The Influence of Conservation Agriculture Adoption on Input Demand and Maize Production in Butha Buthe, Lesotho

A Thesis
Presented for the
Master of Science Degree
The University of Tennessee, Knoxville

Eric Bisangwa
August 2013

ACKNOWLEDGEMENTS

First and foremost, I offer my sincerest gratitude to my major professor Dr. Dayton M. Lambert who has supported me throughout my thesis with his inspirations, patience, knowledge, valuable suggestions and endless help during my study in the Department of Agricultural and Natural Resource Economics at the University of Tennessee. I would also like to thank my graduate committee members: Dr. Roland K. Roberts, Dr. William M. Park, Dr. Neal Eash, and Dr. Michael D. Wilcox, Jr. for their extremely helpful corrections, support and advice on my thesis and classes.

This master's education would never be possible without the financial, spiritual and moral support and prayers from Blount Community Church leaders and members. I am forever grateful for my God-given family in the U.S., Duane Graves, Ph. D and Jennie Graves, their daughters, Rachel and Andrea, and their sons-in-law and family members for their support and acceptance of me in their family and for their love. You have all made me feel at home and made my academic carrier easy, and I am eternally grateful for everything you have done for me.

I am very honored to have studied and worked with wonderful students some of whom grew to be my friends in the department and who for almost 3 years offered me great help support and encouragement: Pattarawan Watcharaanantapong, Tingting Tong, Haijing Zhuang, Daegoon Lee, Tianpeng Zhou, Shikha, Olga Khaliukova, Zidong (Mark) Wang, William McNair, Carey Wolanin and other friends. I am so grateful for what they have done for me.

Portions of this thesis were made possible by the United States Agency for International Development and the generous support of the American People for the Sustainable Agriculture and Natural Resources Management Collaborative Research Support Program under terms of

Cooperative Agreement No. EPP-A-00-04-00013-00 to the Office of International Research, Education, and Development at Virginia Polytechnic Institute and State University.

ABSTRACT

This thesis examines the factors influencing adoption of conservation agriculture (CA) technologies and the effects adoption has on input demand, maize production, and farm profit in the province of Butha Buthe, Lesotho. In Lesotho, conventional agricultural practices such as plowing and brush burning for land preparation continue to cause soil erosion and reduce yields. Conservation agriculture technologies have been promoted by various organizations to improve soil structure, conserve water, reduce soil erosion, improve farmer household wellbeing, and increase food security. However, adoption of CA by smallholder farmers in Lesotho and other sub-Saharan countries has been relatively slow.

Using data from a survey of 432 households, this thesis applies regression analysis to determine the factors influencing farmer adoption decisions of CA. Findings suggest that the use of CA practices is related to a number of household, farm and farmer characteristics, and the presence of extension efforts in the surveyed region. Agricultural training, farm size, education, access to fertilizer, distance to fields, household demographic structure, livestock ownership, and input prices played an important role in the decision to use CA. Results from the adoption model suggested that CA adoption was positively associated with farm profits and labor demand for crop production. Maize production and other input demands were not associated with CA adoption.

Farmers were not responsive to prices as would be expected by profit maximizers. Farmers in Butha Buthe may not be maximizing profit with respect to input decisions for producing maize. Rather, their primary concerns may be growing maize for subsistence. The presence of non-government organizations, extension services and government efforts to promote CA in Butha Buthe may also explain the relative unresponsiveness of farmers to maize

prices and input costs. Further research isolating these causes is warranted to understand what role input prices play in determining production and inputs demand decisions given the promotion of this technology by NGOs and other extension services, and the potential role CA may play in the wellbeing of smallholder farmers in sub-Saharan Africa.

TABLE OF CONTENTS

CHAPTER 1: INTRODUCTION 1
1.1. General Background 1
1.2. Research objective 3
CHAPTER 2: LITERATURE REVIEW 4
2.1. Conservation Agriculture (CA) definition and global situation 4
2.2. Conservation agriculture situation in Africa 4
2.3. Arguments in favor of conservation agriculture 6
2.4. Concerns and challenges facing adoption of conservation agriculture 8
CHAPTER 3: CONCEPTUAL FRAMEWORK 13
3.1. Conceptual framework: agricultural household model 13
CHAPTER 4: METHODS AND PROCEDURES 23
4.1. Data 23
4.2. Quadratic approximation of the normalized restricted profit function 24
4.3. Conservation Agriculture Adoption and Maize Production Decisions 27
4.4. Empirical Model 28
4.5. Factors hypothesized to influence CA adoption 30
4.5.1. Farmer characteristics hypothesized to influence CA adoption 30
4.5.2. Field level characteristics hypothesized to influence CA adoption 31
4.6. Model estimation, evaluation and analysis 32
4.6.1. Three Stage Least Squares estimation 32
4.6.2. Model diagnostics 33
CHAPTER 5: RESULTS AND DISCUSSION 35
5.1. Preliminary Analysis: Descriptive Statistics 35
5.1.1. Household Production and Consumption of Staples 36
5.1.2. Sources of household principle food staples 37
5.1.3. Income Sources 39
5.1.4. Household construction materials 40
5.1.5. Household head demographics 41
5.1.6. Household head and spouses residence 42
5.1.7. Agricultural training sources 43

5.1.8. Post harvest treatment of crop residues 44
5.1.9. Quantities of inputs used by CA and non-CA fields.. 44
5.1.10. Input prices reported in the 2010 season.. 47
5.1.11. Farmer attitudes towards farming and conservation agriculture....................................... 47
5.1.12. Conservation agriculture adoption: regression results.. 50
5.1.13. Effect of CA on input demand, maize output and field profitability 54
CHAPTER 6: CONCLUSIONS 56
References:... 58
Appendix.. 72
VITA 85

LIST OF TABLES

Table 1: Sample size of respondents who used conservation agriculture (CA). 35
Table 2: Principal food staples in Butha Buthe, Lesotho... 37
Table 3: Sources of principal food staples in Butha Buthe, Lesotho.. 38
Table 4: Household income source in Butha Buthe, Lesotho.. 40
Table 5: Roofing characteristics in Butha Buthe, Lesotho. 41
Table 6: Household demographic variables by CA adoption Status. 42
Table 7: Household head residence in Butha Buthe, Lesotho. 43
Table 8. Agricultural training by CA adoption status... 43
Table 9: Respondents reporting using crop residues. 44
Table 10. Mean quantities of inputs used and maize output by CA and non-CA fields............... 46
Table 11. Inputs prices.. 47
Table 12: Knowledge, understanding and attitudes of agriculture in Butha Buthe, Lesotho. 49
Table 13. Probit maximum likelihood estimates and marginal effects explaining CA adoption. 53
Table 14. Association between CA adoption, profit, maize yield, and inputs demand. 54
Table A1: Sampling of Households by Village 73
Table A2: Means of variables used for probit regression of CA adoption 73
Table A3: Transport means in Butha Buthe, Lesotho... 74
Table A4: General farming characteristics in Butha Buthe, Lesotho. 75
Table A5: Housing material characterization in Butha Buthe, Lesotho. 76
Table A6: Household characteristics in Butha Buthe, Lesotho. 77
Table A7: General farming characteristics in Butha Buthe, Lesotho. 78
Table A8: Storage problems in Butha Buthe. 79
Table A9: Knowledge, understanding and attitudes of Agriculture in Butha Buthe, Lesotho. 80
Table A10: Knowledge, understanding and attitudes of agriculture in Butha Buthe, Lesotho (continued). 81
Table A11: Knowledge, understanding and attitudes of agriculture in Butha Buthe, Lesotho (continued) 82
Table A12: Knowledge, understanding and attitudes of agriculture in Butha Buthe, Lesotho (continued). 83

LIST OF FIGURES

Figure 1: Profit between CA and non-CA fields. 20
Figure 2: Maize output between CA and Non-CA fields. 21
Figure 3: labor demand between CA and non-CA fields. 21
Figure 4: Fertilizer demand between CA and non-CA fields. 22
Figure 5. Villages surveyed. 84

LIST OF ATTACHMENTS

Survey used for data collection in Butha Buthe, Lesotho. Lesotho_Baseline_survey.pdf

CHAPTER 1: INTRODUCTION

1.1.General Background

Lesotho is a landlocked country surrounded by the Republic of South Africa. The Kingdom of Lesotho is known for extensive soil erosion, a history of poor land management practices, extreme topography and diverse soil composition; all of which contribute to land degradation and the formation of deep gullies called *dongas* (Showers, 2005; Marake, 2008; Pendo, 2011). These factors contribute to approximately 1 million tons of soil loss per year (Lesotho Mountains Research Group, 1996). Chronic soil loss eventually reduces crop productivity and may lead to food insecurity. Research suggests that most erosion occurs on cropland (Chakela, 1981; Ministry of Agriculture, 1996). Like many sub-Saharan African countries, subsistence farmers in Lesotho depend directly on land and water resources to feed their families.

Arable land availability is a factor limiting agricultural production, and is becoming increasingly scarce as more land is being used for urban development and extensive livestock grazing. Increasing livestock numbers and overgrazing also reduce agricultural productivity (Poulter, 1981). In 1996, only 13% of Lesotho’s total arable land was used to produce crops. By 2005, arable land dwindled to 9% (Lesotho Mountain Research Group, 1996). More frequently, landlessness poses a serious problem complicating the livelihoods of rural peoples. The proportion of landless households increased from 12.7% (in 1970) to 25.4% (in 1986) and to 32.6% in 1996 (Government of Lesotho, 2000).

Chakela and Contour (1987) confirmed that Lesotho has also been impacted by the HIV/AIDS pandemic, where the adult prevalence rate was estimated to be 23% in 2011 (World Health Organization, 2009, Global AIDS Response Country Progress Report, 2011). HIV/AIDS continues to have serious consequences on food security; higher infection rates reduce the number of people able to work on farms. Healthy men also seek employment in South Africa, further reducing labor available for agriculture (Silici et al., 2011).

Smallholder farmers in sub-Saharan Africa have practiced conventional farming for many years. Conventional agriculture involves one or a combination of activities including harrowing, plowing, and hoeing. These practices are typically associated with soil disturbances that lead to erosion and sedimentation of streams and waterways (Mashingaidze and Mudahara, 2005). However, the general perception of farmers in sub-Saharan Africa is that conventional farming creates a favorable soil structure for seed bed preparation, increases mineralization of soil organic matter, and controls weed growth (Chiputwa et al., 2011); in other words, to “farm” is to “plow”. Yet conventional farming compacts soil, depletes soil organic matter and soil nutrients, and is a major cause of soil losses; up to 150 tons annually in Africa (FAO, 2001a; FAO, 2001b; Knowler and Bradshaw, 2007). While farmers may acknowledge the causal relationship between conventional farming practices and depletion of soil resources, conventional norms of what farming “means” still run deep in many communities (Giller et al., 2009).

To address erosion and other problems exacerbated by conventional farming, agronomists have advocated the adoption of conservation agriculture (CA) technologies (Chiputwa et al., 2011; Kassam et al., 2010, Thierfelder and Wall, 2010). According to the Food and Agriculture Organization (2001) (cited in Kassam et al., 2009), CA has the potential to stabilize or increase yields of grains and legumes while improving soil quality, reducing soil erosion, and decreasing production costs in the long-term. Studies from different countries suggest that, although a large number of small-scale farmers have adopted CA practices, the spread of these best management practices tends to be relatively slower among small-scale farmers (Kassam et al., 2009). Still, CA continues to be promoted across different regions worldwide, including sub-Saharan Africa where CA adoption is encouraged by NGOs and international aid agencies.

1.2.Research objective

The objective of this research is to identify the factors influencing the adoption of CA technologies in the Butha Buthe district of Lesotho, and to determine the *ceteris paribus* associations of CA adoption and demand for seed, fertilizer, labor, and profits from maize production.

CHAPTER 2: LITERATURE REVIEW

2.1. Conservation Agriculture (CA) definition and global situation

Conservation agriculture is characterized by three principles: 1) minimum soil disturbance (no tilling and direct planting of crop seeds); 2) permanent organic soil cover with crop residues; and 3) establishing and maintaining cover crops and crop rotations (Food and Agricultural Organization, 2007; 2009; Pretty, 2008). Hobbs et al. (2008) and Gowing and Palmer (2008) characterized CA as a set of cropping practices designed to sustain high crop yields without depleting water or soil resources. Conservation agriculture has been practiced for about 5 decades and has spread widely, but adoption has lagged in countries where most small-scale farming is practiced. In 2009, about 106 million hectares of the world's total arable land was used to produce crops under CA systems (Kassam et al., 2009); still, this is a relatively small percentage of the arable land under cultivation (8%). Most cropland managed under CA is found in South America, the United States, China, India and a few countries in Africa (Derpsch and Friedrich, 2009). Africa's total contribution is only 0.4% of the total global area managed under CA systems (470,100 hectares), compared to South America where CA is practiced on 49,586,900 hectares (46.6% of total global area under CA). North America follows, with 39,981,000 hectares managed under CA (37.5% of the total global area managed using CA).

2.2. Conservation agriculture situation in Africa

Farmers in at least 14 African countries are currently practicing CA extensively; including Kenya, Uganda, Tanzania, Sudan, Swaziland, Lesotho, Malawi, Madagascar, Mozambique, South Africa, Zambia, Zimbabwe, Ghana and Burkina Faso. CA has been promoted by the Food and Agriculture Organization (FAO), Le Centre International des Recherche Agronomique pour le Developpement (CIRAD), the African Conservation Tillage Network, International Council for Research in Agroforestry (ICRAF), the International Maize and Wheat Improvement Center (CIMMYT), the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), and the International Institute for Tropical Agriculture (IITA) (Haggblade and Tembo, 2003; Baudron et al., 2007; Boshen et al., 2007; Kaumbutho and Kienzle, 2007; Nyende et al., 2007; SARD, 2007; Shetto and Owenya, 2007; Erenstein et al., 2008). New Partnership for Africa's Development (NEPAD) and the Alliance for a Green Revolution in Africa (AGRA) have also incorporated CA into regional agricultural development programs.

In Lesotho, CA has been practiced for about 30 years (Marake, 2008), where conservation agriculture is typically associated with a system entailing minimum tillage practices on at least some part of the farm. Currently, CA in Lesotho is commonly called "*likoti*", a Sesotho name for "basin agriculture". The method involves digging potholes that are approximately 20 cm across and 15 cm deep in a 75 x 75 cm grid-like pattern. Seeds are directly planted into each pothole (typically 1 to 3 seeds) along with some inorganic or organic fertilizer. In the following season, seeds are planted again in the same pits. Crop residues are retained and staple crops are rotated and/or intercropped.

The *likoti* system has shown promise as a means of increasing yields and conserving soil and water resources (Silici, 2011). In 2000 and 2001, the Africa Inland Mission and the Rehoboth Christian Church began promoting CA in Butha Buthe and in Qacha's Nek. Through the Conservation Farming Network Group (CFNG) (launched by the FAO), the use of jab planters, animal drawn and tractor drawn no-till planters were encouraged, but the three main principles of CA are not always practiced (Marake, 2008).

2.3. Arguments in favor of conservation agriculture

When practiced correctly, CA stabilizes crop yields, thereby increasing household food security, and economic and social wellbeing. Haggblade et al. (2003) reported that early CA adopters increased crop productivity by 30 to 70%. These findings were also noted by Pretty (1998, 2000) in the Butha Buthe and Tebellong districts of Lesotho.

Conservation agriculture has been extensively adopted in South America. Research in Brazil and Paraguay compared yields from conventionally tilled and CA managed fields, finding that yields declined 5 to 15% after 10 years under conventional tillage, while fields managed under CA increased 5 to 15% during the same period (Derpsch, 2008a). The same study in Brazil found that over a 17-year period, maize yields under a CA system increased by 86%, soybean yields under a CA system increased by 56%, while fertilizer and herbicides use declined by 30% and 50% for maize and soybeans, respectively. There were also considerable differences in soil erosion for fields managed under CA compared with fields managed using conventional tillage methods (Derpsch, 2008a).

Yield differences ranged between 20 to 120% higher for CA managed fields compared with conventionally managed fields in Latin America, Africa and Asia (Pretty et al., 2006; Landers, 2007; Erenstein et al., 2008; FAO, 2008; Hengxin et al., 2008; Rockstrom et al., 2009). In Paraguay, smallholder farmers successfully produced crops that were initially thought inappropriate for no-till systems (e.g., cassava). Planting cassava in CA managed fields in combination with cover crops resulted in substantial yield increases, with yields sometimes doubling compared to those produced on conventionally managed fields (Derpsch and Friedrich, 2009).

Conservation agriculture has received attention as a “pro-poor strategy”, improving smallholder agricultural productivity, and as a means to adapt agricultural systems in semi-arid regions to climate change (Gowing and Palmer, 2008; Marongwe et al., 2011). In sub-Saharan Africa, maize yields are below the world average of 5,000 kg ha^{-1}. Most yields in southern African countries have stagnated at approximately 1,500 kg ha^{-1} (Webber and Labaste, 2010). One of the most promising outlooks associated with CA is that it can be adapted to different farming systems, with different combinations of crops and inputs tailored to regions. However, this inherent advantage underscores the problem of determining which practice combinations are suitable for specific socioeconomic and agro ecological contexts.

Mapeshoane et al. (2005) evaluated the technical performance and agronomic and socio-economic factors determining the adoption and adaptation of minimum tillage technologies in Lesotho. They concluded that CA was more effective in terms of soil erosion control, yield stability, reduced machinery use and lower fuel costs compared with conventional tillage systems. This finding was also consistent with Mueller et al.’s (1985) and Wandel and Smithers’s (2000) research. Mapeshoane and Marake (2006) observed an increase in organic matter accumulation of 3.1% on farms practicing CA, compared with 1.7% accumulation on conventionally managed fields over a two year period. Farmers in Brazil recognized that CA improved soil quality, reduced soil erosion, and conserved moisture compared to conventional tillage. Water infiltration rates were also higher for CA managed fields compared with conventionally managed fields (Landers, 2007).

CA systems are relevant for addressing old and new challenges such as climate change, high energy costs, and environmental degradation. In Africa, CA is expected to increase food production while reducing the detrimental effects of tillage (FAO, 2008). Recently, adoption of CA by farmers in several African countries has shown potential to improve rural livelihoods through sustainable but intensified production (Silici et al., 2011).

The observed advantages of CA, compared with traditional cultivation practices, were its ability to diversify production, increase social capital through farmer groups, and decrease dependence on food aid. Twomlow (2006, 2008), Nyagumbo (1999), Fowler et al. (2001) and Mashingaidze et al. (2006) reported that crop yields increased up to 3.5 tons (t) ha^{-1} in Zimbabwe for farmers practicing CA. In addition to yield increases, Lafond et al. (2008) found that CA required fewer inputs in terms of energy per unit area and per unit output, reduced machinery and fuel costs, and equipment depreciation. In the long run, the fertilizer amount required for the same level of output was reduced, increasing profit margins (Hengxin et al., 2008). Kliewer et al. (1998) and Sorrensen and Montoya (1984) found that rotating crops and establishing of short-term green manure cover crops on plots could also reduce herbicide costs because of reduced weed infestations over time. In these studies, farmers adopting CA tended to use less fertilizer but enjoyed higher yields.

2.4. Concerns and challenges facing adoption of conservation agriculture

Numerous challenges exist for CA adoption in Lesotho. According to Silici (2010, 2011), three factors impeding adoption of *likoti* are: 1) “distortion of economic incentives” caused by donor gifts of inputs and tools; 2) the education level of primary decision makers; and 3) weak knowledge networks in communities.

Some principles of CA may pose social problems, particularly the practice of permanent soil cover with crop residues (Hobbs, 2007). Crop residues have value as animal feed, which poses a major challenge in terms of retaining residue on fields. Farmers in Southern Africa use residues to feed animals. In countries with open grazing like Zimbabwe, Mozambique, Botswana and South Africa, livestock are permitted to graze on harvested fields (ICRISAT, 2006). In countries like Lesotho, traditional farming systems permit livestock grazing on fields for extended periods, farmers in South Africa fence fields to provide permanent soil cover (Nkala, 2011), but in some countries this could result in contentious social relationships with neighbors (Twomlow, 2008; Silici et al., 2011).

The vast majority of farmers in Lesotho are smallholder farmers whose primary concern is feeding their families. Timely planting, weed management, retention of crop residue, and adherence to traditional cultivation methods may overshadow interest in adopting new technologies (Umar et al., 2011). Farmers tend to conclude that CA is difficult because they perceive that their small land holdings should be used to produce food for their families and animals (Erenstein et al., 2012). In addition, to "farm" is generally synonymous with plowing. In Lesotho, land availability is a constraint, which further challenges the adoption of CA (Knowler et al., 2003; Bolliger et al., 2006; Friedrich and Kassam, 2009; Giller et al., 2009). Lack of trained extension agents, and lack of tools, such no-till planters, also tend to slow the adoption process (Garcia-Torres et al., 2003; Fowler and Rockstrom, 2000; Derpsch, 2003; Hobbs, 2006; Derpsch and Friedrich, 2009).

Although many small-scale farmers have adopted CA practices worldwide, experience suggests that the spread of CA tends to be relatively slower among smallholder farmers (Kassam et al., 2009). Some stigma may be attached to CA practices in terms of adoption by producers more oriented towards producing grains for market. Adopting no-till type practices may be perceived to be regressive by managers of larger operations since the usual practice of tilling land with a tractor is abandoned. On the other hand, the lack of no-till planters and other low impact machinery may also be a bottleneck for the adoption of CA by larger operators. Farms equipped to produce for markets usually operate more land.

Even with successful results in Latin American countries, some researchers have suggested that the more sanguine aspects of CA may not be enough to encourage its adoption in food insecure or resource poor regions (Gowing and Palmer 2008; Giller et al., 2009). The FAO (2008) also posited that because of the learning curve associated with CA adoption, adoption rates may be slower where smallholder farming systems are the norm.

According to Riches et al. (1997), weeding CA managed fields accounts for 60% of the labor required for crop production. The increased demand for labor to weed and prepare land may also discourage CA adoption where labor shortages exist or where labor is relatively expensive.

In Zimbabwe, farmers managing CA demonstration plots received inputs from NGOs and other agencies. Yield gains from demonstration trials were attributable to other factors, including timely planting, the availability and placement of fertilizers, and better moisture conservation (Nyagumbo et al., 2009; Marongwe et al., 2011). Yield benefits from CA-managed trials encouraged diffusion of CA by other farmers. However, farmers tended to practice CA on relatively smaller portions of their land holdings due to the extra labor required for weeding, and the challenge of retaining crop residues on fields because of communal grazing pressure (ICRISAT, 2009).

In the specific context of Africa, the majority of farmers are resource poor, using less than 1 hectare to produce food for household consumption. Researchers and funding agencies now understand that projects promoting CA generally overlooked the socioeconomic contexts of farmers. Carney (2002) and Toner (2002) argued that CA could alleviate poverty in some resource poor regions. However, some researchers caution against this conclusion. Giller et al. (2009) and Gowing et al. (2008) argued that a critical analysis of CA's potential in the region has not been performed. Mazvimavi et al. (2009) further argued that lack of peer reviewed studies on CA adoption in the region may lead to misinformed conclusions about how farmers adopt technologies. According to Giller et al. (2009) and Doss (2006), technology adoption means the technology must be sustainable even after projects introducing the technology have terminated, but they argue that the criteria for CA adoption is unclear in sub-Saharan Africa. Nkala et al. (2011) argue that CA adoption should not be understood as an "all or nothing" decision. Kaumbutho et al. (2007) add that adoption is a continuous but non-linear process that occurs in phases or steps, and sometimes ends in partial rather than full adoption. Giller et al. (2009) confirm that partial adoption typifies the case of sub-Saharan African farmers because they are generally risk averse and therefore cautious about experimenting with new technologies. This attitude encourages farmers to continue conventional farming methods on some of their fields.

In Zambia, Haggblade et al. (2003) suggest that lack of inputs constrains adoption of CA by smallholder famers. However, farmers are aware of the yield stability of CA, so the practice is used on some of their plots to hedge against drought and famine. In addition to partial adoption, some farmers disadopt CA. Farmers typically disadopt after projects that provide inputs end. Examples are found in Zambia, raising questions about the sustainability of CA (Giller et al., 2009; Bolliger, 2007). Haggblade et al. (2003) and Mashingaidze et al. (2006) explain that some farmers practice CA to access low cost or free inputs and technical support, but when that support ends they resume conventional farming practices. Disadoption occurs because new technologies often come with specific requirements that smallholder farmers may not be able to afford. For example, input prices, coordination of activities needed to successfully practice CA, and lack of efficient equipment, such as jab planters, disc planters and zero till drills, which are usually provided by organizations spearheading technology interventions, are difficult to find in many southern African markets (Lal, 2009; Heltberg et al., 2002). Traditional cultivation methods only require hand hoes, machetes and slashers, all of which most sub-Saharan Africa farmers own (Nkala et al., 2011). Research suggests that solving adoption and disadoption problems requires a deeper understanding of farmer experiences, knowledge of local input markets and socioeconomic conditions, and consideration of individual household objectives rather than assuming that one technology fits in all situations (Dumanski et al., 2006).

Giller et al. (2009, p. 24) argue that “the plow has become a symbol of agriculture such that there is need to transform the mindsets of all stakeholders in agriculture, including farmers, extension agents, researchers, university professors and politicians who doubt the possibility of a successful yield without tillage.” Giller et al. (2009, p. 5526) add that non-farmer interventions, or so called “top down approaches in technology dissemination,” fail due to lack of ownership of those technologies by farmers, leading to questions as to whether those technologies address the needs of farmers, or really just those of scientists and policymakers. It is important therefore that smallholder farmers are included as active participants in the technology development and dissemination (Nkala et al., 2011).

CHAPTER 3: CONCEPTUAL FRAMEWORK

3.1. Conceptual framework: agricultural household model

Households whose main source of food is from crops produced on their own land have to make decisions about how much grain to produce, input use, food storage, and time allocated to working on or off their farm (Benjamin, 1992). This thesis applies the Agricultural Household Model (AHM) developed by Singh et al. (1986) and earlier by Becker (1962) to conceptualize how CA adoption decisions may influence input purchases, household income, and maize production. The conceptual model developed in this thesis provides a theoretically consistent approach towards examining the association between maize production, input demand for maize production, and the use of CA technology to produce maize. The key focus is on how market prices, farm attributes, household characteristics, access to agricultural training, are associated with the CA adoption decision and decisions about maize production, and input demands.

The AHM suggests that consumption decisions about resources and time endowments (e.g., leisure and work) are *separable* or *non-separable*; a distinction that is important in examining CA adoption because, at least initially, the labor required to initiate CA is typically hypothesized to be greater than labor required in conventional tillage systems because of basin digging, weeding, residue maintenance, and possible crop rotation planning and management (Marongwe et al., 2011). In smallholder farming systems, household labor constraints may be binding because farmers may not be able to afford the costs of purchasing other inputs that could offset labor demand (e.g., fertilizer, herbicides or hired labor). In other words, time spent farming one’s own land has a premium tied to securing food for household consumption. To the extent that women allocate a disproportionate share of time working in fields in addition to raising families (Giller et al., 2009), adoption of CA may be lower in cases where women's labor time is binding.

Separability essentially means that household production decisions are entirely independent of consumption decisions. Separability of labor allocation decisions is driven by the tradeoff between the opportunity costs of time, wage-labor markets, and input and output markets. When separability holds, households are assumed to maximize profit from agricultural production (such that marginal value of production equals marginal factor costs) independent of utility maximization (such that the marginal utility of consumption equals the price of consumed goods). In this circumstance, time and capital investment dedicated to agricultural production are independent of household consumption decisions for food, non-agricultural goods, and leisure. Separability naturally implies that markets for inputs, staple crops, and labor are *complete,* while *non-separability* means that household food production decisions (e.g., time allocated to wage employment or working on the farm) are co-determined with consumption decisions (e.g., leisure time or how much food is needed to feed the household). Non-separability generally results when markets are incomplete (Benjamin, 1992).

The distinction between separable and non-separable decision making is typically motivated by examining the AHM when markets are complete. In this case, resource allocation can be analyzed as a recursive, two-step system where profits from agriculture are maximized first (Benjamin, 1992). Then, given a full income constraint that includes maximized profits from agricultural production, household demand for food, non-agricultural goods, and leisure can be analyzed (Sadoulet and de Janvry, 1995). Assuming separability, the recursive two step maximization problem of the household begins with maximization of profit from agriculture:

1) $\max_{\{y,x,l\}} \pi = p \cdot y - p_x \cdot x - w \,.\, l$

2) $\text{s.t.}: g(y, x, l; z^q, ca = 1) = 0$ (technical constraint for CA adopters),

3) $g(y, x, l; z^q, ca = 0) = 0$ (technical constraint for non-CA adopters).

where π is profit from agricultural production; *p* is the output price for agriculture goods; *y* is quantity of agricultural output; p_x is the price of inputs; *x* are inputs used in production; *w* is the wage price; *l* is labor used in production; z^q is a set of exogenous household attributes and farm characteristics; and *ca* indicates whether conservation agriculture was used or not used in production of maize. The function *g* is a technical constraint stating that maize production is non-negative.

Solving the above problem for output and input yields output supplied and input demand as functions of exogenous variables (z^q), the use of CA in the production set, and prices For example,

4) $y_{nca} = y_{nca}(p, p_x, w;\ z^q, ca = 0)$ (maize supply for CA non-adopters),

5) $y_{ca} = y_{ca}(p, p_x, w; z^q, ca = 1\ )$ (maize supply for CA adopters),

6) $x^s_{nca} = x^s_{nca}(p, p_x, w; z^q, ca = 0\ )$ (seed demand for CA non-adopter),

7) $x^s_{ca} = x^s_{ca}(p, p_x, w; z^q, ca = 1)$ (seed demand for CA adopter),

8) $x^F_{nca} = x^F_{nca}(p, p_x, w; z^q, ca = 0)$ (fertilizer demand for CA non-adopter),

9) $x^F_{ca} = x^F_{ca}(p, p_x, w; z^q, ca = 1)$ (fertilizer demand for CA adopter),

10) $l_{nca} = l_{nca}(p, p_x, w; z^q, ca = 0)$ (labor demand for CA non-adopters),

11) $l_{ca} = l_{nca}(p, p_x, w; z^q, ca = 1)$ (labor use for CA adopters).

where y_{ca} and y_{nca} is the maize supply for *ca* adopters and non-ca adopters respectively; x_{ca}^{s} and x_{nca}^{s} is the seed quantity for *ca* and non-*ca* adopters respectively; x_{ca}^{F} and x_{nca}^{F} is the fertilizer quantity for *ca* and non-*ca* adopters respectively; l_{ca} and l_{nca} is the labor quantity for *ca* and non-*ca* adopters respectively. Evaluated at the optimal supply and input demand levels maximizing profit and then reintroducing the arguments into the profit equation, the indirect profit function is:

12) $\pi_{nca}^{*} = \pi_{nca}^{*}(p, p_x, w; z^q, ca = 0)$ (profit function for non-CA adopters),

13) $\pi_{ca}^{*} = \pi_{ca}^{*}(p, p_x, w; z^q, ca = 1)$ (profit function for CA adopters).

where π_{ca}^{*} and π_{nca}^{*} are indirect profit functions for *ca* and non-*ca* adopters respectively. Given maximized profit from agricultural production, the household subsequently maximizes utility:

14) $\max_{\{c_a, c_m, c_l\}} u\,(c_a, c_m, c_l;\ z^q)$,

15) $\mathrm{s.t.}: p \cdot c_a + p_m \cdot \mathrm{c_m} + w.c_l = \pi^* + wE$ (full budget constraint of the household),

16) $c_l + l^s = E$ (a time endowment constraint),

where c_a is consumption of agricultural goods; c_m is consumption of non-agricultural goods; p_m price of non-agricultural goods; E is a time endowment constraint; c_l is consumption of leisure, and l^s is the total labor supplied. The maximized profit (π^*) solved in the first stage enters the household's full income constraint as a constant.

The reduced form demand equations for consumption are:

17) $c_i = c_i(p_a, p_m, c_l, \pi^*;\ z^q\ ), i = a, m, l$ (household demand for agricultural, non-agricultural good and leisure),

where *a* indexes agricultural goods, *m* indexes non-agricultural goods, and *l* indexes leisure. Profit from agriculture is a function of optimized revenue from production less inputs costs plus;

18) $\pi^* = p \cdot y^* - p_x \cdot x^* - w.\, l^*,$

where $\pi^*$is the indirect profit function; y^* is the optimal commodity output level, x^* are the optimal levels of non-labor inputs, and l^* is the optimal level of labor used to produce crops.

Extending the framework to agricultural profit as a function of the inputs analyzed in this thesis, the household profit maximization problem for agricultural inputs, maize output, and farm profit, given the adoption of CA, is:

19) $\max_{\{y,x,l\}} \pi = p \cdot y - r_1 \cdot x^S - r_2 \cdot x^F - w \cdot l,$

20) $\text{s.t.}: g(y, x, l;\ z^q, ca = 1) = 0$ (technical constraint for CA adopters),

21) $g(y, x, l;\ z^q, ca = 0) = 0$ (technical constraint for non-CA adopters),

where p is the unit price of maize; y is maize production; r_1 is the per unit seed cost; x^S is the seed quantity; r_2 is the per unit fertilizer cost; x^F is quantity of fertilizer used; *w* is the labor wage; *l* is labor used; z^q is a vector of farm and household characteristics; and *ca* indicates whether conservation agriculture was used to produce maize. Evaluated at optimality, the solution to the profit maximization problem yields an indirect profit function;

22)

$$\pi^*_{ca}(p, r_1, r_2, w; z^q, ca) = p\ .\ \mathrm{y}^*_{ca}(p, r_1, r_2, w; z^q, ca) - r_1\ .\ x^{S*}_{ca}(p, r_1, r_2, w; z^q, ca) - r_2\ .\ x^{F*}_{ca}(p, r_1, r_2, w; z^q, ca) - w.\ l^*_{ca}(p, r_1, r_2, w; z^q, ca)$$

23)

$$\pi^*_{nca}(p, r_1, r_2, w; z^q, ca) = p\ .\ \mathrm{y}^*_{nca}(p, r_1, r_2, w; z^q, ca) - r_1\ .\ x^{S*}_{nca}(p, r_1, r_2, w; z^q, ca) - r_2\ .\ x^{F*}_{nca}(p, r_1, r_2, w; z^q, ca) - w\ .\ l^*_{nca}(p, r_1, r_2, w; z^q, ca)$$

where y^*_{ca} and y^*_{nca} are the optimal levels of maize output for *ca* and non-ca adopters respectively; x^{S*}_{ca} and x^{S*}_{nca} are the optimal levels of seed use for *ca* and non-ca adopters respectively; x^{F*}_{ca} and x^{F*}_{nca} are the optimal levels of fertilizer use for *ca* and non-ca adopters respectively; l^*_{ca} and l^*_{nca} are the optimal levels of labor used to produce maize by *ca* and non-ca adopters respectively.

By Hotelling's Lemma, the input demand and output system is (Chambers, 1988):

24) $\frac{\partial \pi^*_{ca}}{\partial p} = y^*_{ca} = y^*_{ca}(p, r_1, r_2, w; z^q, ca)$ (maize supply for ca adopters),

25) $\frac{\partial \pi_{nca}^{*}}{\partial p} = y_{nca}^{*} = y_{nca}^{*}(p, r_1, r_2, w; z^q, ca)$ (maize supply for non-ca adopters),

26) $\frac{\partial \pi_{ca}^{*}}{\partial r_1} = -x_{ca}^{S*} = -x_{ca}^{S*}(p, r_1, r_2, w;\ z^q, ca)$ (seed demand for ca adopters),

27) $\frac{\partial \pi_{nca}^{*}}{\partial r_1} = -x_{nca}^{S*} = -x_{nca}^{S*}(p, r_1, r_2, w;\ z^q, ca)$ (seed demand for non-ca adopters),

28) $\frac{\partial \pi_{ca}^{*}}{\partial r_2} = -x_{ca}^{F*} = -x_{ca}^{F*}(p, r_1, r_2, w;\ z^q, ca)$ (fertilizer demand for ca adopters),

29) $\frac{\partial \pi_{nca}^{*}}{\partial r_2} = -x_{nca}^{F*} = -x_{nca}^{F*}(p, r_1, r_2, w;\ z^q, ca)$ (fertilizer demand for non-ca adopters),

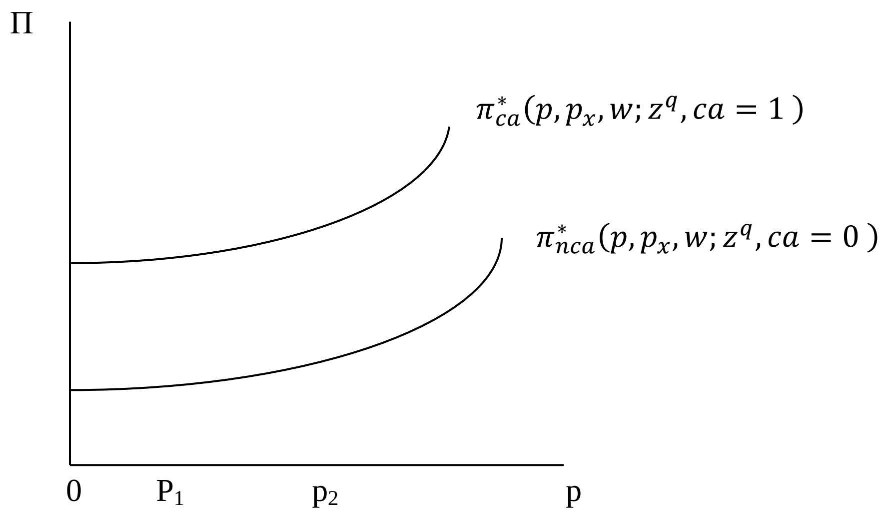
30) $\frac{\partial \pi_{ca}^{*}}{\partial w} = -l_{ca}^{*} = -l_{ca}^{*}(p, r_1, r_2, w; z^q, ca)$ (labor demand for ca adopters),

31) $\frac{\partial \pi_{nca}^{*}}{\partial w} = -l_{nca}^{*} = -l_{nca}^{*}(p, r_1, r_2, w; z^q, ca)$ (labor demand for non-ca adopters),

where the '*' implies that maize output and input demand are evaluated at their profit maximizing levels. The recursive approach outlined by Sadoulet and de Janvry (1995) suggests that, with profit maximized, households proceed to maximize utility given profit earned from agricultural production. The maximized profit enters the full income constraint of the household (Benjamin, 1992; Offutt, 2002).

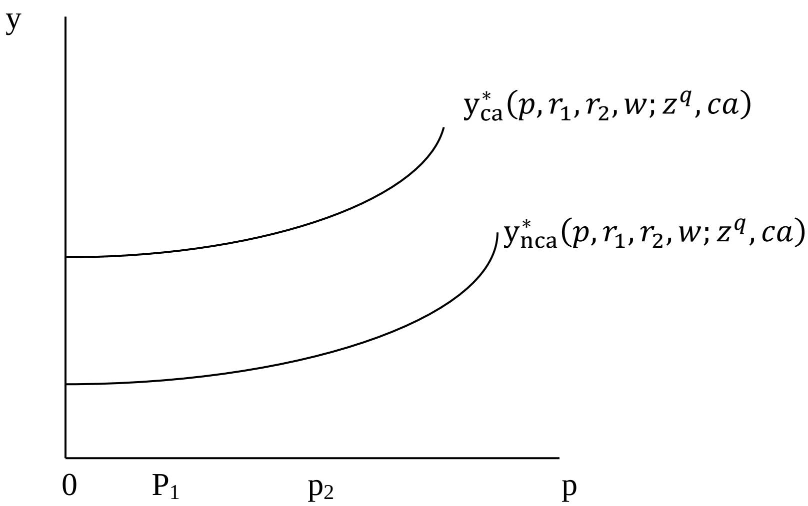
The profit function was restricted to be homogeneous of degree one and is expected to be convex in prices. This is a sufficient condition implying that producers are profit maximizers. It is hypothesized that the profit function exhibits a parallel upward shift by a constant if CA positively increases profits.

Figure 1: Profit between CA and non-CA fields.



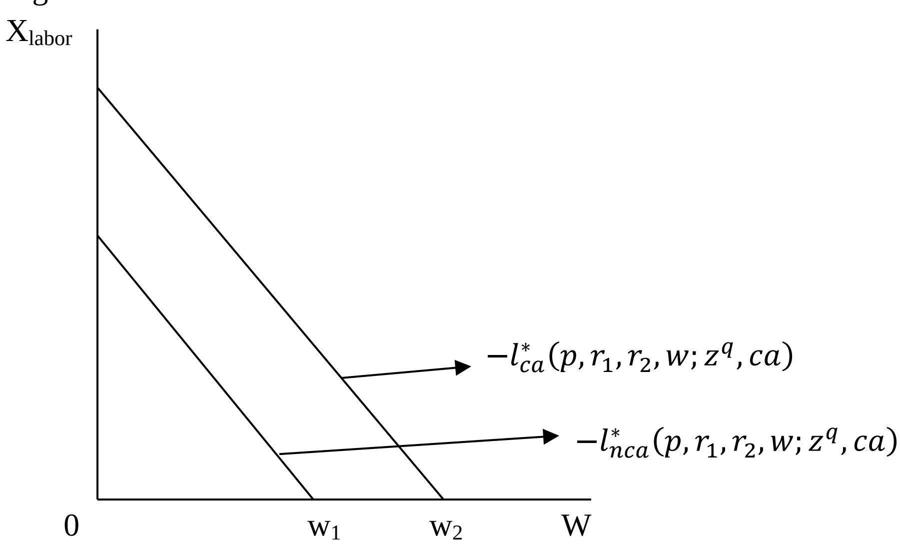
Maize production is also expected to increase, also exhibiting an upward parallel shift assuming CA increases maize output (see graph B).

Figure 2: Maize output between CA and Non-CA fields.



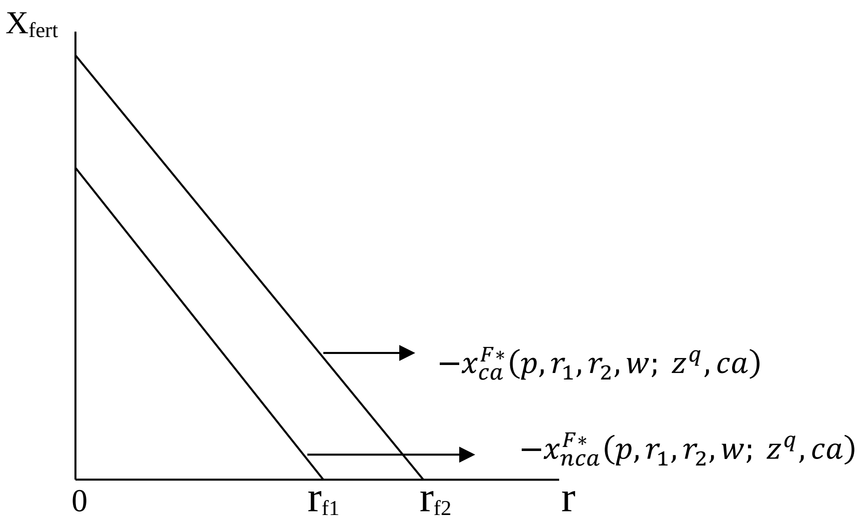
Demand for labor is expected to increase by a constant under CA systems due to increased labor requirements for weeding and land preparation (e.g., basin digging).

Figure 3: labor demand between CA and non-CA fields.



Fertilizer demand for CA farmers is also expected to increase, at least in the short-run, but seed application rates are not expected to be affected by CA.

Figure 4: Fertilizer demand between CA and non-CA fields.



Failure to satisfy the convexity condition suggests that the profit function may not accurately reflect the decision-making behavior of households as profit maximizing producers. In a broader context of policy analysis, this condition is important to consider in terms of the impetus behind technology adoption by small holder producers. For example, assumptions that CA technologies are a pro-poor strategy in terms stabilizing or increasing household income may be difficult to maintain in circumstances where the primary objective of households is not profit maximization. The conceptual model developed here provides a framework, wherein these assumptions can be more closely examined using a theoretically informed empirical model of technology adoption.

CHAPTER 4: METHODS AND PROCEDURES

4.1. Data

This thesis uses a household survey of 432 households in the Butha Buthe district of Lesotho (figure 1). A research team from the University of Tennessee and the National University of Lesotho, along with support from Growing Nations, and Reverend Pete West of the Rehoboth Christian Church conducted interviews between November and December 2010.

A cluster sampling strategy was used to survey farm households in the Butha Buthe district in northern Lesotho (Lohr, 1999). The sampling design used three key information sources to increase the precision of the instrument; (1) population Census data; (2) the importance of agriculture in terms of employment and subsistence; and (3) information about ongoing CA outreach efforts in the Butha Buthe district. A sample of 432 individuals was surveyed from 10 villages of the 19 villages initially considered for the survey (see table 1).

The survey was designed to collect data about: 1) household demographics; 2) socio-economic characteristics; 3) access to various livelihood assets and land ownership; 4) characteristics of farms using CA; 5) access to and type of agricultural services and training available; and 6) attitudes of farmers towards CA (see Annex for survey details). More detailed descriptive statistics for each of the above data are provided in Appendix.

About 210 observations of seed prices, 34 observations of fertilizer prices, 271 observations of labor prices, and 77 observations of maize prices were not reported by farmers. For respondents reporting quantities of inputs and maize but unable to recall input costs and maize prices, village averages were used to impute missing price information, by assuming that farmers in the same village face the same prices.

4.2. Quadratic approximation of the normalized restricted profit function

The impact of CA adoption on maize production and input demand was estimated using a restricted, normalized quadratic indirect profit function (Diewert and Wales, 1987). Assuming profit maximizing producers operate in competitive markets, the restricted profit function captures information about agricultural production and structure in both the short and long term (Fernandez-Cornejo, 1992). The restricted profit function satisfies the requirements of a theoretically consistent model of producer profit maximization: homogeneity, symmetry, monotonicity and curvature conditions (Chambers 1988). The quadratic profit function with three inputs (fertilizer, seed, and labor) and one output (maize) is;

$$32)\qquad \pi\,(p,r,w) = \alpha_0 + \sum_{i=1}^{n} \alpha_i r_i + \alpha_3 w + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} \alpha_{ij}\, r_i r_j + \frac{1}{2}\alpha_{33} w + \sum_{i=1}^{n} \alpha_{ij} r_i w + \alpha_p p + \alpha_{pp} p + \sum_{i=1}^{n} \alpha_{ip} r_i p + \alpha_{wp} p\, w + \varepsilon_\pi,$$

where *i* = 1, 2 (fertilizer and seed); *p* is the maize prize; *r* are input prices (seed and fertilizer); *w* is wage paid to labor; and ε_π is the truncation remainder from the second order Taylor expansion around an arbitrary indirect profit function with prices as the key arguments (Chiang, 1984).

Normalization by the maize price restricts input demand and output supply to be homogenous of degree zero while the indirect profit function is restricted to be homogenous of degree one by this convention (Chambers, 1988). This condition implies that only relative prices matter in the decision mix of input quantities used and maize quantities produced. Normalizing the indirect profit function by the maize price:

33) $$\bar{\pi}(p,r,w) = {\alpha_0}^* + \sum_{i=1}^{n} \alpha_i \, \bar{r}_i + \alpha_3 \bar{w} \; + \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \alpha_{ij} \bar{r}_i \bar{r}_j + \frac{1}{2} \alpha_{33} \bar{w}^2 + \sum_{i=1}^{n} \alpha_3 \, \bar{r}_i \bar{w} \; + {\varepsilon_\pi}^*$$

.

where:

${\alpha_0}^* = (\alpha_0 + \; \alpha_{pp} + \alpha_p)$,

${\alpha_1}^* = (\alpha_i + \; \alpha_{ip})$,

$\bar{\pi} \, = \, \frac{\pi}{p}$, $\bar{r}_i \, = \, \frac{r_i}{p}$, $\bar{w}_i \, = \, \frac{w_i}{p}$, and

$\alpha_{ij} = \; \alpha_{ji} \, \forall_i$, (symmetry restrictions).

For the three input-one output case (dropping *) and applying Hotelling's Lemma, the output and input demand system is (Fernandez-Cornejo, 1992):

34) $$\frac{\partial \bar{\pi}(p,\bar{r},\bar{w})}{\partial \overline{r_1}} = -x^S(p,r,w) = \; \alpha_1 + \; \alpha_{11} \overline{r_1} + \; \alpha_{12} \overline{r_2} + \alpha_{13} \bar{w} + \varepsilon_1,$$

35) $$\frac{\partial \bar{\pi}(p,\bar{r},\bar{w})}{\partial \overline{r_2}} = -x^F(p,r,w) = \; \alpha_2 + \; \alpha_{12} \overline{r_1} + \; \alpha_{22} \overline{r_2} + \alpha_{23} \bar{w} + \varepsilon_2,$$

36) $$\frac{\partial \bar{\pi}(p,\bar{r},\bar{w})}{\partial \bar{w}} = -l(p,r,w) = \; \alpha_3 + \; \alpha_{13} \overline{r_1} + \; \alpha_{23} \overline{r_2} + \alpha_{33} \bar{w} + \varepsilon_3.$$

The maize supply function is similarly derived, following Fernandez-Cornejo (1992);

37) $$\frac{\partial \pi(p,\bar{r},\bar{w})}{\partial p} = y(p,r,\mathrm{w}) = \; \alpha_0 - \; \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \alpha_{ij} \bar{r}_i \bar{r}_j - \frac{1}{2} \alpha_{33} \bar{w}^2 - \sum_{i=1}^{n} \alpha_3 \, \bar{r}_i \bar{w} \; + \varepsilon_y$$

Combining equations 33-37, the system of equations estimated is:

$$\begin{bmatrix} \overline{\Pi} \\ y \\ -x^S \\ -x^F \\ -l \end{bmatrix} = \begin{bmatrix} 1 & \bar{r}^S & \bar{r}^F & \overline{w} & \frac{1}{2}{\bar{s}^{S}}^{2} & \bar{r}^S\bar{r}^F & \bar{r}^S\overline{w} & \frac{1}{2}{\bar{r}^{F}}^{2} & \bar{r}^F\overline{w} & \frac{1}{2}\overline{w}^2 & ca & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & -\frac{1}{2}{\bar{s}^{S}}^{2} & -\bar{r}^S\bar{r}^F & -\bar{r}^S\overline{w} & -\frac{1}{2}{\bar{r}^{F}}^{2} & -\bar{r}^F\overline{w} & -\frac{1}{2}\overline{w}^2 & 0 & ca & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & \bar{r}^S & \bar{r}^F & \overline{w} & 0 & 0 & 0 & 0 & 0 & ca & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & \bar{r}^S & 0 & \bar{r}^F & \overline{w} & 0 & 0 & 0 & 0 & ca & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & \bar{r}^S & 0 & \bar{r}^F & \overline{w} & 0 & 0 & 0 & 0 & ca \end{bmatrix} \begin{bmatrix} \alpha_0 \\ \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_{11} \\ \alpha_{12} \\ \alpha_{13} \\ \alpha_{22} \\ \alpha_{23} \\ \alpha_{33} \\ \delta_1 \\ \delta_2 \\ \delta_3 \\ \delta_4 \\ \delta_5 \end{bmatrix} + \begin{bmatrix} \varepsilon_{\Pi}^{*} \\ \varepsilon_y \\ \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \end{bmatrix}$$

The error terms $(\varepsilon_\pi, \varepsilon_1, \varepsilon_2, \varepsilon_3, \varepsilon_y)$ are assumed to be independent and identically distributed with mean zero and $\text{cov}(\varepsilon_\pi, \varepsilon_1, \varepsilon_2, \varepsilon_3, \varepsilon_y) = \Omega$.

Price elasticities were estimated at each point in the data series for output, non-labor variable inputs, labor, and their cross relations. Examination of elasticities provides some indication about the convexity of the profit function (convex in terms of prices).

4.3. Conservation Agriculture Adoption and Maize Production Decisions

An Average Treatment Effect (ATE) model is used to measure the partial effect of CA adoption on input demand and maize production. Application of this approach assumes that the population using CA is not necessary randomly drawn from the general population (Cameron and Trivedi, 2005). In addition, CA adoption is likely coterminous with input application decisions because fertilizer inputs are frequently promised by local NGO's to producers who agree to experiment with CA in the study region. As previously hypothesized, the adoption of CA will be associated with a shift in the intercepts of the input, profit and maize supply equations. Estimation of the ATE model uses an approach suggested by Wooldridge (2002, procedure 18.1, p. 623). Under assumptions ATE.1 (Wooldridge, 2002, p. 605), the expected difference in the observed outcomes between farmers using CA on their fields compared with other farmers is conditioned on household and farm characteristics (z^q):

The difference in expected in profit is:

38)

$$E\ [\pi | ca = 1, G(\beta' z^q)] - E\ [\pi \mid ca = 0, G(\beta' z^q)] = E\ [\pi_{ca} - \pi_{nca} \mid G(\beta' z^q)]$$

The difference in expected yield is;

39) $$E\ [y | ca = 1, G(\beta' z^q)] - E\ [y \mid ca = 0, G(\beta' z^q)] = E\ [y_{ca} - y_{nca} \mid G(\beta' z^q)]$$

The difference in seed use is;

40) $$E\ [x^S | ca = 1, G(\beta' z^q)] - E\ [x^S \mid ca = 0, G(\beta' z^q)] = E\ [x^S_{ca} - x^S_{nca} \mid G(\beta' z^q)]$$

The difference in fertilizer use is;

$$41)\qquad E\ [x^F|ca=1, G(\beta' z^q)] - E\ [x^F\ |\ ca=0, G(\beta' z^q)] = \ E\ [x^F_{ca} -\ x^F_{nca}\ |G(\beta' z^q)]$$

Finally, the difference in labor use is;

$$42)\qquad E\ [l|ca=1, G(\beta' z^q)] - E\ [l\ |\ ca=0, G(\beta' z^q)] = \ E\ [l_{ca} -\ l_{nca}\ |G(\beta' z^q)]$$

where *E* is an expectation operator; *G* is a function modeling the probability that a farmer used CA; and β are parameters determining the probability of adoption. The expected differences test the hypothesis that, all else equal, CA affects production by some constant. A positive impact is reflected as an upward shift in the intercept of the profit and maize yield equations; in other words $E\ [\pi_{ca} -\ \pi_{nca}\ |G(\beta' z^q)] > 0$ and $E\ [y_{ca} -\ y_{nca}\ |G(\beta' z^q)] > 0$. Seed demand is not expected to be different between CA and non-CA managed fields. However, given the presumed increased labor demand and fertilizer requirements associated with CA, it is expected that demand for these two inputs will be higher for CA fields; therefore, $E\ [x^F_{ca} -\ x^F_{nca}\ |G(\beta'\, z^q)] >$ 0 and $E\ [l_{ca} -\ l_{nca}\ |G(\beta'\, z^q)] > 0$.

4.4. Empirical Model

To examine the factors influencing the adoption of CA technology, farm and household characteristics were regressed on an indicator variable of CA adoption using procedure 18.1 outlined by Wooldridge (2002, page 623). The adoption equation was estimated as a probit regression of CA use (a binary variable) on farm and household characteristics to obtain the fitted probabilities $\hat{G}(\hat{\beta}' z^q)$.

The probit model estimated in the first stage of the ATE model is:

43) $$\Pr(ca_{hj} = 1) = \beta_0 + \beta_1 EdHH_h + \beta_2 AgTain_h + \beta_3 Agehh_h + \beta_4 Fieldha_{hj} + \beta_5 SeedOwnGift_h + \beta_6 SexHH_h + \beta_7 FertOwnGift_h + \beta_8 WalkField_{hj} + \beta_9 FieldPassdown_{hj} + \beta_{10} PerStapleFarm_h + \beta_{11} Age15to55_h + \beta_{12} Femfields_h + \beta_{13} LivIncome_h + \beta_{14} OffIncome_h + \beta_{15} Remitt_h + \beta_{16} CropBeerIncome_h + \beta_{17} FarmexperHH_h + \beta_{18} Credit_h + \varepsilon_{hj},$$

where *h* = household 1, 2….*H*; *j* = the set of fields operated by farmer *h* (1, 2….*J*); and ε_{hj} is an independent and identically distributed random error with expected mean zero and a scalar variance of one. All variables are recorded at the household level except variables related to field activities such as field size, distance to field, and field ownership, which were recorded at the field level.

The CA technology variable enters linearly into field level input demand and output equations:

44) $$\pi_{hj} = Z_{hj}^{\pi}\,\alpha^{\pi} + \delta^{\pi} \cdot ca_{hj} + \varepsilon_{hj}^{\pi}$$ profit equation,

45) $$y_{hj} = Z_{hj}^{y}\,\alpha^{y} + \delta^{y} \cdot ca_{hj} + \varepsilon_{hj}^{y}$$ maize supply equation,

46) $$-x_{hj}^{F} = Z_{hj}^{F}\,\alpha^{F} + \delta^{F} \cdot ca_{hj} + \varepsilon_{hj}^{F}$$ fertilizer demand equation,

47) $$-x_{hj}^{S} = Z_{hj}^{S}\,\alpha^{S} + \delta^{S} \cdot ca_{hj} + \varepsilon_{hj}^{S}$$ seed demand equation,

48) $$-l_{hj} = Z_{hj}^{l}\,\alpha^{l} + \delta^{l} \cdot ca_{hj} + \varepsilon_{hj}^{l}$$ labor demand equation,

where Z_{hj} is the linear portion of the price-demand system equation with restrictions imposed, and α is a matrix of coefficients relating prices to profit, input use, and maize output. The binary variable *ca* (= 0 or 1) is instrumented with $[1, Z, \hat{G}(\hat{\beta}' z^q)]$ providing a direct way of testing the effect of CA adoption on production, inputs demands, and field profit holding other factors constant. Failure to reject the joint null hypothesis $\delta^{\pi} = \delta^{S} = \delta^{F} = \delta^{l} = \delta^{y} = 0$ suggests that CA technology is uncorrelated with profit, input demand, and maize output.

4.5. Factors hypothesized to influence CA adoption

4.5.1. Farmer characteristics hypothesized to influence CA adoption

The education level of the household head (*EdHH*) is hypothesized to be positively associated with CA adoption. According to Wall (2007), CA technologies are relatively knowledge intensive; therefore household heads with higher educational attainment are more likely to use CA technologies on their fields.

The association between farmer age (*Agehh*) and years of making farm decisions (*FarmExperHH*) on CA adoption is difficult to anticipate. According to Adesina and Zinnah (1993), young farmers are more open to change current practices than older farmers because they tend to be more aware and knowledgeable about new technologies. On the other hand, Langyintuo and Mekuria (2000) found that older farmers may have accumulated more capital over the years and may be more trusted by credit agencies, providing them comparative advantage in terms of accessing loans.

The percentage of people in a household between the age of 15 to 55 (*Age15to55*) is hypothesized to be positively associated with CA adoption. Unless people in households are working off farm, households with relatively more individuals of prime working age are more likely to adopt CA because of the labor demand for weeding and land preparation requirements.

Weeding activities are traditionally done by women in most sub-Saharan countries (Constantina, 1985). In addition, women are also responsible for other household activities such as child rearing, cooking, and cleaning (Giller et al., 2009). It was hypothesized that CA would be less likely practiced on fields managed by women.

Lack of access to loans or credit may constrain smallholder farmers from adopting new technologies that require initial capital or input investments (Feder et al., 1985). Access to credit was hypothesized to be positively associated with CA adoption.

4.5.2. Field level characteristics hypothesized to influence CA adoption

Field size (*fieldha*) is hypothesized to be negatively associated with the use of CA. Mechanized implements are more likely to be used on larger fields, while CA is more likely to be used on smaller areas due to relatively intensive labor requirements of basin digging, and the challenge of retaining crop residues (ICRISAT, 2009).

Agricultural training (*AgTrain*) is hypothesized to be positively associated with CA adoption. CA technology is relatively knowledge intensive (Wall, 2007). Therefore, farmers who have been trained in agriculture are more likely to use CA on their fields. In addition, farmers who are trained by NGOs or extension services are likely to receive input subsidies if they practice CA.

Ownership of fertilizer or receiving fertilizer from government or non-government organizations (*FertOwnGift*) is hypothesized to be positively associated with the use of CA. Ownership of seed or receiving seeds from government or non-government organizations (*SeedOwnGift*) is also hypothesized to be positively associated with the use of CA.

The walking distance from home to a field (*Walkfield*) is hypothesized to be negatively associated with the use of CA on the fields. CA is more likely to be used on fields located closer to home because they are easy to monitor.

Off farm income (*OffIncome*), remittances (*Remitt*), and income from beer sales (*CropBeerIncome*) are hypothesized to be negatively associated with CA adoption. These activities provide access to cash that may be enough to keep the household secure in terms of food. Livestock income (*LivIncome*) is hypothesized to be negatively associated with the use of CA on the fields. Forage for livestock competes with crop residue retention.

4.6. Model estimation, evaluation and analysis

4.6.1. Three Stage Least Squares estimation

Iterated Three Stage Least Squares (3SLS) was used to estimate the equation system because (1) CA adoption is likely codetermined with planting and input decisions, and (2) the ATE framework applied here suggests the decision to adopt CA may be correlated with the residuals of the production variables; maize output, profit, and inputs. In other words, there is some likelihood that the CA adoption pattern of individuals in the survey is not random. The symmetry restriction also forces parameters to be shared across equations, which renders correlation between the residuals of the profit, input demand, and maize output equations.

Conceptually, in the first stage, new "fitted" regressors are obtained and subsequently, the predicted values are included in the original regression equation to obtain consistent estimates of α. The instrumental variables (Z^{IV}) for each equation must be uncorrelated with the disturbance terms of the corresponding equation ($E\ [Z_h^{iv\prime}\varepsilon_h] = 0$). In this case, the Three Stage Least Squares (3SLS) estimator is a consistent estimator.

The ATE estimation procedure suggested by Wooldridge (2002, p. 623) is a modification of the more general idea of instrumental variable estimation, using the predicted values of the probit regression (the adoption equation) as an instrument for the observed use of CA (a binary 0/1 variable). Normalized input prices are also included as instrumental variables to estimate the likelihood of using CA on a field. The normalized input prices enter the adoption equation as a linear, quadratic, and interactions as they appear in the quadratic profit function. This convention follows Wooldridge (2002) to generate predicted values of CA use. Wooldridge notes that this procedure has an important robustness property because the probability model does not have to be correctly specified (Wooldridge, 2002).

4.6.2. Model diagnostics

Multicollinearity is evaluated to determine if two or more correlated independent variables compromise estimation of the standard errors and inference (Mansfield and Helms, 1982). Variance inflation factors (VIF) are used to diagnose the effects collinear relationships between independent variables have on the standard error estimates. A VIF greater than 10 indicates that multicollinearity may compromise the efficiency standard errors (Neter, Wasserman, and Kutner 1985).

The pseudo-R^2 is used to evaluate the overall fit of the probit model. Somer's D is used to determine the strength and direction of associations between predicted probabilities and observed responses of variables, ranging from -1 (no association) to +1 (perfect association) (Bruin, 2011), and a Wald test is used to test the joint hypothesis that the coefficients in the probit model are not different from zero. The observed values of profit, seed, fertilizer, and labor were correlated with their predicted values to determine how well the model predictions for profit, inputs, and maize output correspond with the observed maize production, profit and input demand.

CHAPTER 5: RESULTS AND DISCUSSION

5.1. Preliminary Analysis: Descriptive Statistics

The descriptive statistics of the survey were divided into two categories; household level responses and field level responses. There were 427 surveys with usable responses in the household category, with 55 farmers reporting they used CA. In the field level category, there were 611 fields managed by farmers, with 569 usable field level responses. Of the 569 fields, 51 were managed with CA. In some cases only two categories (*CA adopters* versus *non-CA Adopters*) are discussed.

Table 1: Sample size of respondents who used conservation agriculture (CA).

Variable Description	Total	Percent
CA Current	89	20.8%
CA Farm	101	23.7%
CA Adopters	55	12.9%
CA Abandoners	12	2.8%
Non-CA Adopters	326	76.3%
New CA Adopters	34	8%
CA OLD	67	15.7%
Observations	427	100%

Notes: CA is defined as farmers who practiced no-till or used basins for planting.

The category *CA current* (20.8%) are farmers who practiced CA in the 2010 growing season. This category includes *CA adopters* and *new CA adopters*. The category *CA farm* (23.7%) is the farmer group who practiced CA on any of their fields in one of the seasons covered by the survey (2009 or 2010 growing seasons). The category *CA adopters* (12.9%) are farmers who practiced CA on any of their fields in both seasons (2009 and 2010 growing seasons). The category *CA abandoners* (2.8%) were farmers who practiced CA in the 2009 season but had resumed conventional farming in the 2010 growing season. The category *non-CA adopters* (76.3%) were farmers who never practiced CA in any of the seasons covered by the survey. The category *new CA adopters* (8%) were farmers who practiced conventional farming in the 2009 growing season but practiced CA in the 2010 growing season. The category *CA old* (15.9%) are farmers who practiced CA in the 2009 growing season; and includes *CA adopters* and *CA abandoners*.

5.1.1. Household Production and Consumption of Staples

Maize was the main principal food staple. Most farmers did not plant crops in other seasons, so the core analysis focuses on the 2010 production season for maize by *CA adopters* and *non-CA adopters*. Table 2 uses observations from the 2010 growing season presented as *CA current* in table 1, comparing the household principle food staples reported by *CA adopters* and *non-adopters*. Principal food staples consumed by households are divided into three categories; primary, secondary and tertiary food staples. Maize was the principal food staple of *CA adopters* and *non-CA adopters*. Most CA and non-CA adopters, 93.3% and 93.2% respectively, consumed maize as their main food staple. Beans and sorghum comprised the secondary staple group, with 39.3% and 35.3% of CA and non-CA households (respectively) consuming sorghum as their secondary food staple. About 37.1% and 36.5% of CA and non-CA households (respectively) consumed beans as their secondary food staple. Finally, beans and green vegetables made up the bulk of the tertiary food staple, where beans represented 36% and 27.5% of CA and non-CA households, respectively. Green vegetables comprised 18% and 16.6% of CA and non-CA households, respectively. Principal staple food consumed by households was an important aspect to examine because it explains why maize represented the most common crop produced by farmers.

Table 2: Principal food staples in Butha Buthe, Lesotho.

	CA-adopters (percent)	Non-CA adopters (percent)
Principal Staple		
Maize	83 (93.26)	315 (93.20)
Sorghum	4 (4.29)	15 (4.44)
Others	2 (2.25)	7 (2.08)
No response	0 (0.00)	1 (0.30)
N	89	338
Secondary Staple		
Maize	6 (6.74)	15 (4.45)
Sorghum	35 (39.33)	119 (35.31)
Beans	33 (37.08)	123 (36.50)
Green Veggies	11 (12.36)	29 (0.8.61)
Others	4 (4.50)	21 (6.23)
No response	0 (0.00)	30 (8.90)
N	89	337
Tertiary Staple		
Sorghum	14 (15.73)	38 (11.24)
Beans	32 (35.96)	93 (27.51)
Green Veggies	16 (17.98)	56 (16.57)
Others	9 (10.11)	46 (13.61)
No response	18 (20.22)	105 (31.07)
N	89	338

Notes: CA is defined as farmers who practiced no-till or used basins for planting.

5.1.2. Sources of household principle food staples

Table 3 represents the sources of the principle staple foods, again using observations from the 2010 growing season. This was important to examine to determine which categories contributed to household consumption, which may help explain why a household adopted CA.

Table 3: Sources of principal food staples in Butha Buthe, Lesotho.

	CA-adopters	Non-CA adopters
Source of principal staple		
Produced	64.08%	71.65%
Purchased	29.11%	25.13%
Credit	1.69%	1.51%
Aid/Gift	5.17%	1.71%
N	89	329
Source of secondary staple		
Produced	76 .59%	75.76%
Purchased	18.11%	20.70%
Credit	0.23%	0.81%
Aid/Gift	5.07%	2.73%
N	88	298
Source of tertiary staple		
Produced	78.45%	72.18%
Purchased	18.45%	23.62%
Credit	0.28%	0.82%
Aid/Gift	2.82%	3.38%
N	71	226

Notes: CA is defined as farmers who practiced no-till or used basins for planting.

About 64.1% of the maize consumed by households who used CA in 2010 was produced on their own fields, 29.1% was purchased, while 5.2 % was received as food aid or a gift. Of the non-CA household group, 71.7% of their primary food staple was produced on their own fields, 25.1% was purchased, while 1.7% was received as food aid or a gift. Similarly, 76.6% of the secondary food staple consumed by CA farmers was produced on their own land, 18.1% was purchased, and 5.1% was received as food aid or a gift. For non-CA farmers, 75.8% of the secondary staples were produced on the farm, 20.7% was purchased, and 2.7% was received as food aid or a gift. CA users produced 78.5% of their tertiary staples, 18.5% were purchased and 2.8% was received as food aid or a gift. Non-CA farmers produced 72.2% of their tertiary staples on the farm, 23.6% were purchased, with 3.4% received as food aid or a gift. The difference between the principle food staple consumed by households and the source of principle food staple suggests that CA household production of staple foods is lower than what they need for consumption compared to conventional households. For example, about 93% of CA adopters and non-CA adopters consumed maize as their primary food staple, but only 64% and 72% of what was consumed by CA and non-CA adopters respectively was produced on their own fields. This may provide some indication why farmers who practiced CA in the 2009 and 2010 growing seasons appeared to have a relatively high dependence on food aid, suggesting that food insecure households may be more willing to experiment with CA on their fields because of free inputs from government and non-government efforts in the region.

5.1.3. Income Sources

Comparison between household income sources reported by CA adopters and non-CA adopters are made in table 4. The comparison is important because access to income from different sources other than agriculture may affect farmer decisions about trying new agriculture technologies. About 24.4% of CA farmers received income from working for other farmers, while 19.3% of non-CA adopters income was from remittances. A secondary source of income for both CA farmers and non-CA farmers was non-farm employment, representing 17.6% and 17.8% of household income, respectively. Tertiary income sources for both groups were crop sales, with 15.7% and 16.2% for CA and non-CA farmers reporting these sources, respectively. Both groups also received some income from brewing beer and pensions. CA adopters were less dependent on salaried non-agriculture positions and remittances compared with non-CA farmers. Agriculture appears to matter more to CA farmers in terms of an income generating activity.

Table 4: Household income source in Butha Buthe, Lesotho.

	CA-adopters	Non-CA adopters
Income from other farmers	24.38%	12.24%
Crop sale income	15.74%	16.21%
Livestock sale income	6.16%	8.34%
Brewing income	13.88%	9.55%
Remittance income	8.02%	19.25%
Off farm employment income	17.56%	17.77%
Income from a shop	2.09%	0.75%
Pension income	10.12%	10.59%
Income from renting fields	0.47%	0.53%
Income from other activities	1.74%	4.78%
N	86	322

Notes: CA is defined as farmers who practiced no-till or used basins for planting.

5.1.4. Household construction materials

The descriptive statistics for the household roofing materials discussed below (table 5) are based on the observations for 2010 season, comparing roof materials used by CA and non-CA adopters. While there are more detailed descriptions of housing characteristics in the appendix, roofing is presented here because it may play an important role with respect to the CA adoption decision. Responses were categorized into CA and non-CA adopters. There were few key differences in the materials used to build a house between CA and non-CA farmers, with a larger percentage in each category using more iron sheets as the primary roofing material, about 58% and 64% for CA and non-CA, respectively. Thatch was the second most common roofing material, with 37% and about 40% for CA and non-CA, respectively. The use of thatch as a roofing material likely increases demand for crop residue that could otherwise be used for soil cover, thereby affecting CA adoption negatively.

Table 5: Roofing characteristics in Butha Buthe, Lesotho.

	CA-adopters (percent)	Non-CA adopters (percent)
Primary Roof Material:		
1. Iron Sheets	52 (58.43)	218 (64.50)
3. Thatch	35 (39.33)	110 (32.54)
5. Clay Tile	1 (1.12)	5 (1.48)
7. Other	1 (1.12)	2 (0.59)
No Response		
N	89	338
Secondary Roof Material:		
1 Iron Sheets	6 (6.74)	5 (1.48)
3 Thatch	33 (37.08)	134 (39.64)
5 Clay Tile	0 (0.00)	1 (0.30)
7 Other	2 (2.25)	4 (1.18)
No Response	48 (53.93)	194 (57.40)
N	89	338
Tertiary Roof Material:		
1 Iron Sheets	0 (0.00)	
3 Thatch	0 (0.00)	0 (0.00)
5 Clay Tile	0 (0.00)	0 (0.00)
7 Other	0 (0.00)	0 (0.00)
No Response	89(100)	338(100)
N	89	338

Notes: CA is defined as farmers who practiced no-till or used basins for planting.

5.1.5. Household head demographics

On average, CA adopters were not different from non-CA adopters in terms of number of people in the household (6 members) but CA farmers were relatively older. Years of making farming decisions did not appear to be associated with the decision to adopt CA. However, in terms of the education level of the household head, CA adopters had relatively more education than non-CA adopters. About 20.5% and 16.1% of the CA and non-CA household heads (respectively) had no formal education, while 76.8% and 85.6% of the CA and non-CA household head reported having a primary school education level. About 20.9% and 14.1% of the CA and non-CA completed high school, while 2.3% and 0.4% of the CA and non-CA farmers (respectively), had attended some college. All CA households headed by women had some formal education, while 4.3% of the non-CA households headed by a spouse had no formal education.

Table 6: Household demographic variables by CA adoption Status.

Item	CA adopters	Non-adopters
Sample (% of 427)	55(12.9%)	326 (76.3%)
Mean Household Size (Std Dev)	6 (3.1)	6 (3.0)
Mean Head of Household Age (Std Dev)	58 (13.1)	54 (15.9)
Mean Years Making Farm Decisions (Std Dev)	20.4 (14.2)	21.5 (17.0)
Some Primary School	76.75%	85.55%
Some High School	20.93%	14.07%
College Education	2.33%	0.37%

Notes: CA is defined as farmers who practiced no-till or used basins for planting.

5.1.6. Household head and spouses residence

About 92% and 85% of household heads for CA and non-CA adopters, respectively, lived in their own house. Of the remaining respondents, 6.8% and 13.1% of CA and non-CA adopters respectively lived outside Lesotho,. About 95.9% and 95.7% of the spouse household heads for CA and non-CA farmers, respectively, lived in their own house, while 4.1% and 3.2% for the remaining respondents for CA and non-CA lived outside Lesotho. This suggests that relatively more non-CA household heads may seek employment outside of Lesotho.

Table 7: Household head residence in Butha Buthe, Lesotho.

	CA-adopters	Non-CA adopters
Household Head Residence		
This house	81 (92.05%)	286 (85.12%)
Other house	0 (0.00%)	2 (0.60%)
Other village, same district	0 (0.00%)	4 (1.19%)
Other district	1 (1.14%)	0 (0.00%)
Out of Lesotho	6 (6.82%)	44 (13.10%)
Spouse Head Residence		
This house	47 (95.92%)	180 (95.74%)
Other house	0 (0.00%)	1 (0.53%)
Other village, same district	0 (0.00%)	0 (0.00%)
Other district	0 (0.00%)	1 (0.53%)
Out of Lesotho	2 (4.08%)	6 (3.19%)

Notes: CA is defined as farmers who practiced no-till or used basins for planting.

5.1.7. Agricultural training sources

About 40% of non-CA adopters had received agricultural training. About 66.8% of farmers that had recently abandoned CA had received formal training. Approximately 24% of farmers who were using CA in 2009 and 2010 seasons had not received any agricultural training, suggesting some evidence of CA diffusion. Farmers may be seeing the advantages of using CA from other farmers and decide to use it on their field.

Table 8. Agricultural training by CA adoption status.

Item	CA adopters	Non-Adopters
Sample (% of 427)	55 (12.9%)	326 (76.3%)
Agricultural Training	76.4%	39.6%
Trained through Extension	21.8%	12.3%
Trained by NGO	43.6%	11.7%

Notes: CA is defined as farmers who practiced no-till or used basins for planting.

5.1.8. Post harvest treatment of crop residues

Table 9 summarizes post-harvest residue use. On average, both groups indicated that a larger amount of residue is used to feed animals, representing about 57% of *CA adopters* and 59% of *non-CA adopters*. In addition, relatively more crop residue was used for fuel by *non-CA adopters*. However, *CA adopters* reported leaving relatively more residue in their fields.

Table 9: Respondents reporting using crop residues.

Item	CA adopters	Non-adopters
Sample (% of 427)	55 (12.9%)	326 (76.3%)
Residue removed for fuel	12.9%	24.9%
Residues removed for animals	25.9%	34.6%
Residues left for animals	31.5%	24.2%
Residues left for cover	29.8%	16.3%

5.1.9. Quantities of inputs used by CA and non-CA fields.

Input quantities used by CA adopters and non-CA adopters are based on field-level data (number of observations = 611, Table 10). Seed and fertilizer quantities used exclude observations that were more than 100 kg per hectare (these observations were above the 99% percentiles of the population). Labor hired is the number of people hired times the number of days they worked on a plot. Total labor represents the number of people who worked on the plot, including family labor. Labor used excludes responses exceeding 100 days (observations above 99% percentiles). It is clear that conventional farmers reported higher maize production per field than CA farmers. This is expected because, on average, conventional fields were larger than CA fields. However, there was not much difference in yield between the two groups. In fact, CA farmers reported slightly higher production than conventional farmers. On average, conventional farmers used more fertilizers, seeds and labor than farmers using no-till or basin planting. CA farmers also used less labor, fertilizer and seed than non-CA farmers. Farmers practicing CA also reported higher maize yield but lower maize production per field. The average size of CA fields was smaller than conventional fields, suggesting that CA may be first practiced on smaller plots; a finding consistent with Haggblade et al. (2003).

Table 10. Mean quantities of inputs used and maize output by CA and non-CA fields.

	CA fields					Non-CA fields				
Variable name	N	Mean	St.dev	Min	Max	N	Mean	St.dev	Min	Max
Fertilizer (kg ha^{-1})	45	6.91	11.47	0.00	50	484	26.54	24.90	0.00	100
Seed (kg ha^{-1})	45	4.29	8.50	0.002	50	484	7.84	8.88	0.02	90
Hired Labor (people $day^{-1}field^{-1}$)	12	11.5	10.04	0.58	31	376	15.3	18.2	0.02	97.3
Total labor (people $day^{-1}field^{-1})^{-}$	50	19.64	20.09	0.005	87	523	34.05	22.66	0.14	99
Female labor (female $day^{-1}field^{-1})^{-}$	52	7.5	7.6	0.00	28	558	12.6	14.9	0.00	88
Male labor (male $days^{-1}field^{-1}$)	52	9.7	15.3	0.00	60	560	15.3	15.7	0.00	96
Maize yield (kg ha^{-1})	54	1161	1737.2	11.84	8649	272	1102.5	1570.5	11.84	9266
Maize Production (kg $field^{-1}$)	52	148.21	268.76	0.00	1500	562	263.66	443.91	0.00	4000
Field size (hectare)	52	0.47	0.57	0.00	2.83	562	0.76	0.70	0.00	6.48

Notes: CA is defined as fields on which no till or basin planting was practiced. Non-CA fields are those fields on which no-till or basin planting was never practiced in any of the seasons covered by the survey. CA fields are fields on which no till or basin planting was practiced in both season (2009 and 2010 growing seasons). St.dev is standard deviation of the mean.

5.1.10. Input prices reported in the 2010 season

Table 11 presents the input prices paid by producers in Maluti. Wages are reported as Maluti per person per day. On average, CA farmers purchased fertilizer and seeds at lower prices than non-CA farmers, possibly suggesting an influence of NGO efforts and extension services in terms of input provision. However the price for hired labor was higher for CA farmers.

Table 11. Inputs prices.

	CA fields				Non-CA fields			
Variable name	Mean	St.dev	Min	Max	Mean	St.dev	Min	Max
Seed Price (M kg^{-1})	2.83	5.66	0.00	20.86	7.20	10.49	0.00	60.00
Fertilizer Price (M kg^{-1})	0.98	1.82	0.00	11.00	1.40	2.00	0.00	18.00
Labor price (M $Person^{-1}day^{-1}$)	160.74	47.65	13.3	200	144.6	123.9	1.00	1130
Maize price (M kg^{-1})	2.37	0.28	1.00	2.5	2.367	0.37	0.75	4.00
Field observations	52				559			

5.1.11. Farmer attitudes towards farming and conservation agriculture

Farmer attitudes towards agricultural production and conservation agriculture practices are presented in table 13. Most farmer understanding, knowledge, and attitudes about agriculture were shared between CA farmers and conventional farmers. For instance, more than 80% of all respondents agreed that cover crops should be maintained on the field and that inorganic fertilizer is the best product for maintaining soil quality. More than 90% of all respondents agreed that crop rotation is a best practice, that timely weeding is important, and that pesticide applications are necessary to produce a successful crop. More than 59% of farmers disagreed that off-farm income is more important than large crop harvests, but more than 73% disagreed that crops should be grown for markets. This suggests that the farmers perceived farming as a means to produce food for home consumption. This observation is supported by farmer responses about the purpose of farming, where more than 94% of respondents in both categories agreed that farm produce was critical for feeding family members.

About 90% of CA and conventional farmers agreed that staple crops should be planted on the majority of fields, and that growing food is better than buying it from others; again suggesting that crops are produced mostly for home consumption. However, about 50% of the respondents in both categories also agreed that planting decisions should be made based on current market prices. About 73% and 76% of CA and conventional farmers, respectively, agreed that the labor time spent farming could be replaced by chemicals and machines. Approximately 31% and 36% of CA and non-CA farmers (respectively) disagreed that tilling causes erosion. More farmers (44.9% and 66.9% for the CA and non-CA group respectively), agreed with the premise that land preparation begins with a plow. Farmers who had adopted CA were more divided on this question than non-CA adopters, with about 45% agreeing and 40% disagreeing that land preparation begins with a plow. These two attitudes related to tillage practice and plowing for land preparation suggest that preferences for conventional methods of farming are still strong in the mindset of even those that already adopted CA technology.

Table 12: Knowledge, understanding and attitudes of agriculture in Butha Buthe, Lesotho.

	CA-adopters (percent)	Non- adopters (percent)
Tilling causes erosion		
Disagree	28 (31.46)	124 (36.98)
Agree	47 (52.81)	166 (49.11)
Crops should be grown for sale		
Disagree	65 (73.03)	256 (75.74)
Agree	18 (20.22)	66 (19.53)
Farm labor can be replaced by chemicals and machines		
Disagree	16 (17.98)	52 (15.38)
Agree	65 (73.03)	258 (76.33)
Cover crops must be maintained on fields		
Disagree	4 (4.49)	33 (9.76)
Agree	76 (85.39)	275 (81.36)
Crop rotation best practice		
Disagree	3 (3.37)	12 (3.55)
Agree	84 (94.38)	306 (90.53)
Farm produce necessary to feed family		
Disagree	4 (4.49)	15 (4.46)
Agree	85 (95.51)	316 (94.05)
Plant based on current market prices		
Disagree	37 (41.57)	143 (42.31)
Agree	46 (51.59)	166 (49.11)
Off farm income more important than harvest		
Disagree	53 (59.55)	199 (58.88)
Agree	24 (26.97)	95 (28.11)
Staples crops should be produced on majority of the fields		
Disagree	3 (3.37)	25 (7.40)
Agree	83 (96.63)	307 (90.83)
Growing food better than purchasing		
Disagree	8 (8.99)	22 (6.51)
Agree	81 (91.01)	313 (92.60)
Multi-production is better than single crop		
Disagree	8 (8.88)	23 (6.80)
Agree	79 (88.76)	305 (90.24)
Crop residue should be fed to livestock		
Disagree	57 (64.04)	166 (49.11)
Agree	22 (24.72)	135 (89.94)
Land prep. begins with plowing		
Disagree	36 (40.45)	97 (28.70)
Agree	40 (44.94)	226 (66.86)
N	89	336

Notes: CA is defined as farmers who practiced no-till or used basins for planting.

5.1.12. Conservation agriculture adoption: regression results

The probit regression results are reported in Table 15. McFadden's pseudo-R^2 was 0.468, meaning that approximately 46.8% of variability in the dependent variable (CA adoption) was explained by the covariates. The variance inflation factors for all variables were less than 10 except for seed price, suggesting that multicollinearity may not be a serious problem. Somer's D was 0.843, which suggests a reasonable association between predicted probabilities and observed responses of variables.

The results from the adoption model suggests that agricultural training had a positive and significant effect on the adoption of CA, a finding consistent with Haggblade and Tembo (2003b) who found that extension services increased the likelihood of adopting new technologies. Access to agricultural training by a farmer increased the probability of adopting CA by 0.10.

Field size was negatively associated with the use of CA on a field, suggesting that CA was practiced on relatively smaller plots. The finding is consistent with Haggblade et al. (2003) and research by ICRISAT (2009). A one hectare increase in field size decreased the probability of practicing CA on a field by 0.05.

The education level of the household head was positively associated with CA adoption. This finding in consistent with Langyintuo and Mekuria (2005) and Wall (2007), who concluded that the more educated a farmer was, the more they were likely to adopt a new technology. Knowler and Bradshaw (2007), Rahm and Huffman (1984), and Shortle and Miranowski (1986) also reached similar conclusions about the learning curve associated with the adoption of new technologies and its correlation with farmer education levels. Compared to household heads without college level education, the probability of using CA on a field owned by a household head with a college education increased by 0.13.

Ownership of maize seeds or receiving seeds as a gift was not associated with the probability of using CA on a field, possibly because many farmers store seeds. However, farmers who did not receive fertilizer as a gift were less likely to use CA. Subsidized fertilizer provided by NGOs working in the area was correlated with probability of adoption. Compared to farmers who did not receive fertilizer as gifts, the probability of using CA on a field by farmers who received fertilizer as a gift or at a subsidized price increased by 0.07.

The distance from home to the field was negatively associated with the use of CA. Given the labor required to weed and prepare land, farmers may prefer to work intensively on fields closer to home. Smaller plots are also generally located near home. It is likely that these fields are used to produce food consumed at home because they are easier to monitor. A one minute increase in the walking distance from home to a field decreased the probability of using CA on that field by 0.002.

An increase in the percentage of people in a household between the age of 15 and 55 increased the probability of a household using CA technology on at least one of their fields, a finding similar to Doss (2006) and Marenya and Barrett's (2007) studies. A 1% increase in the number of people in a household between the age of 15 and 55 was associated with a 0.08 increase in the probability of using CA.

Income from livestock was negatively associated with CA adoption. Livestock sales may provide enough revenue for farmers to complement what is produced for household consumption. Farmers may not be willing to try a new technology because of this relatively secure form of investment (Tizale, 2007). Livestock are typically fed on what would otherwise be used as residue to cover soils. A 1% increase in total income from livestock sale decreases the probability of using CA on the field by 0.001.

Seed and labor prices were positively associated with the adoption of CA, but fertilizer prices were not associated with the use of CA. Seed price was not expected to have any association with the adoption decision because seeds can be stored from previous seasons. The reason for this may be associated with the ownership of these inputs and gifts from NGO's and/or government extension services.

Table 13. Probit maximum likelihood estimates and marginal effects explaining CA adoption.

Variable name	Variable Units	Estimates	Marginal effect	VIF
Intercept		-4.2504***		
Age, household head	Age	0.0139	0.0013*	1.72
Agricultural training	Yes or no	1.1234**	0.1015**	1.13
Field size	Hectares	-0.5477**	-0.0495**	1.17
Male, household head	Yes or no	-0.1082	-0.0098	1.38
Household head college education	Yes or no	1.4219**	0.1285**	1.30
Seed owned or received as gift	Yes or no	0.7682	0.0694	1.99
Fertilizer owned or received as gift	Yes or no	0.7977**	0.0721**	1.22
Walking time to field	Minutes	-0.0219**	-0.0020**	1.13
Field passed down	Yes or no	0.2103		1.12
Crop sale and beer income	Percent of total income	0.0008	0.0001	2.43
Access to credit and loan	Yes or no	0.2355	0.0213	1.17
Percent staple produced on farm	Percent of total staple	-0.0004	-0.0000	1.20
Age between 15 and 55	Percent of household size	0.8958**	0.0810**	1.39
Maize managed by female	Yes or no	-0.0602	-0.0054	1.39
Livestock income	Percent of total income	-0.0137**	-0.0012**	1.66
Off farm income	Percent of total income	0.0072	0.0006	2.44
Remittance income	Percent of total income	-0.0019	-0.0002	2.01
Seed price	Maluti per kilogram	0.4221**	0.0382**	10.58
Fertilizer price	Maluti per kilogram	-0.4505	-0.0407	8.29
Labor price	Maluti per person per day	0.0351**	0.0032**	7.31
Seed price squared		-0.0917**	-0.0083**	6.68
Seed and fertilizer prices interaction		0.1495**	0.0135**	2.99
Seed and labor prices interaction		-0.0042*	-0.0004**	2.53
Fertilizer price squared		0.0567	0.0051	5.22
Labor and fertilizer prices interaction		-0.0074	-0.0007	2.95
Labor price squared		-0.0003**	-0.0000**	6.73
Observations		569		
Percent adopting CA		12.9%		
Pseudo R^2		0.468		
Somer's D		0.843		

* $p < 0.10$, ** $p < 0.05$

5.1.13. Effect of CA on input demand, maize output and field profitability

Table 16 reports the regression results of the associations between CA adoption and profit, maize yield and inputs demand. The observed values of profit, seed, fertilizer, and labor were significantly correlated with their predicted values.

Table 14. Association between CA adoption, profit, maize yield, and inputs demand.

Parameters	Definition	Coefficient	T-Value	Corr (y, $\hat{y}$)
α_0	Profit intercept	235.8185***	5.44	-----
α_1	Seed demand intercept	-8.1909	-1.07	-----
α_2	Fertilizer demand intercept	-22.9532	-1.47	-----
α_3	Labor demand intercept	-4.0316***	-4.05	-----
α_{11}	Seed price	0.4309	1.06	-----
α_{12}	Interaction of seed and fertilizer prices	-0.1531	-0.08	-----
α_{13}	Interaction of seed and labor prices	-0.0033	-0.04	-----
α_{22}	Fertilizer prices	-3.0445	-0.70	-----
α_{23}	Interaction of fertilizer and labor prices	-0.0136	-0.04	-----
α_{33}	Labor prices	0.0008	0.09	-----
δ^{π}	CA effect on profit	236.3583*	2.16	0.26***
δ^{S}	CA effect on seed demand	-213.852	-1.53	0.19***
δ^{F}	CA effect on fertilizer demand	-7.2272	-0.40	0.27***
δ^{L}	CA effect on labor demand	-21.0335	-0.46	0.17***
δ^{y}	CA effect on maize output	-0.6822	-0.23	0.05
Observations		490		529

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Standard are robust to hetereoskedasticity.

The results suggest that CA adoption was positively associated with field-level profitability. However, CA adoption was uncorrelated with maize yield output and input demand. This result was expected for seed demand because it was hypothesized that seeding rates would not be affected by the use CA on the field, but these results were different from what was hypothesized for labor and fertilizer demands.

The null hypothesis that the CA coefficients were jointly equal to zero, $\delta^{\pi} = \delta^{S} = \delta^{F} = \delta^{L} = \delta^{y} = 0$, was rejected at the 1% level of significance, meaning that at least one of the predictors regression coefficients is not equal to zero(Wald test, χ_5^2 = 15.48, p < 0.0001). In this case, the use of CA on a field was associated with field profit.

The convexity of the system (i.e., the appropriateness of the profit maximizing assumption) is examined by estimating the elasticities of supply and input demand with respect to prices. Price elasticities were inconsistent with the assumptions of profit maximization, indicating that the indirect profit function was not convex in prices. The curvature violations suggest that, *inter alia*, producers may not be maximizing profit and household utility sequentially, putting the separability assumption into question. Violation of the separability assumption poses challenges if explanation of long term behavior is the primary research goal. In this analysis, it seems evident that separability was not maintained due to the cross sectional data used in the analysis, as well as the market distortions that may send mixed price signals to producers through input subsidies, aid from NGOs, and relatively weak markets for domestically produced maize.

CHAPTER 6: CONCLUSIONS

This thesis examined the factors influencing adoption of CA technology and the effect of CA adoption on input demand, profitability, and production of maize in the Butha Buthe district of Lesotho. Factors influencing the CA adoption decision include agricultural training, field size, education of the household head, the percent of household members between age 15 to 55, walking distance to fields, and income from livestock sales. Some other factors assumed to influence CA adoption decision were not associated with CA adoption, including access to credit, input prices, off-farm income, sex of the household head, age of the household head, and years of making farm decisions.

The use of CA on a field was positively associated with field profitability, but not input demands or maize production. The results suggest that input prices play an ambiguous role in determining the farmer's decision to adopt CA. There are at least three reasons contributing to this result. The first is the cross-sectional nature of the survey; two years may be too short a time to model input use and technology adoption decision making using a rigorous economic behavioral framework. The nature of the cross section survey data also makes it difficult to identify causal relationship because both the outcome and sample variables used for analysis are continuous. Longer panel data series may better elucidate these relationships. Second, markets for inputs may be imperfect to the extent that some inputs are provided gratis if farmers practice CA. Third, farmers in Butha Buthe may be more concerned with food security for their families rather than profit maximization.

Microeconomic theory requires the indirect profit function to be convex in prices. As applied in this thesis, producer behavior was inconsistent with the assumptions of profit maximization. Firstly, the presence of non-government organizations and government extension efforts promoting CA in Butha Buthe may contribute to the price unresponsiveness of farmers, thereby complicating the analysis of inputs demand use. In addition, the descriptive statistics suggests that there may be a lack of separability between household production and consumption decisions in Butha Buthe; farmers tend to produce maize mainly for subsistence and they are likely to practice CA if inputs are provided through NGOs and extensions at a low cost or for free.

Secondly, less than 10% of total sample data represented CA farmers. In addition, some respondents did not report the prices at which they bought inputs or sold output; the average prices reported at the village level were used instead. However, assuming that farmers in the same village face the same prices may cause upward or downward bias if farmers actually faced different prices than those that were imputed.

Further research isolating these causes is warranted to understand what role input prices play in determining input demands, maize production, and profitability given the promotion of CA by NGOs and other extension service, and the potential role CA may play in the wellbeing of smallholder farmers in sub-Saharan Africa.

References:

Adesina, A. A and M.M. Zinnah. 1993. “Technology characteristics, farmers’ perceptions and adoption decisions: A Tobit model application in Sierra Leone.” *Agricultural Economics, Vol* 9, Issue 4, pp 297-311.

Baudron, F., Mwanza, H.M., Triomphe, B., Bwalya, M. 2007. “Conservation Agriculture in Zambia: A Case Study of Southern Province. African Conservation Tillage Network.” Centre de Coope´ ration Internationale de Recherche Agronomique pour le De´velopment, Food and Agricultural Organization of the United Nations, Nairobi, Kenya.

Becker, G.S. 1988."Family Economics and Macro Behavior." *Amer. Econ. Rev*.78:1-13

Benjamin, D. 1992. “Household Composition, Labor Markets, and Labor Demand: Testing for separation in Agricultural Household Models.” *Econometrica*, 60.

Bolliger, A. Magid, J. Amado C.T.J., Neto F.S., Ribeiro, M., Calegari A,. Ralisch, R, de Neergaard, A. 2006. “Taking Stock of the Brazilian "Zero-Till Revolution": A Review of Landmark Research and Farmers' Practice.” *Advances in Agronomy, Volume 91* Elsevier.

Bolliger A. 2007. “Is Zero-Till an appropriate agricultural alternative for disadvantaged smallholders of South Africa? A study of surrogate systems and strategies, smallholder sensitivities and soil glycoproteins.” PhD Thesis. University of Copenhagen.

Boshen, P., Darty, B.A., G.D. Dogbe., E.A. Boadi., B. Triomphe., S. Daamgard-Larsen,. and J. Ashburner. 2007. “Conservation Agriculture as practiced in Ghana.” Rome: FAO.

Bruin, J. 2011. newtest: command to compute new test. UCLA: Statistical Consulting Group. http://www.ats.ucla.edu/stat/stata/ado/analysis/.

Carney D. 2002. “Sustainable Livelihoods approaches: Progress and Possibilities for change.” Department for International Development. London.

Chakela. Q. K. 1981. “Soil Erosion and Reservoir sedimentation in Lesotho.” Scandinavian Institute of African Studies, Uppsala, Sweden.

Chambers R.G. 1988. “Applied Production Analysis: A Dual Approach.” Cambridge University Press.

Chiang, A. C .1984. “Fundamental Methods of Mathematical Economics.” *Third Ed.* McGraw-Hill, Inc

Chiputwa, B., Langyintuo, A.S. & Wall, P. 2011. “Adoption of conservation agriculture technologies by smallholder farmers in the Shamva district of Zimbabwe: A Tobit application.” In: 2011 Annual Meeting. Southern Agricultural Economics Association, Corpus Christi, Texas, February 5-8, 2011.

Constantina S.R. 1985. “ Economic Development and Cultural Change.” Vol. 33, No. 2 pp.299-317. University of Chicago press.

CTIC/FAO. 2008. Mitigating climate change: Conservation Agriculture stores soil carbon. Recommendations of the Conservation Agriculture Carbon Offset Consultation, West Lafayette, IN, 28–30 October. On WWW at http://www.fao.org/ag/ca.

Derpsch, R. 2003. “Why and how to use green manure cover crops in a zero tillage system. Experiences from Latin America.” *In* 2003 Zero tillage Under Cover. Proceedings of a Conference sponsored by the South Dakota Zero tillage Association, February 4-5,2003 at Sioux Falls Convention Center, Sioux Falls, South Dakota," pp. 5-13.

Derpsch, R. 2008a. “No-tillage and Conservation Agriculture: a progress report.” In: T. Goddard, M.A. Zoebisch, Y.T. Gan, W. Ellis, A. Watson and S. Sombatpanit (eds) No-Till Farming Systems. *Special Publication* No. 3 (pp. 7–39). Bangkok: World Association of Soil and Water Conservation (WASWC).

Derpsch, R. and Friedrich, T. 2009. “Global overview of Conservation Agriculture adoption.” Invited Paper, 4th World Congress on Conservation Agriculture: Innovations for Improving Efficiency, Equity and Environment, 4–7 February. New Delhi: ICAR. On WWW at http://www.fao.org/ag/ca.

Diewert, W.E., Wales, T.J. 1987. “Flexible Functional forms and Global Curvature Conditions.” *Econometrica*, 55(1):43-68.

Doss C. 2006. Analyzing Technology Adoption using micro-studies: Limitations, challenges and opportunities for improvement. *Agric. Econ.*, 34: 207-219.

Dumanski J, Peiretti R, Benites JR, McGarry D, Pieri C. 2006. “The paradigm of Conservation Agriculture.” World Association of Soil and Water Conservation. Paper No. pp. 1-70.

Erenstein, O., Sayre, K., Wall, P., Hellin, J., Dixon, J. 2012. “Conservation Agriculture in Maize- and Wheat- Based Systems in the (sub) tropics: Lessons from Adaptation Initiatives in South Asia, Mexico, and Southern Africa.” *Journal of Sustainable Agriculture*, 36: 180 -206.

Erenstein, O., Sayer, K., Wall, P., Dixon, J. and Hellin, J. 2008. “Adapting no-tillage agriculture to the smallholder maize and wheat farmers in the tropics and sub-tropics.” In: T.Goddard, M.A. Zoebisch, Y.T. Gan, W. Ellis, A. Watson and S. Sombatpanit (eds) No-Till Farming Systems. *Special Publication* No. 3 (pp. 253–277). Bangkok: World Association of Soil and Water Conservation (WASWC).

Erenstein, O. 2006. “Intensification or extensification? Factors affecting technology use in peri-urban lowlands along an agroecological gradient in West Africa.” *Agricultural Systems,* 90, pp. 132–158.

Feder, G., Just, R.E. and Zilberman, D. 1985. "Adoption of agricultural Innovations in Developing Countries: A Survey." *Economic Development and Cultural change,* vol. 33, 255-298.

Fernandez-Cornejo, J. 1992. "Short- and Long-Run Demand and Substitution of Agricultural Inputs." *Northeast. J. Agr. and Resour*. Econ. 20:36-49.

Fowler, R. and J. Rockström. 2001. "Conservation tillage for sustainable agriculture. An agrarian revolution gathers momentum in Africa." *Soil & Tillage Research* 61: 93-107.

Garcia-Torres, L., Benites, J., Martinez-Vilela, A., Holgado-Cabrera, A. 2003. "Conservation Agriculture: Environment, Farmers Experiences, Innovations, Socio-economy, Policy." Kluwer Academic Publishers, Boston, USA.

Giller, K.E., Witter, E., Corbeels, M. and Tittonell, P. 2009. "Conservation agriculture and smallholder farming in Africa: the heretics' view." *Field Crops Research* 114 (1), 23–34. doi:10.1016/j.fcr.2009.06.017.

Gowing, J. W., and M. Palmer. 2008. "Sustainable agricultural development in sub-Saharan Africa: the case for a paradigm shift in land husbandry." *Soil Use and Management,* 24:1, 92-99.

Haggblade, S. and G. Tembo. 2003b. "Conservation Farming in Zambia." paper presented at the In WEnt, IFPRI, NEPAD, CTA conference "Successes in African Agriculture" Pretoria December 1-3, 2003

Haggblade, S. and G.Tembo. 2003. "Conservation farming in Zambia". EPTD Discussion Paper. Environment and Production Technology Division, International Food Policy Research Institute.

Heltberg R, Tarp F. 2002. "Agricultural Response and Poverty in Mozambique." *Food Policy* 27: 103-124.

Hengxin, L., L. Hongwen., F. Xuemin, and X. Liyu. 2008. "The current status of conservation tillage in China." In: T. Goddard, M.A. Zoebisch, Y.T. Gan, W. Ellis, A. Watson and S. Sombatpanit (eds) No-Till Farming Systems. *Special Publication* No. 3 (pp. 413– 428). Bangkok: World Association of Soil and Water Conservation (WASWC).

Hobbs, P.R. 2006. "Conservation Agriculture: What is it and why is it important for future sustainable food production." Proceedings of an International Workshop on Increasing wheat Yield Potential. CIMMYT, Obregon, Mexico. March 20-24th 2006. Accepted for publication in 2006.

Hobbs P R. 2007. "Conservation agriculture: what is it and why is it important for future sustainable food production." *Journal of Agricultural Science* 145: 127–137.

Hobbs P R, Sayre K, Gupta R. 2008. "The role of conservation agriculture in sustainable agriculture." *Philos. Trans. Roy. Soc.* B 363, 543–555.

ICRISAT. 2006. "Is Conservation agriculture an option for vulnerable households?." Briefing Note by Twomlow, S. and L. Hove. Bulawayo. Zimbabwe.

ICRISAT. 2009. 'Trends in Conservation Farming Adoption and Impacts', A report of the 2009 CA panel study carried out by ICRISAT and jointly supported by FAO, and GRM International.

Kassam, A., T. Friedrich. 2009. "Adoption of Conservation Agriculture Technologies: Constraints and Opportunities." Invited paper at the *IV World Congress on Conservation Agriculture.* 4-7 February 2009, New Delhi, India.

Kassam A H, T. Friedrich, F Shaxson, P. Jules. 2009. “The spread of Conservation Agriculture: Justification, sustainability and uptake.” *International Journal of Agriculture Sustainability* 7(4): 292-320.

Kassam A., T. Friedrich and R. Derpsch. 2010. “CA in the 21st Century: A Paradigm of Sustainable Agriculture.” European Congress on CA, Madrid, October. Available at: http://www.marm.es/es/ministerio/servicios generales/publicaciones/Opening_plenary_sessions_tcm7-158496.pdf.

Kaumbutho P, Kienzle J, eds. 2007. “Conservation agriculture as practiced in Kenya: two case studies. Nairobi.” African Conservation Tillage Network, Centre de Coopération Internationale de Recherche Agronomique pour le Développement, Food Agric. Organ. United Nations.

Knowler, D. & Bradshaw, B. 2007. "Farmers' adoption of conservation agriculture: A review and synthesis of recent research." *Food Policy, Elsevier, vol*. 32(1), pages 25-48, February.

Knowler, D., B. Bradshaw, and D. Gordon. 2003. “*The economics of conservation agriculture*.” Rome, Italy: FAO.

Kliewer, L., Casaccia, J. and Vallejos, F. 1998. Viabilidad da reduc¸a˜o do uso de herbicidas e custos no controle de plantas daninhas nas culturas de trigo e soja no sistema de plantio directo, atrave´s do emprego de adubos verdes de curto periodo. Resumo de Palestras: I Semina´ rio Nacional Sobre Manejo e Controle de Plantas Daninhas em Plantio Direto, 10–12 August.1998, RS, Editora Aldeia Norte, Passo Fundo, pp. 120–123.

Lafond, G.P., Walley, H., Schoenau, J., May, W.E., Holzafel, C.B., McKell, J. and Halford, J. 2008. “Long-term vs. short-term conservation tillage.” Proceedings of the 20th Annual

Meeting and Conference of the Saaskatchewan Soil Conservation Association, 12–13 February, Regina, Saaskatchewan, pp. 28–43.

Lal R. 2009. “The plough and agricultural sustainability.” *Sustainable Agric*., 33: 66-84.

Landers, J. 2007. “Tropical Crop-Livestock Systems in Conservation Agriculture: The Brazilian Experience.” *Integrated Crop Management*, Vol. 5. Rome: FAO.

Langyintuo, A.S. and M. Mekuria. 2000. “Farmers Strategy for Sustainable Food Security Determinants of the adoption of improved rice varieties in the inland valleys of northern Ghana”. A Tobit model application.

Langyintuo, A.S. and M. Mekuria. 2005, “Modeling Agricultural Technology Adoption Using the Software STATA”, Presented at a Training Course, Econometric Application to Modeling the Adoption of Agricultural Technologies, 21 – 25 February, 2005, Harare, International Maize and Wheat Improvement Center (CIMMYT), Harare, Zimbabwe.

Lesotho Mountain Research Group (LMRG). 1996. “Towards an Integrated perspective on Land Degradation in the Mountains of Lesotho.” A report on the Inaugural Meeting held at Malealea Lodge, Ministry of Environment, Maseru, Lesotho.

Lohr, S. L. 1999. Sampling: Design and Analysis, Pacific Grove, CA: Duxbury.

Marongwe. L. S, K. Kwazira, M. Jenrich, C. Thierfelder, A. Kassam & T. Friedrich. 2011. “An African success: the case of conservation agriculture in Zimbabwe.” *International Journal of Agricultural Sustainability, 9:1, 153-161.*

Marake, M. 2008. “CA in Lesotho: Current Practices and Prospects.” Paper Presented to the Africa Soil Science Society’s Conference on the Promotion of CA in Africa, Nakuru, Kenya, February.

Marenya, P.P. & Barrett, C.B., 2007. "Household-level determinants of adoption of improved natural resources management practices among smallholder farmers in western Kenya." Food Policy, Elsevier, vol. 32(4), pages 515-536.

Mashingaidze A.B.and Mudhara M. 2005. "Non-Governmental Organizations (NGO) efforts to Mexico, and Southern Africa." *Journal of Sustainable Agriculture*, 36: 180 -206.

Mazvimavi K, Twomlow S. 2009. "Socioeconomic and institutional factors influencing adoption of conservation agriculture by vulnerable households in Zimbabwe." *Agric. Syst.*, 101: 20-29.

Mazvimavi, Kizito; Ndlovu, Patrick V.; Nyathi, Putso; and Minde, Isaac J. 2010. "Conservation Agriculture Practices and Adoption by Smallholder Farmers in Zimbabwe" Cape Town, South Africa, September 19-23, 2010.

Ministry of Agriculture (MOA). 1988. Soil Conservation Handbook for Lesotho, Conservation Division: Maseru: Lesotho.

Mueller, D.H., R.M. Klemme,. and T.C. Daniel. 1985. "Short- and long-term cost comparisons of conventional and conservation tillage systems in corn production". *Journal of Soil and Water Conservation*, 40(5): 466-470.

MOHSW. 2012. National HIV and AIDS Estimates for Lesotho. Maseru, LS: MOHSW.

Neter, J., W. Wasserman, and M. Kutner. 1985. *Applied linear statistical models (2nd edition)*. Illinois: Richard Irwin, Inc.

Nkala, P., Mango, N., Corbeels, M., Veldwisch, G., Huising, J., 2011. "The Conundrum of Conservation Agriculture and Livelihoods in Southern Africa." *African Journal of Agricultural Research*, 6(24): 5750 – 5770.

Nyagumbo, I. 1999. “Conservation Tillage for sustainable crop production systems: experiences from on-station and on-farm research in Zimbabwe (1997-1998).” In Kaumbutho P.G and T. E. Simalenga. (Editors). Conservation Tillage with Animal Traction. ATNESA. Harare. Zimbabwe.107-114.

Nyagumbo, I., Mbvumi, B. M., Mutsamba, E., 2009. “CA in Zimbabwe: socio-economic and biophysical studies.”A paper presented at the SADC Regional Conference on Sustainable Land Management, Windhoek, Namibia, 7–11 September.

Nyende, P., Nyakuni, A., Opio, J.P. and Odogola, W. 2007. “Conservation Agriculture: A Uganda case study.” Rome: FAO.

Offutt, Susan. 2002. "The future of farm policy analysis: A household perspective."*American Journal of Agricultural Economics* 84.5: 1189-1200.

Pendo Maro. 2011. “Environmental Change in Lesotho”: An Analysis of the Causes and Consequences of Land-Use Change in the Lowland Region.

Poulter. S.M. 1981. “ Law and Population Project.” Faculty of Law, National University of Lesotho. Roma, Lesotho.

Pretty JN. 1998. “The Living Land: Agriculture, Food Systems and Community Regeneration in Rural Europe.” London. Earth scan Publications Ltd.

Pretty J. 2000. “Can sustainable Agriculture feed Africa? New evidence on progress, processes and impacts.” Centre for Environment and Society. University of Essex. Colchester. United Kingdom.

Pretty, J., Noble, A.D., Bossio, D., Dixon, J., Hine, R.E., Penning de Vries, F.W.T. and Morison, J.I.L. (2006. “Resource-conserving agriculture increases yields in developing countries.” *Environmental Science & Technology* 3 (1), 24–43.

Pretty, J. 2008. “Agricultural sustainability: concepts, principles and evidence.” Philosophical Transactions of the Royal Society of London B 363 (1491), 447–466.

Rahm, M.R., and Huffman, W.E. 1984. “The adoption of reduced tillage: The role of human capital and other variables*”. American Journal of Agricultural Economics*, 66, 405-413.

Riches CR, S.J. Twomlow., H. Dhliwayo . 1997. “Low input weed management and Conservation Tillage in Semi-Arid Zimbabwe.” *Expt. Agric.*, 33: 173-187.

Rockstrom, J., M. Falkenmark.2000. “Semi-arid crop production from a hydrological perspective-gap between potential and actual yields.” *Critical Review on Plant Science* 19(4), 319–346.

Rockstrom, J., Kaumbutho, P., Mwalley, J., Nzabi, A.W., Temesgen, M., Mawenya, L., Barron, J., Mutua, J. and Damgaard-Larsen, S. 2009. “Conservation farming strategies in East and Southern Africa: yields and rain water productivity from on-farm action research.” *Soil & Tillage Research* 103, 23–32.

Sustainable Agriculture and Rural Development. 2007. SARD and Conservation Agriculture in Africa. SARD Policy Brief 18. Rome: FAO.

Shetto, R. and Owenya, M. (eds). 2007. “Conservation Agriculture as practiced in Tanzania: three case studies.” Rome: FAO.

Shortle, J.S., Miranowski, J.A., 1986. “Effects of risk perceptions and other characteristics of farmers and farm operations on the adoption of conservation tillage practices.” *Applied Agricultural Research* 1 (2), 85–90.

Showers B.K. 2005. “ Imperial Gullies.” *Ohio University Press: Athens*

Silici, L. 2009. “The role of social capital in the adoption and the performance of Conservation Agriculture: the practice of Likoti in Lesotho.” PhD Thesis, Departimento di Economia, Universita degli Studi Roma Tre, Rome, Italy.

Silici, L. 2010. “CA and Sustainable Crop Intensification in Lesotho,” in Integrated Crop Management Vol.10, Food and Agriculture Organization of the United Nations, Rome.

Silici,L., P. Ndabe, T. Friedrich and A. Kassam. 2011. “Harnessing sustainability,resilience and productivity through CA: the case of *likoti* in Lesotho.” *International Journal of Agricultural Sustainability*, 9:1, 137-144.

Thierfelder, C, and P.C. Wall. 2010. “Investigating CA (CA) Systems in Zambia and Zimbabwe to Mitigate Future Effects of Climate Change.” *Journal of Crop Improvement*, 24: 113-121.

Tizale, C.Y. 2007. “The dynamics of soil degradation and incentives for optimal management in the Central Highlands of Ethiopia”. PhD thesis, Department of Agricultural Economics, Extension and Rural Development, Faculty of Natural and Agricultural Sciences, University of Pretoria.

Toner A 2002. “Sustainable Livelihoods Approaches - Can they Transform Development?” Bradford Centre for International development. Research Paper Number 2. University of Bradford.

Twomlow, S. J., D. Rohrbach., L. Hove., W. Mupangwa., N. Mashingaidze., M. Moyo., C. Chiroro. 2006. “Conservation farming by basins breathes new life into smallholder farmers in Zimbabwe.” SADC Land and Water Management Program Scientific Conference – February, Lilongwe, Malawi.

Twomlow, S.J., Steyn, J.T., du Preez, C.C., 2006. Dry land farming in southern Africa. In:

Dryland Agriculture 2nd Edition. Agronomy Monograph No. 23. *American Society of Agronomy*, Madison, Wisconsin. pp. 769–836.

Twomlow, S., Urolov, J.C., Jenrich, M., Oldrieve B., 2008. "Lessons from the field – Zimbabwe's Conservation Agriculture Task Force." *Journal of SAT Agricultural Research* 6 (11pages).

Mansfield, E.R., and B. P. Helms. 1982. Detecting multicollinearity. *American Statisticians* 36 (3): 158–160.

Sadoulet, Elizabeth and Alain De Janvry. 1995. *Quantitative development policy analysis.* Baltimore: Johns Hopkins University Press.

Umar, B.B., Aune, J. B., Johnsen, F. H., and Lungu, O.I. 2011. "Options for Improving Smallholder CA in Zambia." *Journal of Agricultural Science*, 3:3(September), 50-62.

United Nations, Food and Agriculture Organization. 2001a. *The Economics of Conservation Agriculture. FAO,* Rome.

United Nations, Food and Agriculture Organization. 2001b. *Conservation Agriculture: Case Studies in Latin America and Africa. Soils Bulletin No. 78. FAO,* Rome.

United Nations, Food and Agriculture Organization. 2007. Workshop on Conservation Agriculture in Southern Africa. Harrison's Conference Centre. Corner 12th Avenue and Wessels Street. Rivonia. Johannesburg. South Africa.

United Nations, Food and Agriculture Organization. 2007. *Agricultural Coordinating Working Group. May 2007 Journal*. FAO Harare. Available from: http://www.zimrelief.info.

United Nations, Food and Agriculture Organization. 2008. Investing in Sustainable Crop

Intensification: The Case for Soil Health. Report of the International Technical Workshop, FAO, Rome, July. Integrated Crop Management, Vol. 6. Rome: FAO. On WWW at http://www.fao.org/ag/ca/.

United Nations, Food and Agriculture Organization. 2009. "Enhancing Crop-Livestock Systems in Conservation Agriculture for Sustainable Production Intensification: A Farmer Discovery Process Going to Scale in Burkina Faso." *Integrated Crop Management,* Vol. 7. Rome: FAO.

Wall, P. C. 2007. "Tailoring conservation agriculture to the needs of small farmers in developing countries: An analysis of issues." *Journal of Crop Improvement* 19: 137–155.

Wandel, J., and J. Smithers. 2000. "Factors affecting the adoption of conservation tillage on clay soils in southwestern Ontario, Canada". *American Journal of Alternative Agriculture,* 15(4).

Webber C. M., and P. Labaste. 2010. "Building Competitiveness in Africa's Agriculture: A Guide to Value Chain Concepts and Application." The World Bank, Washington DC.

Wooldridge J.M. 2002. "Econometric Analysis of Cross Section and Panel Data" *MIT Press, Cambridge, MA (2002.*

Appendix

Table A1: Sampling of Households by Village

Village	Council	Sample	Census	Percent
Ha Rasekila	*Likila*	39	37	105
Ha Tabolane	*Likila*	89	85	105
Joala-Boholo	*Likila*	42	50	84
Ha Keletso (Mafika-Lisiu)	*Liqobong*	60	64	94
Ha Sefako	*Liqobong*	63	62	102
Manoeleng	*Liqobong*	21	22	95
Ha Mou	*Makhunoane*	15	19	79
Mokotjela	*Makhunoane*	34	35	97
Phamong	*Makhunoane*	9	10	90
Maloseng (MAFS)	*Tša-le-Moleka*	61	61	100
	TOTAL	433	445	97

Notes: MAFS indicates that this is a service area for the Lesotho Ministry of Agriculture's CA project.

Table A2: Means of variables used for probit regression of CA adoption

	CA famers				Non-CA farmers			
Variable name	Mean	St.dev	Min	Max	Mean	St.dev	Min	Max
Age, household head	57.69	13.59	32	90	54.08	15.57	20	95
AgTraining	0.84	0.36	0.00	1	0.43	0.50	0.00	1
Field size (ha)	0.47	0.57	0.003	2.83	0.75	0.66	0.00	4.86
Male household head	0.69	0.47	0.00	1	0.70	0.46	0.00	1
Household head college education	0.08	0.27	0.00	1	0.08	0.28	0.00	1
Seed owned or gift	0.85	0.36	5.33	1	0.55	0.50	0.4	1
Fertilizer owned or gift	0.83	0.38	0.00	1	0.66	0.47	0.00	1
Walking time to field	10	13.72	0.00	60	39	46.24	0.00	360
Field Passed Down	0.46	0.50	0.00	1	0.50	0.50	0.00	1
Crop sale and beer income	19.08	31.73	0.00	90	30.74	38.26	0.00	100
Access to credit and loan	0.12	0.32	0.00	1	0.05	0.21	0.00	1
Percent produce on farm	67.57	25.74	20	100	70.47	28.33	0.00	100
Age between 15 to 55	38.15	30.1	0.00	100	34.58	23.87	0.00	100
Female managed fields	0.25	0.44	0.00	1	0.25	0.43	0.00	1
Livestock income	3.53	15.73	0.00	100	10.85	25.18	0.00	100
Off farm income	54.64	45.25	0.00	100	30.37	37.26	0.00	100
Remittance income	8.43	23.18	0.00	100	14.63	30.30	0.00	100
Field observations	52				559			

Table A3: Transport means in Butha Buthe, Lesotho.

	CA-adopters	Non-CA adopters
Bicycles		
None	88 (98.89%)	89 (100%)
1	1 (1.11%)	
Donkeys		
None	33 (36.67%)	32 (35.96%)
1	36 (40.00%)	36 (40.45%)
2	8 (8.89%)	8 (8.99%)
3	6 (6.67%)	6 (6.74%)
4	2 (2.22%)	2 (2.25%)
5	3 (3.33%)	3 (3.37%)
7	1 (1.11%)	1 (1.12%)
More than 7	1 (1.11%)	1 (1.12%)
Horse or Mules		
None	49 (54.44%)	48 (53.93%)
1	29 (32.22%)	29 (32.58%)
2	6 (6.67%)	6 (6.74%)
3	5 (5.56%)	5 (5.62%)
More than 3	1 (1.11%)	1 (1.12%)
Vehicles		
None	79 (87.78%)	78 (87.64%)
1	11 (12.22%)	11 (12.36%)

Notes: CA is defined as farmers who practiced no-till or used basins for planting.

CA adopters are farmers who practiced CA at the time of the survey (summer of 2010). Non-CA adopters are farmers who never practiced CA in any of the seasons covered by the survey.

Table A4: General farming characteristics in Butha Buthe, Lesotho.

	CA-adopters (percent)	Non- adopters (percent)
Space Between Rows (in cm)		
20	1 (1.14)	8 (2.41)
25	1 (1.14)	4 (1.20)
30	8 (9.09)	36 (10.84)
40	1 (1.14)	9 (2.71)
45	7 (7.95)	37 (11.14)
50	1 (1.14)	19 (5.72)
60	24 (27.27)	87 (26.20)
70	5 (5.68)	22 (6.63)
75	32 (36.36)	68 (20.48)
More than 75	6 (6.82)	26 (7.83)
No Response	2 (2.27)	16 (4.82)
Space Between Plants (in cm)		
10	11 (12.36)	79 (23.44)
20	31 (34.83)	102 (30.27)
30	14 (15.73)	86 (25.52)
40	3 (3.37)	6 (1.78)
50	4 (4.49)	10 (2.97)
60	2 (2.25)	4 (1.19)
70	1 (1.12)	0 (0.00)
75	19 (21.35)	19 (5.64)
More than 75	0 (0.00)	0 (0.00)
No response	4 (4.49)	31 (9.20)
Numbers of seeds planted in a hole		
1	2 (2.25)	6 (1.78)
2	17 (19.10)	8 (2.37)
3	59 (66.29)	71 (21.07)
5	2 (2.25)	2 (0.59)
No Response	9 (10.11)	250 (74.18)
N	89	337

Notes: CA is defined as farmers who practiced no-till or used basins for planting.

Table A5: Housing material characterization in Butha Buthe, Lesotho.

	CA-adopters (percent)	Non- adopters(percent)
Primary Wall Material:		
1 Earth/ Mud	68 (76.54)	252 (74.56)
3 Earthen Brick	2 (2.25)	8 (2.37)
5 Board	0 (0.00)	61 (18.05)
7 Cement	15 (16.85)	1 (0.30)
9 Burnt Brick	3 (3.37)	8 (2.37)
11 Other	1 (1.12)	5 (1.48)
No Response	0 (0.00)	0 (0.00)
Secondary Wall Material:		
1 Earth/ Mud	3 (3.37)	6 (1.78)
3 Earthen Brick	2 (2.25)	2 (0.59)
5 Board	0 (0.00)	0 (0.00)
7 Cement	21 (23.60)	65 (19.23)
9 Burnt Brick	2 (2.25)	9 (2.66)
11 Other	0 (0.00)	0 (0.00)
No Response	61 (68.54)	256 (75.74)
Tertiary Wall Material:		
1 Earth/ Mud	0 (0.00)	1 (0.30)
3 Earthen Brick	0 (0.00)	1 (0.30)
5 Board	0 (0.00)	0 (0.00)
7 Cement	0 (0.00)	1 (0.30)
9 Burnt Brick	0 (0.00)	0 (0.00)
11 Other	0 (0.00)	0 (0.00)
No Response	89 (100)	335 (99.11)
N	89	338

Notes: CA is defined as farmers who practiced no-till or used basins for planting.

CA adopters are farmers who practiced CA at the time of the survey (summer of 2010). Non-CA adopters are farmers who never practiced CA in any of the seasons covered by the survey.

Table A6: Household characteristics in Butha Buthe, Lesotho.

	CA-adopters (percent)	Non-CA adopters (Percent)
Latrines/Toilet:		
0 = NO	33 (37.08)	112 (33.14)
1 = YES	56 (62.92)	226 (66.86)
Access to electricity:		
0 = NO	86 (96.63)	332 (98.22)
1 = YES	3 (3.37)	6 (1.78)
Number of rooms:		
0 Rooms	1 (1.12)	4 (1.19)
1 Rooms	8 (8.99)	37 (10.98)
2 Rooms	28 (31.46)	94 (27.89)
3 Rooms	24 (26.97)	74 (21.96)
4 Rooms	13 (14.61)	55 (16.32)
5 Rooms	7 (7.87)	33 (9.79)
6 Rooms	6 (6.74)	17 (5.04)
7 Rooms	1 (1.12)	14 (4.15)
More than 7 Rooms	1 (1.12)	9 (2.68)
Source of water:		
1 Tap	60 (67.42)	252 (74.56)
3 Borehole	7 (7.87)	28 (8.28)
5 Open well	12 (13.48)	40 (11.83)
7 River, Pond, Lake, Swang	1 (1.12)	0 (0.00)
9 Protected spring	3 (3.37)	5 (1.48)
11 Rain water, tank	6 (6.74)	8 (2.37)
Distance to water (in minutes):		
Less than 1 minute	0 (0.00)	5 (1.48)
5	38 (42.70)	143 (42.31)
10	13 (14.61)	59 (17.46)
15	7 (7.87)	21 (6.21)
20	6 (6.74)	36 (10.65)
25	0 (0.00)	3 (0.89)
30	16 (17.98)	40 (11.83)
30	2 (2.25)	3 (0.89)
50	2 (2.25)	3 (0.89)
60	5 (5.62)	25 (7.40)
More than 60	0 (0.00)	5 (1.48)
N	89	338

Notes: CA is defined as farmers who practiced no-till or used basins for planting.

CA adopters are farmers who practiced CA at the time of the survey (summer of 2010). Non-CA adopters are farmers who never practiced CA in any of the seasons covered by the survey.

Table A7: General farming characteristics in Butha Buthe, Lesotho.

	CA-adopters (percent)	Non-adopters (percent)
Number of Fields rented out		
0	89 (96.63)	326 (96.45)
1	3 (3.37)	8 (2.37)
2	0 (0.00)	4 (1.18)
AcreOut		
0	86 (96.63)	330 (97.63)
2	1 (1.12)	5 (1.48)
3	1 (1.12)	3 (0.59)
7	0 (0.00)	1 (0.30)
70	1 (1.12)	
Rent (In Maluti)		
0	87 (97.75)	331 (97.93)
2	0 (0.00)	1 (0.30)
500	0 (0.00)	1 (0.30)
600	0 (0.00)	2 (0.59)
700	0 (0.00)	1 (0.30)
800	0 (0.00)	1 (0.30)
1000	1 (1.12)	0 (0.00)
1050	0 (0.00)	1 (0.30)
4500	1 (1.12)	0 (0.30)
N	89	338

Notes: CA is defined as farmers who practiced no-till or used basins for planting.

CA adopters are farmers who practiced CA at the time of the survey (summer of 2010).

Non-CA adopters are farmers who never practiced CA in any of the seasons covered by the survey.

Table A8: Storage problems in Butha Buthe.

	CA-adopters (percent)	Non-CA adopters (percent)
Primary Storage Problem		
No Response	6 (6.74)	41 (12.24)
Rats	52 (58.43)	190 (56.72)
People	0 (0.00)	2 (0.60)
Weevils	30 (33.71)	96 (28.66)
Other	1 (1.12)	6 (1.79)
Secondary Storage Problem		
No Response	65 (73.03)	249 (73.89)
Rats	3 (3.37)	16 (4.75)
People	2 (2.25)	8 (2.37)
Weevils	17 (19.10)	68 (20.18)
Moths	1 (1.12)	0 (0.00)
Other	2 (2.25)	1 (0.30)
Tertiary Storage Problem		
No response	89 (100)	338 (100)
500	0 (0.00)	0 (0.00)
600	0 (0.00)	0 (0.00)
700	0 (0.00)	0 (0.00)
800	0 (0.00)	0 (0.00)
1000	0 (0.00)	0 (0.00)
1050	0 (0.00)	0 (0.00)
4500	0 (0.00)	0 (0.00)
N	89	338

Notes: CA is defined as farmers who practiced no-till or used basins for planting.

CA adopters are farmers who practiced CA at the time of the survey (summer of 2010). Non-CA adopters are farmers who never practiced CA in any of the seasons covered by the survey.

Table A9: Knowledge, understanding and attitudes of Agriculture in Butha Buthe, Lesotho.

	CA-adopters (percent)	Non-CA adopters (percent)
Timely weeding is important		
No response	0 (0.00)	0 (0.00)
Disagree	1 (1.12)	3 (0.891)
Neutral	0 (0.00)	0 (0.00)
Agree	88 (98.88)	335 (98.52)
Inorganic fertilizer is best for soil quality		
No response	0 (0.00)	7 (2.07)
Disagree	12 (13.48)	27 (7.99)
Neutral	4 (4.49)	9 (2.66)
Agree	73 (82.02)	293 (86.69)
Pesticide application is necessary		
No response	2 (2.25)	3 (0.891)
Disagree	5 (5.62)	22 (6.51)
Neutral	1 (1.12)	11 (3.25)
Agree	81 (91.01)	300 (88.76)
Cover crops must be maintained on fields		
No response	2 (2.25)	4 (1.18)
Disagree	4 (4.49)	33 (9.76)
Neutral	7 (7.87)	24 (7.10)
Agree	76 (85.39)	275 (81.36)
Crop rotation is best practice		
No response	0 (0.00)	6 (1.78)
Disagree	3 (3.37)	12 (3.55)
Neutral	2 (2.25)	12 (3.55)
Agree	84 (94.38)	306 (90.53)
N	89	336

Notes: CA is defined as farmers who practiced no-till or used basins for planting.

CA adopters are farmers who practiced CA at the time of the survey (summer of 2010). Non-CA adopters are farmers who never practiced CA in any of the seasons covered by the survey.

Table A10: Knowledge, understanding and attitudes of agriculture in Butha Buthe, Lesotho (continued).

	CA-adopters	Non-CA adopters
Land is for Basotho to preserve for future generation		
No response	0 (0.00)	1 (0.30)
Disagree	0 (0.00)	0 (0.00)
Neutral	0 (0.00)	1 (0.30)
Agree	89 (100)	334 (98.82)
Farm produce necessary to feed family		
No response	0 (0.00)	1 (0.30)
Disagree	4 (4.49)	15 (4.46)
Neutral	0 (0.00)	4 (1.19)
Agree	85 (95.51)	316 (94.05)
Plant based on current market prices		
No response	0 (0.00)	4 (0.56)
Disagree	37 (41.57)	143 (42.31)
Neutral	2 (6.74)	23 (6.80)
Agree	46 (51.59)	166 (49.11)
Off farm income more important than harvest		
No response	0 (0.00)	2 (0.59)
Disagree	53 (59.55)	199 (58.88)
Neutral	12 (13.48)	40 (11.83)
Agree	24 (26.97)	95 (28.11)
Crops should be grown for sale		
No response	0 (0.00)	0 (0.00)
Disagree	65 (73.03)	256(75.74)
Neutral	6 (6.74)	14 (4.14)
Agree	18 (20.22)	66 (19.53)
N	89	336

Notes:
CA is defined as farmers who practiced no-till or used basins for planting.

CA adopters are farmers who practiced CA at the time of the survey (summer of 2010). Non-CA adopters are farmers who never practiced CA in any of the seasons covered by the survey.

Table A11: Knowledge, understanding and attitudes of agriculture in Butha Buthe, Lesotho (continued)

	CA-adopters (percent)	Non-adopters (percent)
One should strive to grow the most		
No response	2 (2.25)	4 (1.18)
Disagree	22 (24.72)	91 (26.92)
Neutral	3 (3.37)	13 (3.85)
Agree	62 (69.66)	228 (67.46)
Farm labor replaced by chemicals and machines		
No response	1 (1.12)	6 (1.78)
Disagree	16 (17.98)	52 (15.38)
Neutral	7 (7.87)	20 (5.92)
Agree	65 (73.03)	258 (76.33)
Farm Income should be reinvested		
No response	0 (0.00)	2 (0.59)
Disagree	7 (7.87)	23 (6.80)
Neutral	0 (0.00)	7 (2.07)
Agree	82 (92.13)	304 (91.94)
Staples should be planted by majority		
No response	0 (0.00)	1 (0.30)
Disagree	3 (3.37)	25 (7.40)
Neutral	0 (0.00)	2 (0.59)
Agree	86 (96.63)	307 (90.83)
Growing food better than purchasing		
No Response	0 (0.00)	0 (0.00)
Disagree	8 (8.99)	22 (6.51)
Neutral	0 (0.00)	1 (0.30)
Agree	81 (91.01)	313 (92.60)
N	89	336

Notes: CA is defined as farmers who practiced no-till or used basins for planting.

CA adopters are farmers who practiced CA at the time of the survey (summer of 2010). Non-CA adopters are farmers who never practiced CA in any of the seasons covered by the survey.

Table A12: Knowledge, understanding and attitudes of agriculture in Butha Buthe, Lesotho (continued).

	CA-adopters (percent)	Non-CA adopters (percent)
Multi-production is better than single crop		
production	0 (0.00)	2 (0.59)
No response	8 (8.99)	23 (6.80)
Disagree	2 (2.25)	6 (1.78)
Neutral	79 (88.76)	305 (90.24)
Agree		
Necessary to spread crops and inputs across fields		
No response	0 (0.00)	3 (0.89)
Disagree	11 (12.36)	27 (8.04)
Neutral	3 (3.37)	5 (1.49)
Agree	75 (84.27)	301 (89.58)
Crop residue should be fed to livestock		
No response	0 (0.00)	5 (16.07)
Disagree	57 (64.04)	166 (49.11)
Neutral	10 (11.24)	29 (8.58)
Agree	22 (24.72)	135 (39.94)
Tilling causes erosion		
No response	2 (2.25)	8 (2.37)
Disagree	28 (31.46)	124 (36.98)
Neutral	12 (13.48)	37 (10.95)
Agree	47 (52.81)	166 (49.11)
Land prep. begins with plowing		
No response	0 (0.00)	1 (0.30)
Disagree	36 (40.45)	97 (28.70)
Neutral	13 (14.61)	11 (3.25)
Agree	40 (44.94)	226 (66.86)
N	89	336

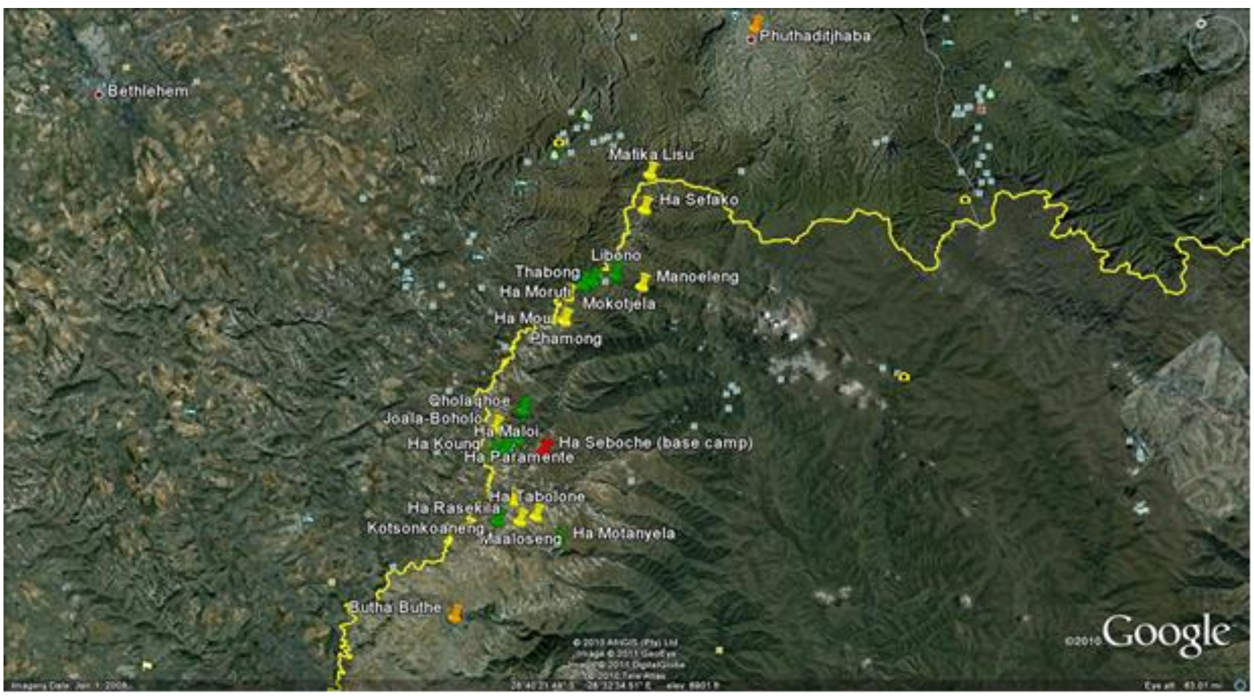
Notes:

CA is defined as farmers who practiced no-till or used basins for planting.

CA adopters are farmers who practiced CA at the time of the survey (summer of 2010).

Non-CA adopters are farmers who never practiced CA in any of the seasons covered by the survey.

Figure 5. Villages surveyed.



Source: SANREM project report, March, 2013.

Yellow represents selected and surveyed villages, green is selected village but not surveyed, and red is researchers' base.

VITA

Eric Bisangwa was born on January 26, 1982 in Kigali, Rwanda. He graduated from APRED Ndera High School in 2001. He then attended School of Finance and Banking where he completed his Bachelor Degree in Business Administration (Majoring in Finance) with Second Class honors. After completion of his undergraduate degree, Eric Bisangwa attended the University of Tennessee where he completed a Master of Science degree in Agricultural and Resource Economics. He is looking forward to pursuing a Doctorate of Philosophy degree in Natural Resources with a concentration in Natural Resource Economics from the University of Tennessee.