CA practices.

The major finding of this study is that practice of CA leads to significantly higher yields of the most important crop in Zimbabwe, yet there is evidence that a number of farmers have discontinued the practice. The paradox of high yield effect and high abandonment is not so inexplicable when the yield effect is considered as good but not fantastic. The yield effect is not good for female headed households and in the dry areas. It can be argued that even in the absence of subsidized inputs from NGOs, the yield increases should be enough motivation for the farmers not to stop CA and apply only those components which do not require cash inputs. The study found that CA plots are relatively smaller which makes the labour requirement less in addition to the fact that some of the labour demands are off season. It can therefore be concluded from this study that the performance of the technology and its profitability are key determinants in the acceptability of any technology by farmers.

The yield impact is real but not as great as some studies suggested. The scale of the yield effect is relative to the specific gender and environmental challenges to adoption. This study has pointed to some indicators on whether CA is relevant for the smallholder farmers. However, it is not conclusive about the factors encouraging CA abandonment. The question remains to whether these factors can be addressed by investments, can they be avoided by modifying the CA package or they just need to be accepted as setting the limits on the adoption on CA.

7.4 Key implications for policy

Zimbabwe is economically and socially justified to support the adoption of CA by farmers. Technology adoption requires close monitoring to determine whether households continue to use CA practices and to use them appropriately. Therefore, better screening of agro-ecological and socio-economic constraints and incentives for adoption of CA are needed in order to achieve effective and durable adoption of CA in Zimbabwe. Furthermore incentives are necessary to ensure that farmers continue to use CA as a productivity boosting and sustainable farming method. Policy interventions may include both market interventions and institutional changes to reduce the barriers to CA adoption. From the above findings and conclusions, the following policy implications were derived.

- The CA policy should be aimed at supporting the poor and vulnerable farmers with inputs and extension advise so that they sustainably adopt this pro-poor technology. Since targeting poor farmers may be the main vehicle for maximising poverty alleviation effects of CA adoption. There is need to incorporate a poverty dimension into agricultural priority setting.
- In order to address the liquidity and supply constraints faced by poor farmers with regards to CA , Zimbabwe should implement various forms of “smart subsidies “ that target specific farmers. However, defining the appropriate system for ensuring delivery of inputs and services remains a challenge.
- Technical innovations to reduce labour demands as well as effective extension to facilitate learning could contribute to greater persistent use of CA. There is greater need for technical adaptations to CA to make is more feasible for smallholders.
- The use of demonstration plots and effective technical backstopping support may be useful when designing CA promotional programmes and continued advisory services may support continued CA practice.

7.4 Direction for future research

The study was certainly not exhaustive and had its limitations emanating from the data, time and methodological constraints. In the absence of these constraints, the value of the research could be enhanced by allowing a more comprehensive analysis as suggested below.

The current study found results which were at odd with each other such as abandonment of CA in the face of improved crop yields of the staple crop. This finding can be explored through a qualitative study to find out why farmers place greater value of subsidized inputs compared to their own yield gain. This will give insights to the fact that farmers overlook the performance of the technology especially in the absence of subsidized inputs. The issues surrounding the targeting of the CA technology especially the role of incentives in promoting or discouraging sustainable adoption can be debated through focus group discussions. Lastly a detailed focus group can be used to assess the value placed on off season activities and how they support or conflict with labour requirements of CA. The fact that the yield effect is lower for female headed households and in drier areas can be a basis for future studies exploring on why some sets of households get less yield benefits and what can be done to make the technology more useful to more people.

The current study failed to capture the demand for labour an important input in the implementation of CA. A measure of labour required for each field activity, even if it is based on farmer recall or even when only self –reported should be included in future studies. This will enable the analysis to come up with returns to labour which gives an indication of the attractiveness of CA relative to conventional tillage. Efforts to extent the current analyses to include a counterfactual and broader measure of household welfare would enhance the impact analysis. Future similar studies may seek to identify appropriate instrumental variables (IVs) in order to deal directly with endogeneity problems and clarify the causality behind the estimated associations. Therefore future research should focus on the full impact assessment of CA at the farm household level.

The future research agenda should be aimed at incorporating a detailed plot level data for soil characteristics to assess the biophysical impact of CA over time. A longer duration panel can capture effectively the dynamics of adoption. Furthermore, future research should focus on the impact of different classifications poverty categories on abandonment decisions and adoption intensity. Research to understand the role of the private sector in distributing fertiliser and thereby facilitating CA might yield insights into alternative mechanisms to encourage the practice sustainably.

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