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Abstract

Owori, Moses O., Conservation Agriculture in Eastern Uganda and Western Kenya: Assessment of Beneficiaries' Baseline Socio-economic Conditions, MS.,
Department of Agricultural & Applied Economics, April 2013.

Despite the key role that smallholder farming plays in food security, income generation and employment for many households in Kenya and Uganda, productivity on these farms has been insufficient to consistently meet household needs. Yields of major staple and cash crops have either stagnated or declined, contributing to the frequent food security challenges that both countries have faced in the past few decades. This has been attributed, in part, to declining soil fertility. Governments, NGOs and other development agencies in eastern Uganda and western Kenya have been combating soil degradation through promotion of the following conservation agriculture (CA) practices: maintaining year-round soil cover, minimizing soil disturbance associated with tillage, and using crop rotations. However, their efforts seem to have had limited success in achieving widespread adoption and sustained use. Failure of past projects highlights the need for a better understanding of the context in which interventions are implemented, and factors that foster or hinder adoption and sustained use of new farming technologies.

The purpose of this study is to assess baseline socio-economic data collected from 790 households (HH) in the Sustainable Agriculture and Natural Resource Management/Collaborative Research Support Program (SANREM/CRSP) Conservation Agricultural Production Systems (CAPS) project areas of Trans-Nzoia and Bungoma districts in western Kenya, and Tororo and Kapchorwa districts in eastern Uganda. Surveys were administered before local farmers began working closely with researchers to co-design and test improved CAPS. The aim of my analysis is to identify socio-economic differences in the four

districts surveyed, and factors that might hinder or foster adoption of improved CAPS by smallholder farmers in these districts.

Descriptive analysis results reveal relevant socio-economic and agronomic differences between the four districts of our study area. Some differences reflect variability in districts' physical characteristics, such as elevation, slope, or soil type; other differences reflect variability in districts' socioeconomic characteristics. For instance there are more female household-heads in Tororo and Trans-Nzoia than in Kapchorwa and Bungoma districts. Households (HHs) are smaller in Tororo compared to the other three districts in the study area. HH-heads in Uganda are generally less educated than HH-heads in Kenya. Lastly, fewer members of the HH participate in agricultural production in Bungoma, and salaried work (off-farm income) is highest in Trans-Nzoia. With regards to physical characteristics, land used for >30 years in agriculture is highest in Tororo, compared to all other districts. Maize plot size is smallest in Tororo district, and there is also very little animal or tractor traction use in Tororo. Little inorganic fertilizer is used in Uganda compared to Kenya, and average maize yield is lowest in Tororo and Bungoma (both of which are lowland sites). Improved seeds are widely used everywhere except in Tororo, but of all purchased inputs, Tororo makes more use of improved seeds than fertilizer or herbicides.

Simple pairwise correlations show that hand weeding is negatively correlated with fertilizer use and percent of crop residue left in the garden. Oxen use and ownership is positively correlated with maize yield, while fertilizer use is positively correlated with house-type and education. Fertilizer use is also positively correlated with herbicide use, improved-seed use, and percent crop residue left in the garden. Cross-tabulation and chi-square tests indicate that use of either hired labor or inorganic fertilizer decrease adoption of CA among those who know of CA.

Logistic regression results concur that use of either hired labor or inorganic fertilizer decrease adoption of CA among those who know of CA. Use of improved seed, however, is associated with higher adoption of CA, but the direction of causality is unknown. Improved seeds seem to be the most affordable of all the purchased inputs, or perceived to have the highest 'bang-per-buck' and thus purchased first with whatever little cash a HH might have. Its affordability for moderate-income HHs (not just the wealthiest HHs) might be the reason it is positively associated with adoption. Moderate-wealth HHs can afford to experiment with CA, but are not so wealthy that they have no need to adopt CA. Location in Tororo district decreases a HH's probability of adopting CA, even after controlling for education, house-type (a proxy measure of wealth), access to land and other HH characteristics. Lastly, duration of time spent using HH land increases adoption of CA, perhaps reflecting increased soil degradation and a perceived need to reverse it.

These findings have important implications for adoption of the SANREM/CRSP East Africa team's CAPS by smallholder farmers in the study area. Differences in farmers' location biophysical, socio-economic characteristics and their perceptions of production problems in different districts will affect their willingness to adopt CAPS components. Blanket recommendations of uniform conservation agriculture practices for all locations should never be done. Instead, such recommendations should be based on outcomes from CAPS trials in each site and should be tailored to a district's specific physical and socioeconomic characteristics.

Conservation Agriculture in Eastern Uganda and Western Kenya: Assessment of Beneficiaries' Baseline Socio-economic Conditions

by
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A thesis submitted to the University of Wyoming in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE
in
AGRICULTURAL AND APPLIED ECONOMICS

Laramie, Wyoming

May 2013

Acknowledgements

First and foremost I wish to thank Dr. Dannele, my Graduate Advisor, for identifying and helping me join the CAPS research team, for offering advice, and for helping me edit this thesis. I would like to sincerely thank her for providing guidance and academic support throughout my studies at the University of Wyoming (UW). Her valuable comments helped improve the quality of my work. I also thank Dr. Jay for serving as a member on my thesis committee and coordinating the grant that enabled me to come to UW. To Dr. Dale, I'm very grateful for the interpretation you gave for some of my initial results; your questions and comments helped reshape and refocus my work. I learned a lot from your insight.

I also wish to extend my heartfelt gratitude to USAIDSANREM/CRSP east Africa CAPs project for funding my studies. Likewise, I gratefully acknowledge that support for this research was provided in part by the Borlaug Leadership Enhancement in Agriculture Program (LEAP) through a grant to the University of California-Davis by the United States Agency for International Development (USAID). The opinions expressed herein are those of the author and do not necessarily reflect the views of USAID.

My sincere thanks also go to the family of Mr. and Mrs. John Kirkladie, and all other people who encouraged me and made me feel at home in Laramie. To all my friends and classmates at UW, thank you for your understanding and encouragement in many of my moments of crisis. Your friendship made my life in Laramie a wonderful experience.

Thank you God, you have always been with me in every step of my life's journeys. Last but not least, I dedicate this thesis to my parents, to all my brothers and sisters and to my Zenah. Your endless love, support and encouragement have always given me the strength to go the extra mile and pursue my dreams even when it seemed too difficult and painful.

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CHAPTER ONE

Introduction and background

Introduction

Most households in sub-Saharan Africa (SSA) rely on low-input rain-fed subsistence farming for their livelihoods that exposes them to a vicious cycle of poverty, hunger and malnutrition (DSIP, 2010; ASDS, 2011). With little or no external inputs to their farming systems, smallholder farmers in SSA face declining soil fertility, the primary natural resource base upon which their livelihoods depend (Giller et al., 2009; Sanchez et al., 1997; Smaling et al., 1997).

Declining soil fertility in SSA is the result of many underlying and interrelated causes. Population growth, for example, has reduced per capita land ownership, which has made it necessary for subsistence farmers to shift from fallow-based systems to continuous cropping (Boserup, 2005; Drechsel et al., 2001). Insufficient access to input markets, or to credit to finance the purchase of inputs, has prevented many smallholder farmers from using modern implements, improved seeds, herbicides, and other inputs that could increase yields and help mitigate declining soil fertility (DSIP, 2010). Limited access to output markets, weak public agricultural institutions and ineffective implementation of agricultural policies have also created hurdles and disincentives for farmers to invest in improving soil fertility (Shiferawet al., 2009; Drechsel et al., 2005).

As if they do not face enough challenges already, climate change is another major problem affecting smallholder farmers in SSA. Direct effects of climate change include less predictable onset of seasonal rains and more severe droughts that scorch farmers' crops

(Kangalawe et al., 2011). Indirect effects of climate include increasing pressure on land for farming and human settlement, degenerating soil fertility, deforestation and other forms of environmental degradation. These effects threaten long-term survival of households that rely solely on smallholder farming (PELUM, 2003).

Many factors that increase the rate of soil erosion in Uganda and Kenya have context specific impacts and involve trade-offs between increasing production and reducing land degradation. For example, government extension and training programs have been shown to contribute to higher value of crop production in the lowlands, but to soil erosion in the highlands. On the other hand, NGO programs focusing on conservation and environment help to reduce erosion, but have less favorable impacts on production in the lowlands (Pender et al., 2004). There are few win-win opportunities to simultaneously increase crop production and reduce land degradation; any strategy designed to increase agricultural production and reduce land degradation must be location specific (Pender et al., 2004).

Several development interventions have been implemented in SSA to combat declining soil fertility. This thesis is concerned with declining soil fertility and related interventions in Uganda and Kenya; specifically, USAID's sustainable agriculture and natural resource management collaborative research support program (SANREM-CRSP). This program supports development and transfer of conservation agriculture production systems (CAPS) with the aim of "increasing smallholder farmers' agricultural productivity and food security through improved cropping systems that contribute to and take advantage of improved soil quality and fertility"(www.oired.vt.edu/sanremcrsp/).

East Africa CAPS Project

The East Africa CAPS project is a partnership between the University of Wyoming, Moi University in Kenya, Makerere University in Uganda, SACRED Africa Training Institute and Manor House Agricultural Centre in Kenya, and Appropriate Technology Uganda (ATU) Ltd. in Uganda. Its goal is to design and field-test CAPS that provide practical and affordable ways for smallholder farmers in western Kenya and eastern Uganda to improve soil fertility and stabilize crop yields by maintaining year-round soil cover, minimizing soil disturbance by tillage and using crop rotations. The East Africa CAPS team has relied on co-design and co-innovation to ensure local participation in the development and testing of CAPS. This approach involves constant reflection and redesign to ensure practical and adoptable outcomes (EA CAPS team, 2010).

The East Africa CAPS project involves four study areas in the Mt. Elgon region along the Kenya-Uganda border: Bungoma and Trans-Nzoia in western Kenya, and Kapchorwa and Tororo in eastern Uganda (figure 1). Kapchorwa and Trans-Nzoia are highland sites located on rich volcanic soils with high agricultural potential, but also high erosion potential. Tororo and Bungoma are densely populated lowland sites located on poor sandy soils.

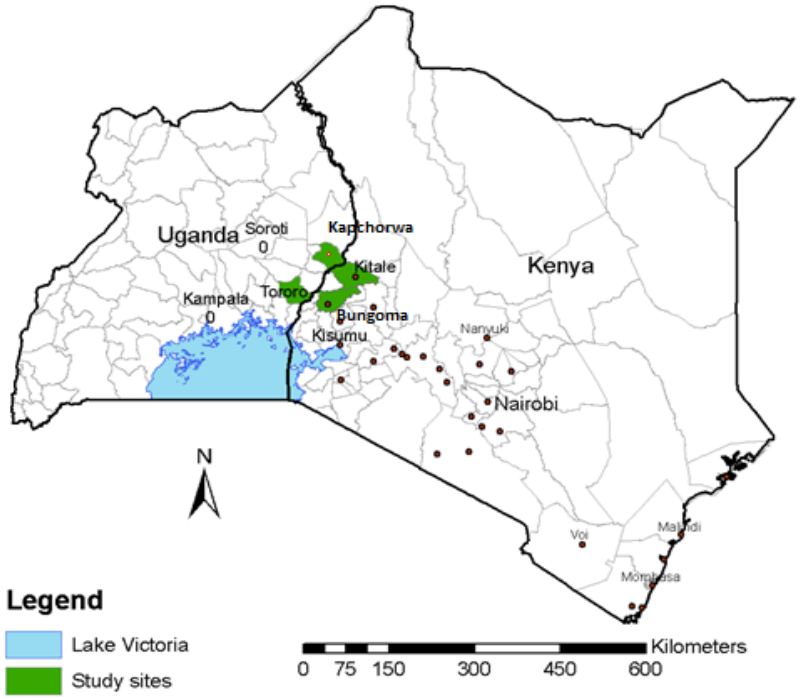

Figure 1: Location of the East Africa CAPS project's study sites: Bungoma, Trans-Nzoia (near Kitale), Kapchorwa and Tororo.

The CAPS project began with a baseline household survey to identify major socio-economic characteristics of household (HHs) in the study areas and likely constraints to CAPS adoption in the future. This survey was followed by a series of meetings with key stakeholder groups to define typical systems for growing maize and dry beans and to co-design CAPS to be tested. In 2011, the project established one on-station and four on-farm field trials at each of the four study areas (20 sites in all). Each field trial consists of three cropping system treatments (1. typical corn-bean intercrop, 2. corn + bean/cover crop relay, and 3. corn-bean-cover crop rotation in four-row strips), imposed on three tillage treatments (a. moldboard plow, b. minimum till, and c. no till), for a total of nine treatments at each study site. Data collection and analysis for each site has focused on soil fertility, crop yield, economics (quantity and value of inputs versus outputs) and market implications of CAPS.

Objectives

The main objective of this study is to generate a deeper understanding of the baseline socio-economic conditions of smallholder farmers in western Kenya and eastern Uganda, as of 2010, who are target beneficiaries of the SANREM-CRSP/East Africa CAPS project. By improving our understanding of the socio-economic complexities underlying current farming practices, such as technology preferences at different locations, this research will help the EA CAPS team and other development agencies working in the region design and implement more acceptable and appealing CAPS. Results from the baseline survey will also serve as a reference point or benchmark for later impact studies to assess how well the original CAPS objectives have been achieved. Specific objectives of this study are to:

1. Improve understanding of demographic characteristics, farming practices, land ownership and other production inputs in the study sites;
2. Identify major challenges and constraints that smallholder farmers in the study area face under traditional farming practices;
3. Identify baseline household characteristics or farming conditions that may foster future adoption of CAPS.
4. Make recommendations for potential ways to make CAPS more appealing to target beneficiaries in the study area.

Limitations

Data collected for this study represent a one-time snap shot, in 2010, of the baseline situation of smallholder farmers at each of the study sites. This limits the survey's ability to effectively capture inter-annual variations in conditions on the ground. The baseline survey was also very broad, which made it difficult to distill variables of interest from collected data. Lastly,

errors in data collection and entry resulted in a large number of missing data. This made several potentially useful variables unusable.

CHAPTER TWO

Literature review

Agriculture and development

The close link between agriculture and economic development is evident in the history of all developed countries of the world (Johnson, 1975). Rapid economic development can be achieved only when a country first improves its agricultural productivity and solves its food security challenges (Timmer, 2002; Pretty et al., 2003). Likewise, economic growth originating in agriculture can help reduce poverty and hunger through increased employment and incomes, which can subsequently stimulate demand for nonagricultural goods and services (Juma, 2011).

Many countries around the world have significantly reduced poverty and addressed food security challenges, but millions of people in SSA struggle daily with poverty, food insecurity, malnutrition and disease (Ali et al., 2000). These issues are multifaceted and caused by many deep-rooted socio-economic, cultural, political and biophysical factors (Goodhand, 2003). In SSA, these problems are closely linked to population growth, intensification of agricultural land-use (specifically, division of limited land resources into smaller and smaller parcels per household due to traditions of inheritance), increasingly unproductive soils, degradation of other natural resources, missing or imperfect rural credit markets, other market distortions, and an unevenly-supportive policy climate (Holmen, 2005). Interaction of these factors complicates livelihood options and outcomes for the majority of SSA's inhabitants, but especially smallholder farmers, who depend heavily on agriculture to feed and support their families.

The above challenges create a degradation spiral that persistently undermines food security and environmental quality in SSA (Thrupp et al., 1999). Unlike other regions of the world where per capita food production has been rising, per capita food production in SSA has

been declining since the early 1970s (figure 2). SSA now has the lowest per capita food production in the world, with little evidence of improvement (Abdulai et al., 2005).

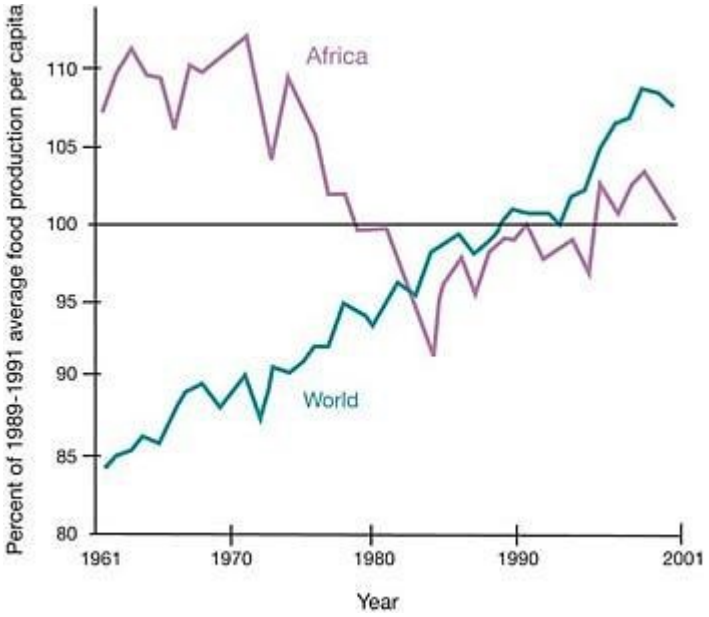

Figure 2: Food production index (net food production per capita, base line 1989-91) for Africa contrasted with the rest of the world, for the period 1961 to 2001 (United Nations Environment Program, 2002). (Source: Dyson, 1999)

Soil fertility degradation on smallholder farms has been cited as the fundamental biophysical cause of food insecurity and poverty in SSA (Sanchez et al., 1997). Soil degradation is a serious problem especially in east Africa where agriculture is a mainstay of the economy. In Uganda, soil fertility degradation and its effects on agricultural productivity occurs through soil erosion, soil fertility mining, soil compaction, water logging, and surface crusting (Nkonya et al., 2004). Smallholder farmers will continue experiencing further declines in agricultural productivity unless the effects of soil fertility degradation are halted.

Land degradation and its effects on crop yield

The United Nations Food and Agriculture Organization defines land as the soil resource, water, vegetation, landscape and microclimatic components of an ecosystem (FAO, 1995). From

this definition, land degradation can be broadly perceived as a temporary or permanent decline in the productive capacity of land. Land degradation is reported to affect up to 60-90 percent of the land area in some regions of SSA, which directly translates into costs for the affected regions (Dreschel et al., 2001). Estimated annual costs of land degradation in Uganda amount to 6-11 percent of the country's agricultural GDP (DSIP, 2011, p44).

The most common and important on-farm effect of land degradation is declining crop yields or a need to use more inputs to maintain yields (Scherr et al., 1996). More serious land degradation may ultimately lead to temporary or permanent abandonment of farmland, or conversion to lower-value uses, such as substituting less-demanding crops like cassava for maize, or converting croplands to grazing lands, or shifting grazing lands to shrubs or forests. Land degradation and low agricultural productivity are problems in many parts of Uganda and Kenya. Soil nutrient depletion, erosion and other manifestations of land degradation are increasing in many parts of Uganda (Pender et al., 2004); erosion is typically more pronounced in highland areas than in lowland areas (Bagoora, 1988).

Land degradation contributes to low and declining agricultural productivity in Uganda. Yield of major staple crops have been stagnant or declining since the early 1990s (Pender et al., 2004; Deininger and Okidi, 2001). Farmers' yields in affected areas are typically less than one-third of yields on research stations (table 1). Average maize yield on farmers' gardens is only 550kgs compared to 5,000-8000kgs on research stations (DSIP, 2010). Assuming these gaps are due, in part, to low soil fertility or inadequate fertility management by farmers, there is considerable potential for much higher productivity on farmers' fields, either through the use of fertilizers or conservation agriculture practices that are thought to enhance fertility through improved crop rotations, reduced tillage and year-round ground cover (Kasule, 2009).

Table 1: Yields of selected crops in Uganda on-farm versus on-station (Source: DSIP, 2010)

Crop	Yield from farmers' fields (kg/ha)	Yield on research station fields (kg/ha)	Yield gap (%)
Maize	550	5,000 - 8,000	810 - 1,350
Beans	360	2,000 - 4,000	460 - 1020
Groundnuts	640	2,700 - 3,500	320 - 450
Bananas	1,870	4,500	140
Coffee	370	3,500	850

Uganda and Kenya

Uganda has one of the lowest-income economies in SSA and is among the poorest countries in the world (McGee, 2000). Kenya is slightly better off, with a gross national income of US$340 compared to Uganda's US$280, though Kenya's gross national income has been decreasing at an alarming rate in recent years (Delve and Ramisch, 2006). Kenya and Uganda have many socio-economic and agricultural characteristics in common. In both countries, poverty is most pronounced in rural areas (FAO, 2013). Rural poverty is multidimensional, and includes features such as food shortage, malnutrition of children, frequent illness with high rates of HIV/AIDS and widespread illiteracy (Delve and Ramisch, 2006).

Agriculture is one of the most important economic sectors in both Kenya and Uganda. It contributes 40-50% of their GDP and 80% of exports; it employs 80% of the countries' population, and it provides a large proportion of raw materials for industry (World Bank, 2002). Regardless of its importance, growth in the agricultural sector has not kept pace with the countries' population growth. Real growth in agricultural output declined from 7.9% in 2000/01 to a mere 0.1% in 2006/07 before recovering to 1.3% and 2.6% in 2007/08 and 2008/09, respectively (UBOS, 2009). These growth rates are smaller than the population growth rate in both countries, implying that per capita agricultural GDP has in effect been declining.

Agriculture in both Uganda and Kenya is dominated by small-scale farming with average farm-size ranging between 0.2-3ha (Shepherd et al., 1998; Esilaba et al., 2005). Like most of SSA, maize is a very important food and cash crop to both Uganda and Kenya, where it is grown in almost all agro-ecological zones (Kibaara, 2005; Nkonya et al., 2005). Maize is grown, for example, by 78% of farmers in eastern Uganda, which is the main maize-growing region in the country (Haggblade and Dewina, 2010). With regards to consumption, maize accounts for 65% of total staple caloric intake and 36% of total food caloric intake; per capita maize consumption in Kenya is88kgs per year (Ariga et al., 2010). In Uganda, maize accounts for 11% of daily caloric intake, and per capita consumption is 31kgs per year (Haggblade and Dewina, 2010).

Agricultural production systems in Kenya and Uganda

Uganda and Kenya have both rain-fed and irrigated agricultural production systems, but rely heavily on rainfall. Performance of rain-fed agriculture varies across diverse agro-ecological zones; for example, the high-humidity, high-altitude zones in both countries generally have higher productivity than low-humidity, low-altitude areas (ASDS, 2010; DSIP, 2010). Western Kenya and eastern Uganda have comparable soil types, but represent a gradient from the lowland ferralsols to highland nitisols in Uganda to humic nitisols in western Kenya (Delve and Ramisch, 2006). Likewise the climate, production technologies, and demography are also similar between the countries (Braun et al., 1997). Rainfall in these areas ranges from 1400 to 2000 mm annually, and is distributed between two cropping seasons. The 'long rains' usually last from March to July and the 'short rains' from August to November (Tittonell et al., 2009).

Soil fertility interventions: predecessors of conservation agriculture

FAO's Consultative Group on International Agriculture Research (CGIAR), Sasaka Global 2000, and the Tropical Soil Biology and Fertility Program (TSBF) invested significant

efforts and resources and devoted much attention to address declining per capita food production in SSA Africa from the 1960s through the late 1990s. These agencies promoted fertilizer use and other soil management practices alongside use of improved crop varieties weed control and plant protection programs.

In an effort to restore soil fertility and improve agricultural productivity on resource-poor smallholder farms in western Kenya and eastern Uganda, national agricultural research institutions in both countries in collaboration with development agencies and international agricultural research centers have designed and implemented numerous soil fertility management practices and technologies in the recent past (Delve and Ramisch, 2006). For example, the National Agricultural Research Systems (NARS), supported by CGIAR, have actively designed and tested many technologies at research stations in both countries; unfortunately, many of these technologies have been shelved because of limited adoption in farm communities (Drechsel et al., 2005).

In Tororo, many organizations have been evaluating a range of soil fertility management options with farmers since 1998, including Africa 2000 Network (A2N), Appropriate Technology (AT-Uganda), the International Centre for Tropical Agriculture (CIAT), Tororo district Department of Agriculture and Extension, farmer group representatives, the Food Security and Marketing (FOSEM) project, the International Center for Research in Agroforestry (ICRAF), the National Agricultural Research Organization (NARO), Makerere University, TSBF, and the Uganda National Farmer's Association (UNFA).

Through an adaptive and collaborative research project, the Integrated Soil Productivity Initiative Through Research and Education (INSPIRE) initiative began with the main objective of introducing, developing, on-farm testing, and disseminating improved soil fertility

management technologies to address the alarming soil productivity problems in Tororo district (Nyende and Delve, 2003). Key practices promoted through the INSPIRE project include use of improved fallows, crop rotations, mineral fertilizers, and incorporation of organic inputs, such as animal manure, green manure, biomass transfer, compost, and crop residues. Although these interventions targeted smallholder farmers, they have had little impact on curbing the high rates of land degradation and soil fertility decline in the region because of limited adoption by smallholder farmers (Nyende and Delve, 2003; Ali et al., 2007; Delve and Ramisch, 2006). Efforts to improve agricultural productivity have been hampered in Uganda's Tororo district, for example, by lack of knowledge about agronomic practices, poor delivery of advisory (extension) services, and limited use of improved farm inputs (DSOER, 1997).

Extensive research and extension efforts have made farmers throughout much of SSA aware of the beneficial effects of improved plant nutrition, through both on-station and field-level development and testing of improved production technologies (Sanchez and Jama, 2002; Delve and Ramisch, 2006; Smaling and Braun, 1996). However, the lack of an economically enabling environment has constrained take-off of improved soil fertility management practices by smallholder farmers (Dudal, 2002).

Conservation agriculture

Hobbs (2007) defines conservation agriculture (CA) as minimal soil disturbance (e.g. no-till) and permanent soil cover, combined with crop rotations. In CA, mechanical soil tillage is reduced as much as possible and external inputs such as agrochemicals and mineral or organic nutrients are applied in a way and extent that does not interfere with, or disrupt, natural biological processes above and below the ground (IIRR and ACT, 2005).

Smallholder farmers in parts of SSA have shown growing interest in CA because of evidence of yield gains of between 10% and more than 100%, depending on input levels, physical environment, and management experience. CA has been relatively popular in Zimbabwe, for example, because smallholder farmers who adopted it have generally seen increased crop production and hence improved food security (Mazvimavi et al., 2009). There are several challenges to adopting CA, however, including the ability to find and afford some of the inputs or technologies associated with CA, as discussed next.

Challenge 1: Fertilizer needs versus use

Proponents of CA technology in SSA actively recommend and promote use of some form of fertilizer as a means of increasing soil fertility alongside any conservation agriculture practices that farmers adopt (Mazvimavi et al., 2010; Bekele et al., 2007). Fertilizers have been promoted for several decades as a way of increasing crop yields in SSA. At the African Fertilizer Summit of 2006, member states set a goal of increasing fertilizer use by 500% by 2015 (IFDC, 2007). However, SSA still has the lowest level of inorganic fertilizer use in the world; application rates are far below recommended rates (50kg/ha versus 250-350kg/ha) (Dar and Twomlow, 2004). Ugandan farmers use an average of 1kg/ha, compared to 35kg/ha in Kenya, 22kg/ha in Malawi, and 13kg/ha in Tanzania (Wallace and Knausenberger, 1997). Factors that limit fertilizer use by smallholder farmers in SSA include high fertilizer prices (Bayite, 2009) and reduced fertilizer availability in countries where government subsidies were removed in the 1990s (Gladwin, 1992). Labor requirements for fertilizer application are another limiting factor, especially when manual methods are used (Binswangeret al., 1988).

Challenge 2: Weed control

Weed control is another hurdle for widespread and sustained adoption of CA in SSA. Hand weeding is the most common weed control method on smallholder farms across SSA (Vissoh et al., 2004). It is also the oldest and most accessible method of weed control for poor smallholder farmers in SSA. Yet hand-weeding imposes physical drudgery on SSA farmers and contributes to low crop production (Gianessi, 2009). Furthermore, research shows that herbicides produce greater yield at less cost than hand weeding (Chikoye et al., 2007). A study in Kenya determined that chemical weeding was one-third the cost of the traditional practice of hand-weeding a field twice during the growing season (Maina et al., 2003).

Despite the cost-effectiveness of herbicides, there are still major barriers to their use by smallholder farmers in SSA, including limited knowledge of herbicides and their use, uncertainty about the availability of herbicides, lack of rural credit markets to finance the purchase of herbicides, lack of herbicides in farmer-usable packages, poor timing of application and lack of extension services and weed science training (Mavudzi et al., 2001).

Challenge 3: Minimizing tillage

Destructive management practices, such as plowing, contribute to the severe farmland degradation that Africa is witnessing. Along with other practices such as burning of crop residues, plowing reduces organic matter in soil and destroys soil structure; on the whole, this leads to a downward trend into poverty for farmers (IRRI, 2009). Minimizing tillage is one of three core practices promoted under CA. Minimum tillage, when used alongside other practices, can limit, arrest, or reverse the effects of unsustainable agricultural practices, especially soil erosion, soil organic matter decline, and physical degradation of the soil, while at the same time reducing pesticide and fuel use (Sijtsma et al., 1998).

Minimum tillage requires farmers to reduce tillage to the bare minimum; at the very least, only rip-planting lines and making holes with hand-hoes for planting seeds yet there are several challenges associated with minimizing tillage by farmers in SSA (Jenrich, 2011). It is necessary that farmers rectify any compaction or hardpan problems caused by previous plowing operations on their land prior to practicing minimum tillage. This helps to loosen the soil and allow crop roots to penetrate deeper into the soil and obtain more nutrients and water (Biamah et al., 1993). This operation often requires specialized equipment like a tine ripper, chisel plow, or subsoiler, which has to be pulled by animals or a tractor (Pedro& Silva, 2001). If farmers do not have access to this specialized tillage and planting equipment, then practicing minimum tillage becomes problematic.

Furthermore, if a field has ridges from the previous season, these might make it difficult to use direct (zero-till) planter machines, though they pose no problem to hand planting (IRRI, 2009). There are also crops such as sweet potatoes that cannot be easily grown without tilling the soil or making mounds. Presence of robust weeds that require several weedings for a farmer to harvest a crop is another challenge. All these challenges present some form of limitation for SSA farmers who would wish to practice minimum tillage on their farmland.

Challenge 4: Leaving crop residue behind

Maintenance of vegetation cover on soil and use of crop residues as mulch to minimize rates of evaporation and moisture loss from soil are other practices promoted in CA (Hobbs, 2007). Mulch can be compared to an umbrella that protects the soil from damage by the sun and the impact of rain; it is recommended that farmers follow the pattern of nature and leave crop residues on the land to decompose and help restore soil fertility (IRRI, 2009).

Just like other practices already mentioned, there are limitations to farmers' ability or willingness to leave crop residues on land, despite having knowledge of its vital role in protecting soils (Freeman and Coe, 2002). For example, most farmers across SSA use crop residues, especially maize stalks for animal feed. The residues are either collected and fed to livestock at home or grazed directly after the crops have been harvested. The most harm is done to soils in the first scenario because the nutrients are removed from the land. If residues are removed entirely, there will be no protective covering to prevent soil erosion or the damaging effects of the sun. Less harm is done when farmers practice controlled grazing to ensure that a portion of the crop residue is left in the field as soil cover. Cattle will also deposit manure directly onto the land. In this way, some nutrients will be returned to the land.

Burning of crop residue at the end of the season is another common practice in many areas across SSA (Bationo and Mokwunye, 1991). This practice leaves the soil bare and thus exposed to rainfall impact and the baking sun, which can cause erosion and rapid loss of nutrients. The soil will quickly lose its fertility, especially soil organic carbon needed for sustainable production.

Most farmers in SSA neither regulate the level of grazing on their land nor return animal manure from the livestock pens back to their gardens. Likewise, off-season burning is rarely controlled, so large areas of land are often left bare during the dry seasons. Other competing uses of crop residues, such as fuel and building materials, also limit the amount of residues that farmers leave on their farmland (Mulumba and Lal, 2008).

SANREM/CRSP East Africa CAPS project

Researchers at the University of Wyoming have partnered with USAID, Kenyan and Ugandan research institutions, NGOs and smallholder farmers to implement a SANREM/CRSP CAPS project in western Kenya and eastern Uganda to help address the continued decline in soil fertility and crop production in the area. The East Africa CAPS project aims to develop and transfer conservation agriculture production systems (CAPS) in Tororo and Kapchorwa districts of eastern Uganda and in Trans-Nzoia and Bungoma districts of western Kenya. The project's major objective is to develop field-scale farming system components through a participatory process that encourages co-innovation and co-design among researchers, advisors, and men and women stakeholders in agriculture.

The East Africa CAPS team adopted an outcome-based definition of conservation agriculture (CA) that focuses on improving soil quality for increased and sustainable productivity by maintaining year-round soil cover, minimizing tillage, and using crop rotations. The team's goal is to develop CAPS that are sustainable with respect to soil productivity, environmental quality, and local/regional socio-ecological and economic constraints. The team also acknowledges that improvement of soil quality to support increased production might not be possible without policy interventions that provide economic incentives for change and influence off-farm economic drivers like supply chains, markets, social networks and alliances, and other household livelihood strategies.

The East Africa CAPS project design includes on-station replicated trials, and on-farm pilot plots, in each project area in Kenya and Uganda. This design provides multiple opportunities for engagement and participation by regional officials, local community leaders, agricultural educators, and local farmers. The CAPS team hopes this co-innovation approach, in which end-users of technology become active participants in its development through frequent

interaction, monitoring, and redesign (Rossing et al., 2009) will proactively anticipate and address design and implementation gaps that have plagued past projects in the region.

Studies of the adoption of new agricultural practices

Primer on logit models of technology adoption

Much attention has been paid to factors that influence farmers' adoption of soil conservation practices. Logit models (and closely-related probit models) are a common method for estimating marginal effects of various farm characteristics, farmer characteristics and farmers' perceptions of conservation practices, on rates of technology adoption (Ervin and Ervin, 1982; Norris and Batie, 1987, 1989; Shiferaw and Holden, 1998; Lapar and Pandey, 1999).

The term 'logit model' is shorthand for a 'logistic regression model', which is used to predict response of a categorical dependent variable (e.g., 0 = the farmer has not adopted CA; 1 = the farmer has adopted CA) to variations in continuous or categorical independent variables (Garson, 2012). Because the dependent variable is categorical, logistic regression models estimate the 'odds ratio' of a categorical event occurring, where 'odds ratio' refers to the ratio of the 'probability the event occurs' to the 'probability the event does not occur'. For example, an 'odds of adopting CA' equal to 2 would mean that, for a given set of farmer characteristic (i.e., a given set of values for the independent variables), the odds that the farmer adopts CA is twice as large as the odds that the farmer does not adopt CA. The odds-ratio is sometimes difficult to interpret, so results of a logistic model can be converted to report simply the probability of the event happening.

As if odds-ratios were not complex enough, logistic regression models actually estimate the 'log-odds' of the dependent variable (i.e., the *log* of the odds-ratio, also known as the 'logit').

Again, this highly unintuitive result can be converted to more intuitive measures, such as the odds-ratio itself, or even better, the *probability* of an event occurring.

One purpose of running a regression model is to estimate a parameter value for each of the independent variables. These parameter values generally describe how a small change in the independent variable affects the dependent variable. In a logistic regression model, parameter values describe how a small change in an independent variable affects the '*log*-odds' of the dependent variable (i.e., the log of the odds-ratio, or equivalently, the log of the ratio of the probability of the event occurring to the probability of the event not occurring) (Sheikh et al., 2003). Although the magnitudes of these parameter values are not easy to interpret, their sign and significance are useful.

Suppose, for example, a parameter value is positive and significant; this implies that an increase in the independent variable (e.g., years of education) causes a statistically significant increase in the log-odds of an event occurring (e.g., adoption of conservation agriculture). Again, parameter values in a logistic regression are not intuitively appealing to most people, so they are usually converted to more appealing measures, such as 'marginal effects.' Marginal effects describe how a one-unit change in the independent variable affects the probability of an event occurring, a concept most people readily understand.

One strength of the logit regression model is that it does not assume a linear relationship between raw values of the dependent and independent variables. Consequently, it has less stringent requirements than Ordinary Least Squares (OLS) regression; specifically, it does not require normally distributed variables, and it does not assume homoscedasticity (Subasi and Ercelebi, 2005; Garson, 2012). This overcomes many of the restrictive assumptions of OLS regression, which available data often do not meet. One potential concern with the logit model

(as with any static model) is that it does not capture the dynamic environment in which households make their adoption decisions. The approach does not incorporate the effect of time-dependent elements in explaining whether and when an individual decides to use or adopt a given CA practice (Odendo et al., 2010). Nevertheless, the logit model is still the most appropriate statistical tool for determining the influence of independent variables on a categorical dependent variable (Long and Freese, 2006; Shiferaw and Holden, 1998).

A generic logit model is specified as follows (Agresti, 1996):

$$\text{Ln}\left[\frac{P_x}{1-P_x}\right] = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \cdots + \beta_k X_{ki} + e,$$

where subscript i is the i^{th} observation in the sample. Suppose the event of interest (Y) is defined as a HH adopting CA after learning about it in the past. Then, the following definitions, assumptions, and results apply:

- P_x is the probability of event Y occurring for an observed set of variables X_i (e.g., the probability that the HH adopts CAPS after hearing or learning about the technology), and (1-P_x) is the probability of non-adoption. β_0 is the intercept term and β_1,β_2...β_k are coefficients (or parameter values) of the explanatory variables x_1, x...x_k.
- $\frac{P_x}{1-P_x}$ is the 'odds ratio', and $Ln\left[\frac{P_x}{1-P_x}\right]$ is the 'log of the odds ratio', or the 'logit'.
- The logistic distribution constrains the estimated probabilities to lie between 0 and 1.
- The estimated probability is $P_x = 1/[1 + \exp(-\beta_0 - \boldsymbol{\beta X})]$.
- If you let $\beta_0 + \boldsymbol{\beta X} = 0$, then $P_x = .50$; as $\beta_0 + \boldsymbol{\beta X}$ gets very big, P_x approaches 1; as $\beta_0 + \boldsymbol{\beta X}$ gets very small, P_x approaches 0.

The predictive success of the logistic regression is typically assessed by looking at either the pseudo-R^2 statistic, which summarizes the strength of relationships between the dependent

and independent variables, or the likelihood ratio test, which indicates how well a model fits the data (Garson, 2012).

Insights from existing studies

Some of the earliest studies on adoption of soil conservation practices were done in the 1950s (Ervin and Ervin, 1982, p. 278). Since then, many empirical studies have sought to understand the effects of social, economic and biophysical factors on adoption of soil conservation practices in different locations around the globe. This section reviews some of these studies to clarify the theoretical framework and form a basis for identifying relevant variables to include in my study.

Ervin and Ervin (1982) studied factors affecting use of soil conservation practices in Monroe County, Missouri, USA. The number and type of conservation practices that farmers applied were significantly influenced by their education level attained, and their perception of the degree of erosion on their farm. Alemu (1999) identified land tenure security as an important factor influencing farmers' decisions to invest in soil conservation in Tigray and Oromiya regions of Ethiopia. Featherstone and Goodwin (1993) investigated factors associated with Kansas farmers' investments in long-term conservation improvements. They showed that differences in farm size, income, and types of existing farming practices were influential.

In a study of farmers' perception and adoption of soil management technologies in western Kenya, Makoha et al., (1999) tested twin hypotheses that (1) farming conditions such as land acreage, availability of farm inputs and crop yields significantly influence farmers' perceptions of new agricultural technologies and probability of adoption, and (2) farmers' perceptions of technology-specific attributes, like access to information about new technologies and their associated profitability, significantly influence adoption decisions. Results from their

study showed that farmers' participation in agricultural seminars and workshops, contact with extension services, and a previous decision to reduce fertilizer use were statistically significant predictors of adoption behavior. Keil (2001) studied adoption of leguminous tree fallows in Zambia, and found that availability of land and labor were positively associated with adoption of improved fallow practices.

Swinton (2000) analyzed the impact of social capital in inducing sustainable land management in areas faced with heavy soil degradation in Peru. They tested whether farming practices influence soil erosion, and whether social capital influences adoption of sustainable farming practices. They found that social capital variables, such as household members' participation in local associations, positively and significantly influenced adoption of soil-conserving farming practices. Berhanu and Swinton (2003) also showed that land tenure security significantly influenced adoption of natural resource conservation practices by smallholder farmers in northern Ethiopia. Calegari and Ashburner (2005) also advise that social capital variables such as land tenure and grazing rights may help solve problems related to use of common pool resources and affect adoption of CA in SSA. Presence of social capital also supports a receptive attitude towards the cultural and institutional changes that accompany innovation adoption and diffusion (FAO, 2010).

Lastly, Demeke (2003) used a binary logistic regression model to study factors influencing adoption of soil conservation practices in northwestern Ethiopia. Their findings indicate that farm size and farmers' perceptions of benefits from conservation practices positively affect their decision to adopt them. Distance of a farmer's plot from their homestead, availability of off-farm employment, and tenure insecurity negatively influence their adoption decision.

CHAPTER THREE

Methods

Study area

The study area comprises four districts: Tororo and Kapchorwa districts in eastern Uganda, and Bungoma and Trans-Nzoia districts in western Kenya. These districts were selected for inclusion in the East Africa CAPS project because of their agro-ecological and geographical locations. Tororo and Bungoma districts are both located in low-lying areas that experience bimodal rain patterns and low soil fertility. In contrast, Kapchorwa and Trans-Nzoia districts are located at relatively high altitudes and have higher agricultural potential with a single long rainy season. All four districts have high human population density and rampant poverty. Farming in these areas is characterized by low-input and low-output systems. Maize, the staple food crop, dominates the cropping pattern and is often intercropped with beans.

Survey design and data collection

Much of the data used in this study were collected during the 2010 East Africa CAPS household baseline survey in Uganda and Kenya. The survey was conducted by three local NGOs (AT-Uganda, Manor House agricultural center, and SACRED-Africa in Kenya). Design of the baseline survey was a collaborative effort between the NGOs, Makerere University in Uganda, Moi University in Kenya, University of Wyoming, and other individual collaborators in the East Africa CAPS project.

The survey employed a two-stage stratified sampling procedure in which each of the four districts formed a sampling stratum in the first stage. Tororo and Bungoma represented low agricultural potential areas, and Kapchorwa and Trans-Nzoia represented high agricultural potential areas. All sub-locations/sub-counties within each stratum were identified using the

latest population census in each country; fifteen of these sub-locations were sampled for the study. A list of all households in each stratum was constructed with help from local administrators during the second stage of sampling. In total, 790 households were sampled, including 202 households from Tororo district, 200, 188 and 200 households from Kapchoprwa, Bungoma and Trans-Nzoia districts respectively. Structured questionnaires were used to collect data; these were administered through face-to-face interviews of household heads, or in their absence, other adult household members who were present.

The structured questionnaire covered broad themes on geographical, household, institutional, socio-economic and biophysical variables. These variables were deemed relevant to understanding baseline conditions in which target households were living and operating at the time of the survey. The data, after being collected, were pooled into a cross-sectional dataset that provides a representative sample of target households in the four districts. In addition to the structured questionnaires, focus group discussions (FGDs) were conducted with farmer groups in each of the study locations. FGDs were designed to capture farmer's perceptions, attitudes and other information that were not captured during the baseline survey.

Analytical model

The baseline data were analyzed in two stages. The first stage was a descriptive statistical analysis, which was helpful in identifying trends and characteristics of HHs in different locations. This was followed by more advanced statistical modeling of dependent variables against selected independent variables. A binary logistic regression model (logit model) was specified and estimated. Variables used in all analyses are explained in detail in the next sub-section. The SPSS statistical package was used for both the descriptive statistical analysis and thelogistic regression analysis.

Variables of interest

The choice of variables explored in this study was guided by previous studies, economic theory, and unique characteristics of the study sites. Table 2 provides a description of each variable hypothesized to influence households' decisions to adopt CA technologies or continue using traditional farming practices. The variables are broadly grouped into household characteristics, institutional factors, and biophysical factors.

Table 2: Description of variables used in analyses

Household (HH) characteristics	
AGE	Age of household head (in years) at time of survey
GENDER	Sex of HH head: 1=male, 2=female
HHSIZE	Number of people in the HH
ACTIVE_LABOR	Number of adult HHmembers actively engaged in agricultural production
HOUSE _TYPE	HH's house type: 1=Temporary, 2=Semi-permanent, 3=Permanent
OCCUPATION	Occupation of HH head
EDUCATION	Education level: 1 if HH head has post primary education, 0 otherwise
TENURE	1 if HH used own land, 0 otherwise
HIRE_LABOR	Use of hired labor: 1 if HH used hired labor, 0 otherwise
MANURE	1 if HH used manure, 0 otherwise
TRACTOR	Tractor use: 1 if HH used tractor, 0 otherwise
EXPERIENCE	HH head's farming experience: number of years a HH has cultivated on its current maize garden
TILLAGE	Tillage method used by HH
FERTILIZER	1 if HH uses inorganic fertilizer, 0 otherwise
SEED	1 if HH used improved seed, 0 otherwise
FERTILITY	HH's perception of soil fertility trends in the area over last decade: 1= Decreasing, 2=Staying the same, 3= Increasing
EROSION	HH's perception of soil erosion trend in the area over last decade: 1= Decreasing, 2=Staying the same, 3= Increasing
RESOURCE	HH has access to community resources: 1 if yes, 0 otherwise
HERBICIDE	1 if HH uses herbicides, 0 otherwise
Institutional factors	
EXTENSION	1 if HH has contact with public extension service agents, 0 otherwise
DISTANCE	HH's distance from nearest urban/trading center (kilometers)
INPUT_CREDIT	1 if HH has access to agricultural input credit at the time of survey, 0 otherwise
CA_KNOWLEDGE	HH knowledge of CA: 1 if HH has learned about CAPS, 0 otherwise

CA_PRACTICE	1 if HH is practicingCA (at least one of the three recommendations), 0 otherwise
GROUP	1 if HH has active membership in a producer or marketing group, 0 otherwise
Biophysical factors	
SLOPE	1 if maize field is sloped, 0 if it is flat
LOCATION	1=Tororo, 2=Kapchorwa, 3=Bungoma, 4= Trans-Nzoia

Rationale for selecting variables for analysis

Age

The effect of age on adoption of new farming practices is not very clear. Some previous studies (Adesina and Zinnah, 1993; Hassan et al., 1998) revealed negative relationship between age of a farmer and adoption, whereas others (e.g., Hossain et al., 1992) found a positive relationship between farmer's age and adoption of conservation farming practices. Furthermore, some studies have reported no relationship between age and adoption of a technology (Ntege-Nanyeenya et al., 1997; Nkonya et al., 1998).

Some older farmers have been found to be more likely to adopt a technology because of their accumulated knowledge, capital and experience (Lapar and Pandey, 1999; Abdulai and Huffman, 2005). On the other hand, young farmers exhibit lower risk aversion and are more likely to adopt new technologies that have long lags between investments and realization of benefits (Featherstone and Goodwin, 1993). The full gains from conservation agriculture are likely to be realized in the long-term because it takes several seasons for the practices to have an impact on soil fertility. Therefore, this study considers age from the perspective of risk aversion and resistance to change. The expected sign of the coefficient on age is that younger farmers will be more likely to use CA technologies than older farmers.

Education

Education is assumed to have a positive effect on the likelihood of a farmer practicing a given CA technology. Previous studies have found that education enables farmers to easily distinguish between technologies whose adoption provides an opportunity for net economic gain and those that do not (Rahm and Huffman, 1984; Abdulai and Huffman, 2005). It is hypothesized that farmers with post-primary education are more likely to adopt CA than those without.

Gender

Gender of a household's head is another potentially important characteristic under consideration in this study. Previous research in Africa has shown that women are less privileged in society and have less access to and control over productive resources like land, cash, labor and information (Quisumbing et al., 1995; Kaliba et al., 2000). Gender *per se* might not affect a HH's decision to use a given CA practice. However, the inherent inequalities in ownership and control of productive resources between men and women might play a role. These inequalities are engrained in the social and cultural systems in which smallholder farmers in the study area live and operate. It is hypothesized that male-headed households are more likely to adopt CA practices than female-headed households.

Farm size

Larger farm size is associated with greater wealth, access to capital, and higher risk-bearing ability, all of which should make investment in conservation agriculture more feasible (Norris and Batie, 1987). Farmers with larger farm sizes are at less risk of loss when they dedicate a less productive portion of their land to experiment with a new technology. This may positively influence adoption of the technology if they perceive that technology positively (Rahm

and Huffman, 1984). It is hypothesized that large farm size increases the likelihood of adoption of CA practices by HHs.

Land Tenure

There is widespread consensus in the literature that it is not just access to land, but also availability of individual, secure, and transferable property rights to land that is strongly associated with a greater tendency towards conservation behavior (Demeke, 2003). Farmers' perceived risk of loss of control over their land at any time is viewed as a big threat to adoption of conservation agriculture practices (Alemu, 1999). Masters and Kazianga (2001) assessed determinants of farmers' investment in conservation practices such as field bunds and micro-catchments in Burkina Faso. They concluded that responding to land scarcity with clearer property rights over cropland and pasture could help promote the use soil conservation practices. It is anticipated that HHs with secure land tenure (i.e., they own the land on which they farm) will be more likely to adopt CA than HHs that do not own the land on which they farm.

Labor

Household labor is one of the most important resources available to smallholder farmers across SSA. A higher proportion of household members who contribute to farm-work generally imply a greater labor force available to the household for timely completion of farm activities. Due to high labor requirements for land preparation, weeding and other soil management practices, a higher proportion of household members who contribute to farm work is hypothesized to have a positive effect on a HH's likelihood of adopting CA.

Occupation

Non-farm occupation offers HHs an opportunity to earn off-farm income, which can mitigate the risk of experimenting with new farming technologies (Mathenge and Tschirley,

2007). However, HHs with off-farm income may decide not to invest their financial resources in soil conservation, but invest instead in off-farm enterprises (Shiferaw and Holden, 1998; Gebremedhin and Swinton, 2003). HHs with less off-farm income, in contrast, have been shown to have less income overall, and to be more concerned with short-term survival than with long-term benefits of soil conservation (Franco et al., 2008). The effect of off-farm income on the likelihood of adoption of CA is therefore difficult to anticipate.

Location

Location of a farm is closely linked to biophysical factors such as rainfall, soil type, slope, and elevation (Ervin and Ervin, 1982). Households at higher elevations, such as in Kapchorwa and Trans-Nzoia districts also have steeper slopes, which are more prone to erosion than those at lower elevations such as in Tororo and Bungoma districts. Households on steeper slopes may find CA more appealing than those on flatter slopes. However, investment costs of adopting conservation practices are generally lower in areas with smaller risk of soil erosion or gentler slopes, and benefits usually surpass costs (Calatrava, 2007). This makes it difficult to anticipate the direction of effect of location on the likelihood of HH adoption of CA.

Distance from nearest urban center

Urban centers provide markets for rural agricultural products. Longer distances to such centers can reduce market benefits of a new technology by creating a physical barrier and increasing transportation costs (Abdulahi and Huffman, 2005). Distance from urban centers also determines whether HHs have access to services such as banking, credit, and competitive input and output markets. Distance refers, here, to physical distance without any measure of road quality or other challenges to travel that are unrelated to distance. It is hypothesized that living farther from the nearest urban center negatively affects a HH's likelihood of using CA practices.

Contact with extension agents

Frequent contact with public extension agents increases HHs' access to extension services, which in turn influences participation in rural agricultural technology development programs. Frequent interaction with extension service providers may have a positive impact on farmers' access to information, managerial capabilities, and productivity (Abdulahi and Huffman, 2005). It might also create social pressure for farmers to use inputs and methods that extension agents advocate, and avoid inputs and methods that extension agents do not advocate (Olaf Erenstein et al., 2007).

Government extension and training programs have been shown to contribute to higher value of crop production in lowlands, but to soil erosion in highlands (Pender et al., 2004). On the other hand, NGO programs focusing on conservation programs and environment help to reduce erosion, but have less favorable impacts on production in the lowlands (Pender et al., 2004). Any strategy designed to increase agricultural production and reduce land degradation must, therefore be location specific because there are few win-win opportunities to simultaneously increase crop production and reduce land degradation (Pender et al., 2004). The effect of contact with extension agents on a HH's likelihood of adopting CAPs is not easy to anticipate.

Membership in village organizations and farmer associations

Membership in grassroots organizations may enable farmers to learn about a new technology from other farmers and development agencies (Nkamleu, 2007). Group membership is thus expected to have a positive effect on a HH's likelihood of using cover crops, reduced tillage, herbicides and other CA practices.

Cross tabulation and chi-square test

I use cross tabulation to measure the degree of association between variables of interest. Cross tabulation is a joint frequency distribution of cases based on two or more categorical variables (Sarma, 2004). Joint frequency distributions are analyzed with the chi-square statistic (χ^2) to determine whether the variables are statistically independent or associated. The chi-square statistic (χ^2) is computed as:

$$\chi^2 = \Sigma \frac{(O_{ij} - E_{ij})^2}{E_{ij}}$$

where

- O_{ij} is the observed frequency, from the data, of HHs with characteristics *i* and *j*,and
- E_{ij} is the expected 'cell frequency', defined as:

$$E_{ij} = \frac{T_i - T_j}{N}$$

where

- E_{ij} is the expected frequency for the cell in the i^{th} row and the j^{th} column;
- T_i is the total number of counts in the i^{th} row;
- T_j is the total number of counts in the j^{th} column, and
- N is the total number of counts in the table.

Empirical specification of the logistic regression model

A logistic regression model, like the one described in chapter 2, was developed to explore how various independent variables affect the probability of adoption of improved soil management practices that can be broadly considered as elements of CA (Agresti, 1996; Long and Freese, 2006). The logistic model explores personal, social, economic, institutional, and geographical factors influencing adoption of CA in the surveyed HHs. This study explores

factors that have influenced adoption of conservation practices that other development agencies designed and disseminated prior to the start of the SANREM/CRSP East Africa CAPS project.

This study uses the logistic model to evaluate factors associated with a HH's decision to practice (or not practice) CA after learning about it. The logistic model only uses data from 267 households that were identified to have learned about or heard about CA prior to the time of the survey. The logistic regression thus captures the likelihood that certain characteristics have affected the households' decision to adopt or use CA practices after learning about them. Recall, from chapter 2, the logistic or logit model takes the following generic form (Agresti, 1996):

$$\text{Ln}\left[\frac{P_x}{1-P_x}\right] = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \cdots + \beta_k X_{ki} + e$$

where the dependent variable (CAPREF) is 1 if CA was learned and being practiced by the HH at time of survey, or 0 if CA was learned but not being practiced. The following subset of variables from table 2 comprises independent variables in the logit model (table 3).

Table 3: Definition of variables used in the logistic regression model

Household (HH) or farm factors	
AGE	Age of HH head
GENDER	1 if HH head is male, 0 otherwise
ACTIVE_LABOR	Number of adult HHmembers actively engaged in agricultural production
HOUSE_TYPE	Categorical variable for the type of house the HH resides in: 1 = Temporary, 2 = Semi-permanent, 3 = Permanent
EDUCATION	1 if HH has post-primary education, 0 otherwise
TENURE	1 if HH used own land, 0 otherwise
HIRE_LABOR	1 if HH used hired labor, 0 otherwise
MANURE	1 if HH used manure, 0 otherwise
TRACTOR	1 if HH used tractor, 0 otherwise
EXPERIENCE	Number of years HH has tilled on its maize plot
FERTILIZER	1 if HH used inorganic fertilizer, 0 otherwise
SEED	1 if HH used improved seed, 0 otherwise
SFFERTILITY	A categorical variable for household's perception of their soil fertility trend with 1 = Increasing soil fertility, 2 = Constant soil fertility, 3 = Declining soil fertility
RESOURCE	1 if HH has access to communal resources, 0 otherwise

Institutional factors	
EXTENSION	1 if HH has contact with public extension service agents, 0 otherwise
GROUP	1 if HH has active membership in a producer or marketing group, 0 otherwise
Biophysical factors	
LOCATION	A categorical variable with 1 = Tororo, 2 = Kapchorwa, 3 = Bungoma, 4 = Trans-Nzoia. STATA automatically converts this variable to four separate dummy variables; category 4 is dropped to avoid the dummy-variable trap.

The logit maximum likelihood estimation (MLE) procedure is used to estimate coefficients on the explanatory variables in the logistic regression, MLE generates coefficient estimates by maximizing the probability (likelihood) that the observed covariances are drawn from a population assumed to be the same as the population reflected in the coefficient estimates (Hutcheson and Sofroniou, 1999). That is, MLE picks estimates that have the greatest chance of reproducing the observed data.

Coefficients of the logistic regression model are interpreted as follows. Given $LN\left[\frac{P_x}{1-P_x}\right] = \beta_0 + \beta X + e$, a slope coefficient, β_k, is interpreted as the magnitude of change in the "log odds" as X_k changes. This is not a very intuitively-appealinginterpretation, so coefficient estimatesare converted to the odds ratio by multiplying both sides of the regression equation by the exponential function. Thus,$\left[\frac{P_x}{1-P_x}\right] = \exp(\beta_0 + \beta X)$, and $\exp(\beta_k)$ is the effect of the k^{th} independent variable on the odds ratio of the dependent variable (i.e., the ratio, probability of a HH adopting CA: probability of a HH not adopting CA). Stated differently $\exp(\beta_k)$ represents the change in the odds of P_x which is associated with a unit change in the k^{th} independent variable and is commonly termed the odds ratio.

This procedure allows a simple interpretation to be given to the relationship between the response and explanatory variable similar to marginal effects interpretation of coefficients in OLS regression. For example an odds ratio of 1 indicates that changes in the explanatory variable

(x) do not lead to changes in the odds of P_x (i.e., the probability of a HH adopting CA). A ratio less than 1 indicates that the odds of P_x decrease as x increases and a ratio greater than 1 indicates that the odds of P_x increases as x increases. Generally stated, for a one unit change in the predictor, the odds of success in the response variable increases by the odds ratio (or for an x unit change in the predictor, the odds of success in the response variable increases by the odds ratio raised to the x power (odd-ratio^x)). The odds can also be converted to a probability, which provides a direct prediction of probability of success at a given level of an explanatory variable. The formula for converting odds to probability is presented below (UCLA, 2013)

$$Probability = \frac{Odds}{1 + Odds}$$

For test of overall model significance I use the log-likelihood statistic (-2LL) which is the most widely use and most powerful way of assessing the goodness-of-fit of a logistic regression model (Hutcheson and Sofroniou1999), While for hypothesis testing of individual parameter significance I use Wald's test. The Wald statistic for β_k is $Wald = \left[\frac{\beta_k}{s.e.\beta_k}\right]^2$, which is distributed chi-square with 1 degree of freedom.

CHAPTER FOUR

Results and Discussion

This chapter discusses results of my descriptive statistical analysis and logistic regressions analysis (includingtests and correctionsfor multicollinearity). The chapter is divided into three sections. The first section presents findings and discussion of a descriptive statistical analysis of socio-economic characteristics of all households surveyed. The second section presents findings and discussion of a descriptive statistical analysis of users and non-users of conservation agricultural practices and motivating factors for adoption. The last section presents findings and discussion ofthe econometric analysis.

Summary of household characteristics

A summary table of all descriptive characteristics for all sampled households in the four study areas is provided in Appendix 1 (table A1). Variables of particular interest are summarized next.

Education, age, gender, family size, and HH agricultural labor

A majority of sampled households (57.3%) had either only primary education or informal/pre-primary education. A larger percent of HH heads in Kenya attained higher levels of education (post-primary) than HH heads in Uganda: 51.6% and 62.5% in Bungoma and Trans-Nzoia versus 21.8% and 35.5% in Tororo and Kapchorwa. The average age of HH heads ranged from 42 to 50 years, with HH heads in Trans-Nzoia being generally older (50.8 years, on average), while those in Kapchorwa being generally younger (42.2 years, on average) than HH heads in other districts. Between 80% and 95% ofhouseholds across the study areas were male-headed (table A1).

Family size in the study area ranged from 6.6 to 7.9 persons (figure4). HHs in highland areas (Trans-Nzoia and Kapchorwa) generally had bigger family sizes than HHs in low-lying areas (Tororo and Bungoma). The number of adult household members actively engaged in agricultural production was highest in Kapchorwa (3.8) and lowest in Bungoma (1.8).

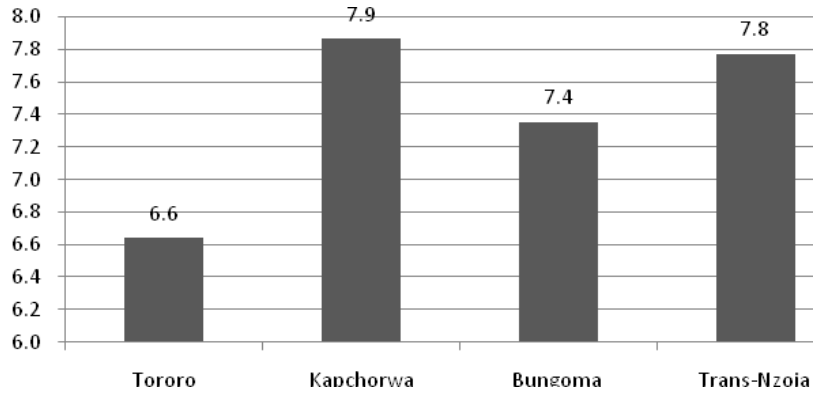

Figure 3: Average household size

Wealth status

The type of house in which a household resides is used as a proxy measure for a HH's wealth status. Building materials used define type of house. Cement or bricks on walls, and iron sheets or roofing tiles on the roof, qualify a house as permanent. Cement walls and a grass roof qualify a house as semi- permanent. Mud walls and a grass roof qualify a house as temporary. Most households, 59.5% across the four districts, reside in semi-permanent houses, while 20.5% live in temporary houses, and 18.7% live in permanent houses (Table A1). A relatively large percentage of households in Trans-Nzoia reside in permanent houses, which reflects a higher wealth status in Trans-Nzoia than other districts (figure 5).

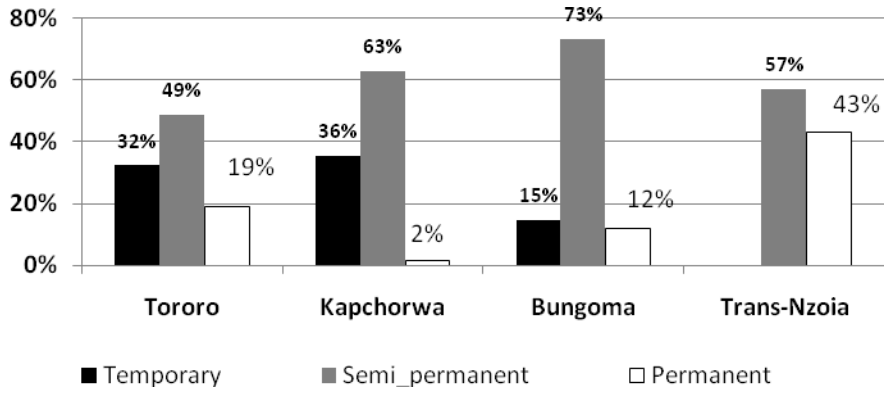

Figure 4: Type of house lived in by a household

Main occupation ofhousehold heads

Roughly 86 and 91% of HH heads in Tororo and Kapchorwa, respectively, rely on agriculture (crop) production as their primary occupation, compared to 76% and 61% of HH heads in Bungoma and Trans-Nzoia (table 4). Off-farm income is an important factor in rural households' livelihood because it provides cash for acquiring productive inputs and it eases credit constraints (Matshe & Young, 2004). The main sources of off-farm employment and income are salaried work and petty trade. Focus group discussions with communities revealed that teaching in nearby schools, and provision of causal labor for nearby factories and plantations are the major forms of salaried employment. The major petty trade activities that households are involved in are sale of basic household necessities such as sugar, foodstuff and clothing. A larger percentage of HHs in Bungoma and Trans-Nzoia have off-farm employment (i.e., salaried work) than HHs in Tororo and Kapchorwa (19.1 and 30% versus 14.4 and 9%, respectively).

Table 4: Household head's occupation by district

Occupation	District				
	Tororo	**Kapchorwa**	**Bungoma**	**Trans-Nzoia**	**Total**
Crop production	171	180	142	119	612
	85.5%	90.5%	75.9%	61.0%	78.4%
Tree crop production	0	1	5	0	6
	0.0%	0.5%	2.7%	0.0%	0.8%
Livestock	0	1	2	16	19
	0.0%	0.5%	1.1%	8.2%	2.4%
Fishing	0	0	2	0	2
	0.0%	0.0%	1.1%	0.0%	0.3%
Crop product marketing	0	0	1	6	7
	0.0%	0.0%	0.5%	3.1%	0.9%
Livestock marketing	1	0	4	5	10
	0.5%	0.0%	2.1%	2.6%	1.3%
Petty trading	6	4	7	11	28
	3.0%	2.0%	3.7%	5.6%	3.6%
Salaried worker	15	10	20	36	81
	7.5%	5.0%	10.7%	18.5%	10.4%
Other	7	3	4	2	16
	3.5%	1.5%	2.1%	1.0%	2.0%
Total	**200**	**199**	**187**	**195**	**781**

Conservation agriculture knowledge and practice

About one third of the sampled HHs had knowledge of conservation agricultural practices acquired from past soil/land/water conservation projects (table 4). However, the proportion of sampled households that practice CA only ranged from 28% in Tororo to 34% in Kapchorwa. That is, about 40 to 50% of HH who report having previous knowledge of CA also report adopting it (41, 46, 49, and 42% in Tororo, Kapchorwa, Bungoma, and Trans-Nzoia, respectively, results that are not directly reported in table 5).

Table 5: Conservation agriculture knowledge and practice by district

Location	Conservation agricultureknowledge and practice			Total
	No	Yes (but not practicing)	Yes (and practicing)	
Tororo	133 (66%)	41 (20%)	28 (14%)	202
Kapchorwa	126 (63%)	40 (20%)	34 (17%)	200
Bungoma	131 (70%)	29 (15%)	28 (15%)	188
Trans-Nzoia	133 (67%)	39 (20%)	28 (14%)	200
Total	523 (62%)	149 (19%)	118 (15%)	790

Tillage technology

The proportion of HH that used a tractor to open their land during the main cropping season of 2010was 1% in Tororo, 1% in Kapchorwa, 2% in Bungoma and 82% in Trans-Nzoia (figure 6). 32% of HHs in Tororo, 90% in Kapchorwa, 76% in Bungoma and 6% in Trans-Nzoia used animal-drawn plows to open land while 67% of HHs in Tororo, 9% in Kapchorwa, 23% in Bungoma and 12% in Trans-Nzoia used hand-hoes to open land. A HH's ability to use a tractor or animal-drawn plow for tillage presumably depends, in large part, on its ability to afford to own or hire them. Indeed, I found that tractor use and wealth status are highly and significantly positively correlated (table A2.1). Size of a HH's cultivated land might also influence the tillage technology used for land opening with large farms requiring animal drawn or motorized implements.

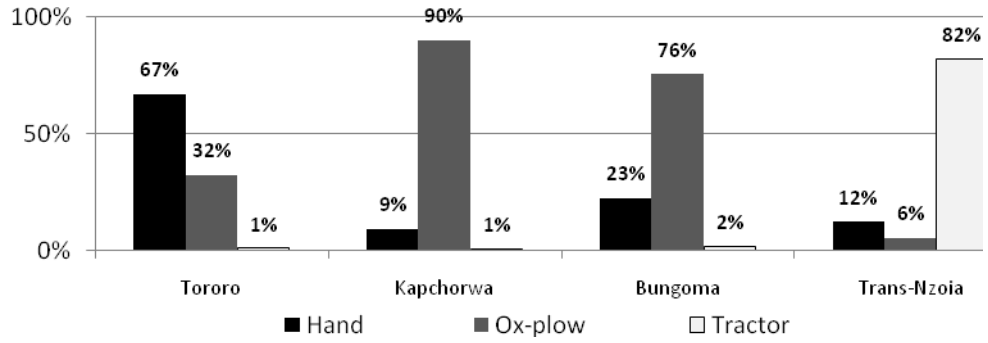

Figure 5: Traction type used by households to open land in 2010 main cropping season

Maize yield

Average maize yield per hectare is highly variable across the four districts (figure 7). Tororo district, which is located in a low agriculture potential zone, had the lowest average yield (264kgs/ha). Trans-Nzoia district, which is located in a high agricultural potential zone, had the highest maize yield (4,642kgs/ha). Comparison of sites with similar agricultural potential, but different proportions of HHs using fertilizer, might reveal additional insights. Average maize yield in Bungoma (a low agricultural potential zone with 79% of HHs using inorganic fertilizer) is almost four times larger than average yield in Tororo (also a low agricultural potential zone, but with 0% inorganic fertilizer use). Similarly, average maize yield in Trans-Nzoia (a high agricultural potential zone with 79% inorganic fertilizer use) is roughly twice as large as average yield in Kapchorwa (also a high agricultural potential zone, but with 27% inorganic fertilizer use). These pairwise comparisons suggest an important benefit from inorganic fertilizer use, but care must be taken not to over-generalize. These sites differ in many other characteristics, which are not controlled for in figures 7 and 8.

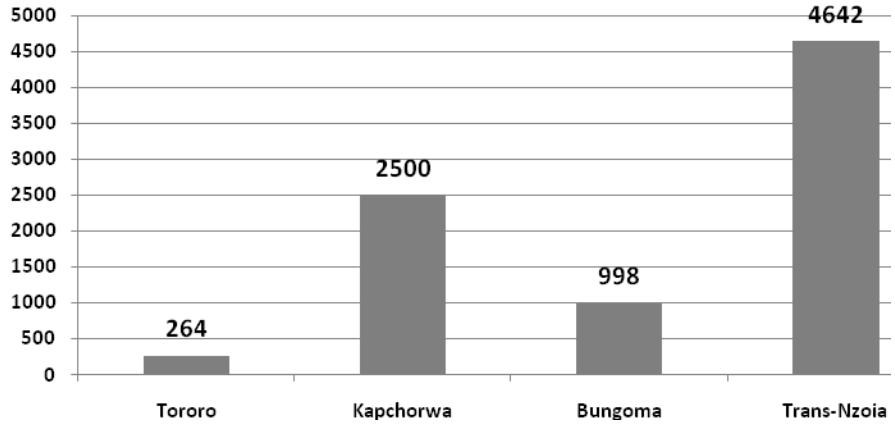

Figure 6: Average maize yield per hectare

Use of inorganic fertilizer

Maize yield is influenced by management practices, such as fertilizer use (figure 8), but is also moderated by biophysical factors such as altitude, climate and soil fertility. An equally large proportion of households in Bungoma and Trans-Nzoia use fertilizer (79%), but Bungoma's average maize yield is 21% of Trans-Nzoia's. Although a relatively small proportion of HHs use fertilizer in Tororo and Kapchorwa (0 and 27%), Tororo's yields are roughly 10% of Kapchorwa's. These comparisons suggest that differences in growing conditions in the lowlands versus highlands of Kenya and Uganda have an important moderating effect on yield potential, even when fertilizer is used. Trans-Nzoia and Kapchorwa, which are located in high agricultural potential zones, have higher maize yield than Tororo and Bungoma, which are located in low agricultural potential zones

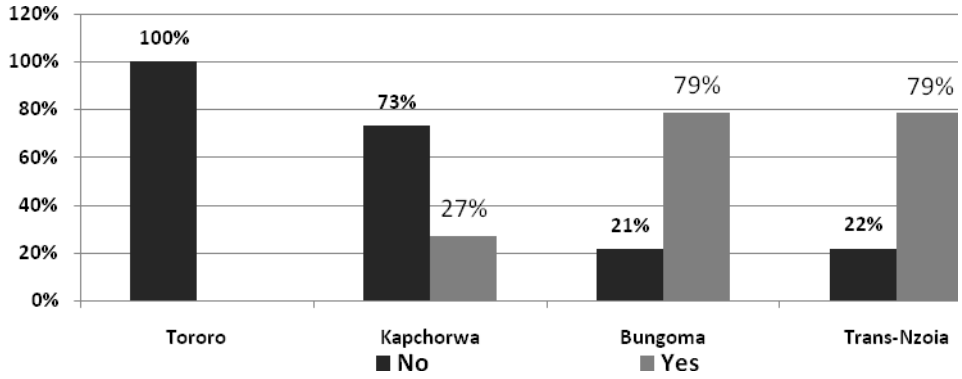

Figure 7: Use of inorganic fertilizer

Perception of soil quality and productivity trends

Soil type has a significant bearing on soil fertility (Wanyama et al., 2010). Soils in lowland Tororo and Bungoma are generally less fertile and less productive than soils in highland Kapchorwa and Trans-Nzoia. However, factors such as the length of time that HHs have cultivated their land and management practices used also influence soil quality. In turn, HHs'

willingness to implement various soil quality management practices depends on their perception of trends in their farm's soil fertility.

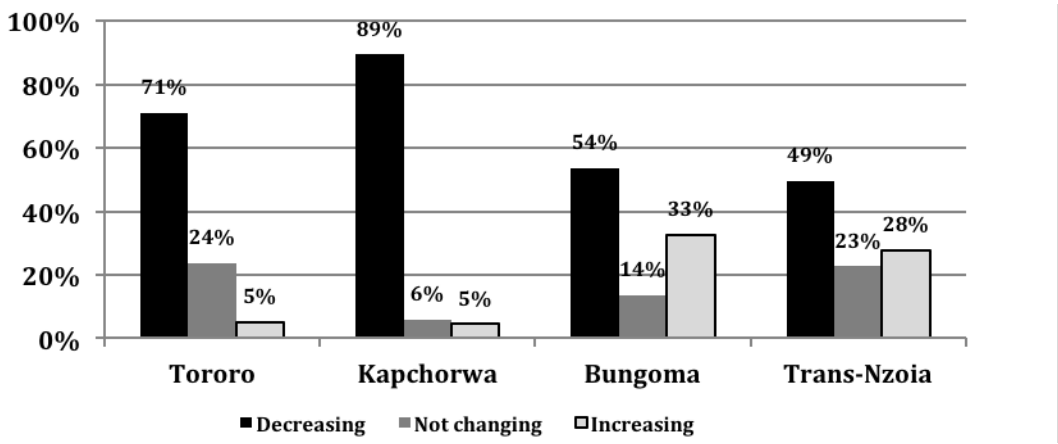

Figure 8: Perception of soil fertility trend over the last decade

In most districts, at least half of all HHs perceive that soil fertility on their land has decreased over the past decade (figure 9). Only a minority of HHs (33% in Bungoma, 28% in Trans-Nzoia, and 5% in each of Kapchorwa and Tororo) perceived that soil fertility in their land has been increasing over the past decade. Kapchorwa district, located on the slopes of Mt. Elgon, had the highest percent of HHs (89%) that perceived fertility of their soils to have decreased over the past decade.

In an FGD with farmers in Kapchorwa, soil erosion was cited as the major cause for declining soil fertility and declining crop productivity. They also clearly linked soil erosion with the high elevation and steep slopes on which their lands are situated. The HH survey confirmed that 77% of households feel soil erosion is a 'big problem' (figure 10). FDGs with farmers in Tororo and Bungoma, on the other hand, revealed a perception that intensive cultivation of land without fallowing, removal of vegetative cover, poor soil structure, and location on a low agricultural potential zone were the causes of low and declining soil fertility in the area. A district production officer in Tororo also identified limited use of fertilizers and other soil

productivity enhancing inputs as a major cause of soil fertility decline and poor crop yields in the district. Although soil erosion was not directly mentioned in FGDs in Tororo, 58% of HHs in the district perceived soil erosion as a big problem on their farmland.

Perception of soil erosion trend over the last decade

A majority of HHs in Bungoma and Trans-Nzoia perceived soil erosion as only a slight problem or not a problem, in contrast, with 58% and 77% of HHs in Tororo and Kapchorwa districts who perceived soil erosion as a big problem (figure 10). Recent field observations and FGDs revealed that most farmers in Trans-Nzoia and Bungoma practice mainly Fanya juu terraces while a few practice one or more forms of soil and water conservation practices, such as, contour plowing, agro forestry and use of legume crops. Terraces seem to have been perceived as most helpful in controlling erosion given other practices were minimally adopted by farmers (Wanyama et al., 2010).

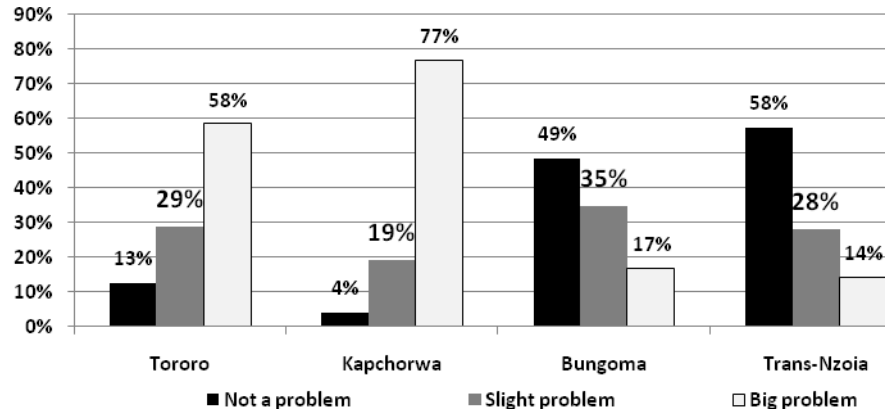

Figure 9: Perception of soil erosion trend over the last decade

Length of time using land

The length of time, in years, that HHs have used their maize plot for crop production is used as an approximate measure of the number of years they have tilled their farmland in

general. Households in Tororo and Bungoma were found to have cultivated their land for longer time periods than HHs in Trans-Nzoia and Kapchorwa (figure 11). The proportion of households that have tilled their land for less than 5 years was highest in Kapchorwa. While the proportion of HHs that tilled their soils between 5 and 20 years was highest in Trans-Nzoia. FGDs with farmers in Kapchorwa revealed that most HHs recently migrated into the area following tribal clashes and cattle rustling from neighboring tribes in surrounding lowland areas.

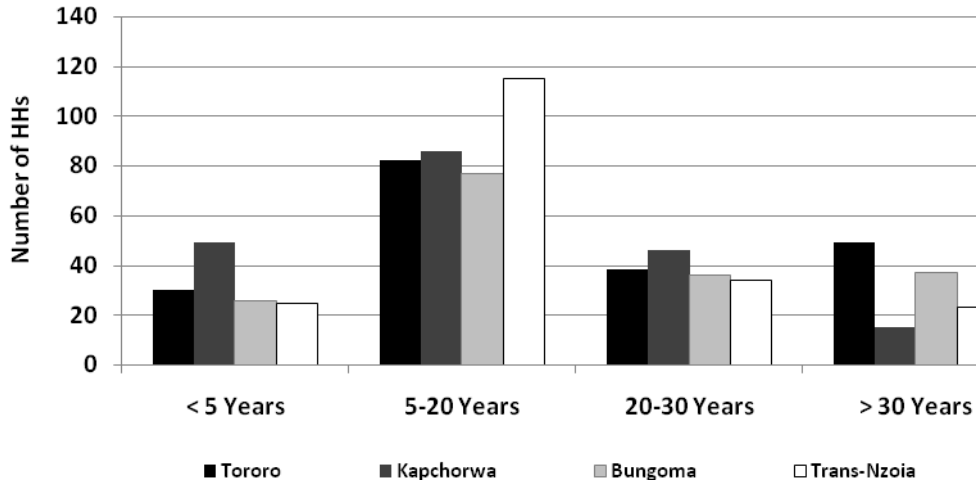

Figure 10: Length of time households have used their maize plot

Availability and use of improved seeds

A majority of HHs in all districts perceives that improved seeds are readily 'available' to them (figure 12). Availability indicates they have access to improved seed if cash were available to buy it.

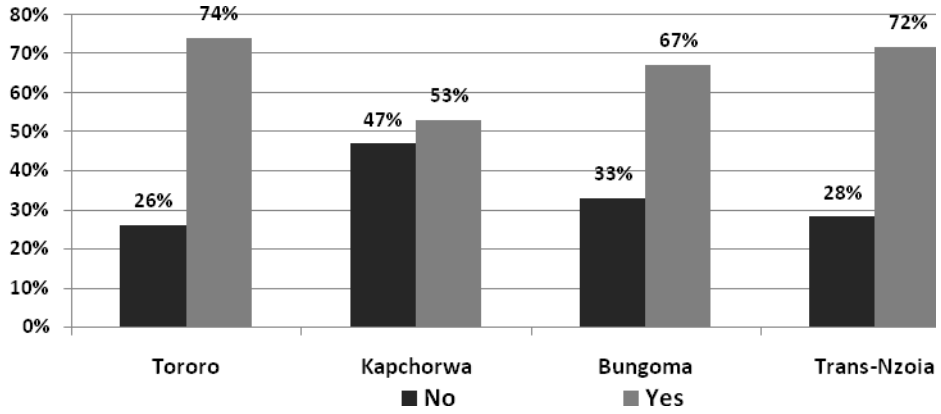

Figure 11: Availability of improved seeds

An even larger majority of HHs in three of the four districts report using improved (hybrid) seeds: 95% in Kapchorwa, 94% in Bungoma, and 97% of HHs in Trans-Nzoia. In Tororo, however, only 12% of HHs used hybrid seeds. Most HHs in Tororo used improved open pollinated variety (OPV) seeds or traditional seeds (figure 13). It can be noted that the proportion of HHs that used improved seeds slightly exceeds the proportion that have access to improved seeds. Possible causes of these findings could be that some respondents did not differentiate between OPV and hybrid seeds or that some HHs under reported level of access in order to attract sympathy and future support from the project.

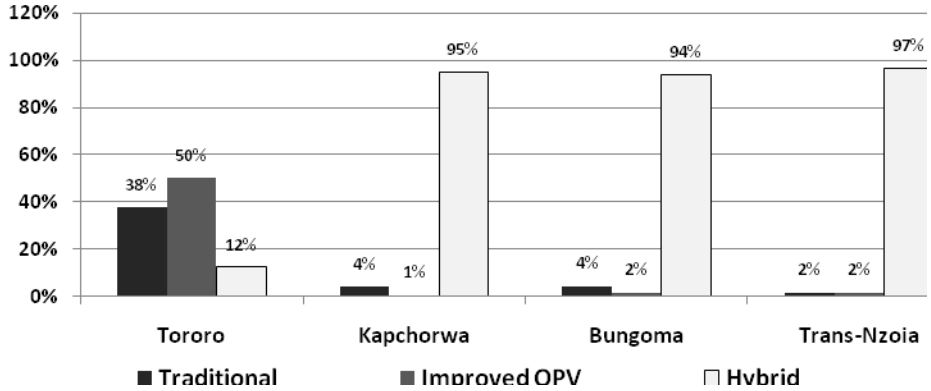

Figure 12: Seed type used by households

Maize plays a dominant role in farming systems of east Africa. Enhancing its productivity through use of improved, high yielding, hybrid seed varieties has the potential to improve the livelihoods of farm households (Langyintuo et al, 2008). The most important reasons given by farmers in Tororo for not using hybrid seeds were high cost of hybrid seeds, long distances from homes to urban centers, and poor transport infrastructure, which limit HHs' access to hybrid seeds. Farmers also cited fake seeds in the market as a reason for not buying hybrid seeds.

An official in Tororo District Farmers Association (TODIFA) indicated that some farmers have the negative perception that hybrid seeds drain nutrients from their soils and would therefore make their land barren. Stakeholders in the Tororo district production office (government department in-charge of provision of technical advice and extension services on crop and livestock production in the district) identified two factors that deter seed companies from having wider seed distribution networks that would make seeds more accessible to smallholder farmers: high transaction costs from dealing with many small seed distributors, and problems of establishing reliable credit systems with rural traders who retail agricultural inputs to farmers in the rural areas.

Characteristics of adopter versus non-adopter households

The previous section summarized characteristics of all HHs within each district, and made comparisons across districts. This section, in contrast, compares characteristics of adopters versus non-adopters of conservation agriculture practices, regardless of their district (but conditional on them knowing about CA prior to the survey). I broadly define adoption of CA in this study; any HH that practiced at least one of the three components of CA (minimum tillage, cover crops and crop rotations) qualified as an adopter. Furthermore, analysis of adoption and

non-adoption of CA was based on a sub-set of HHs that learnt or heard about CA from any source prior to the time of the survey (see table 5).

Differences in various characteristics of adopters versus non-adopters were tested using Pearson's chi-squared test statistic in cross-tabs for categorical variables using SPSS (Howell, 2010; Laird Statistics, 2013) and using t-test for continuous variables (Wolfe and Hollander, 1973) both chi-square and t-test were conducted at 5% significance level. The following characteristics were significantly different between adopters and non-adopters of conservation agriculture practices (table 5): HH head occupation, access to communal resources, contact with public extension service providers, experimentation with new farming technologies, use of hired labor and use of inorganic fertilizer.

Below, I present summary information, for chi-square and t-test statistics for a variety of HH characteristics, for adopters versus non-adopters, regardless of the variables' significance. This information is presented in five sub-sections: HH structure and HH head attributes; HH economic characteristics; HH institutional characteristics; HH location and duration of land use; and HH farming practices and technologies.

Household structure and household-head attributes

HHs that adopted CA did not significantly differ from non-adopters in terms of household structure and household-head characteristics such as HH size, number of active HH members, age of HH head and education level of HH head (table 6).

Table 6: Household structure and household-head characteristics for adopters and non-adopters of conservation agriculture practices

Variable	Description	Non-adopters (N=149)	Adopters (N=118)	Probability (significance)
Education	Primary Post primary	75 74	65 53	0.258 [a]
HH size	Number of people in HH	7.27	7.58	0.44 [b]
ActvHH members	Mean number active HH member	3.38	3.076	0.320 [b]
HH-head Age	Avg Age in years	45.8	46.2	0.816 [b]

[a]Calculated from a Pearson chi-square statistic assuming 1 degree of freedom. If probability is less than 0.05 (5% level of significance) then the null hypothesis of 'no significant difference between adopters and non-adopters' is rejected (Howell, 2010).

[b]Calculated from t-test, if probability is less than 0.05 (5% level of significance) then the null hypothesis of 'no significant difference between adopters and non-adopters' is rejected

Economic characteristics

It was hypothesized that off-farm income and wealth positively influence a HH's likelihood of adopting CA practices. Primary occupation of HH-head served as an indicator for primary source of income for a HH. Salaried work is considered the main source of off-farm income for rural HHs. Off-farm income, if present, may ease liquidity constraints on soil conservation investment or purchase of tillage implements and fertility-enhancing inputs (Bekele and Holden, 1998). Adopters of CA had a slightly higher percentage of salaried workers than non-adopters (table 7).

Table 7: Household-heads' occupation

HH occupation		Non-Adopters	Adopters	Total
Crop production	Count	103	97	200
	Expected Count	110.1	89.9	200.0
	% within Adoption of CAPS	72.5%	83.6%	77.5%
Livestock	Count	6	1	7
	Expected Count	3.9	3.1	7.0
	% within Adoption of CAPS	4.2%	0.9%	2.7%
Crop marketing	Count	2	1	3
	Expected Count	1.7	1.3	3.0
	% within Adoption of CAPS	1.4%	0.9%	1.2%
Livestock marketing	Count	6	0	6
	Expected Count	3.3	2.7	6.0
	% within Adoption of CAPS	4.2%	0.0%	2.3%
Petty trading	Count	8	2	10
	Expected Count	5.5	4.5	10.0
	% within Adoption of CAPS	5.6%	1.7%	3.9%
Salaried worker	Count	14	14	28
	Expected Count	15.4	12.6	28.0
	% within Adoption of CAPS	9.9%	12.1%	10.9%
Other	Count	3	1	4
	Expected Count	2.2	1.8	4.0
	% within Adoption of CAPS	2.1%	0.9%	1.6%
Total	Count	142	116	258
	Expected Count	142.0	116.0	258.0
	% of Total	55.0%	45.0%	100.0%

Chi-Square Test: Value=12.188, df=6, Asymp. Sig. (2-sided) =0.058, N of Valid Cases= 258, 9 cells (64.3%) have expected count less than 5. The minimum expected count is 1.35.

Land ownership (size of land owned)

Adopters of CA practices own more land (4.5 acres) than non-adopters (3.7 acres) with significant difference between the two groups (table 8). Access to land was hypothesized to positively influence HH's likelihood of adopting conservation agriculture practices because farm size is often associated with greater wealth, access to capital and higher risk bearing ability which make investment in conservation agriculture more feasible (Norris and Batie, 1987).

Table 8: Land ownership

Statistics	Non-Adopters	Adopters
Mean (acres)	3.67	4.50
Variance	17.30	38.68
Observations	140	118
Hypothesized Mean Difference		0
df		198
t Stat		1.23[a]
P(T<=t) two-tail		0.22
t Critical two-tail		1.97

[a]Calculated from t-test. If probability is less than 0.05 (5% level of significance) then the null hypothesis of 'no significant difference between adopters and non-adopters' is rejected.

Institutional factors

Institutional factors, such as HH's membership in producer and marketing groups, access to agriculture credit, and access to public extension services, may influence a HH's likelihood of adopting CA practices. Farmers in the study area identified extension service providers, fellow farmers, and religious and community leaders as important sources of information on new farming practices and technologies. NGOs and government production departments have been especially active in agricultural technology diffusion and dissemination in both eastern Uganda and western Kenya where the SANREM/CSRP East Africa CAPS project is being implemented. Most HHs that had contact with public extension agents were non-adopters of CA (table 9).

Table 9: Frequency of interaction with public extension agents

How often do you interact?	Non-Adopters	Adopters	Total
Never	14	3	17
Weekly	4	3	7
Biweekly	5	4	9
Monthly	9	8	17
Seasonally	29	7	36
Yearly	1	5	6
Total	62	30	92

Chi-Square Test: Pearson Chi-Square value = 14.119, df=5, Asymp. Sig. (2-sided) = .015 N of Valid Cases = 92

Makoha et al., (1999) showed that, for farmers in western Kenya, contact with government extension services, and participation in agricultural seminars and workshops, had a statistically significant impact on adoption behavior. Findings in this study show that a lower proportion of HHs that adopted CA were visited by government extension service providers compared to HHs that did not adopted CA practices.

Focus group discussions with farmers that adopted CA, in Kapchorwa and Tororo, indicated that farmers gained motivation to adopt improved soil conservation farming practices through observation and discussion of neighbors' fields, crop yield improvement in fields where CA was applied, availability of technical and financial support from agencies and NGOs promoting CA practices, and training and field visits. The nature of influence of contact with extension agents was not determined *a priori*, however it was noted that frequent contact with extension agents creates a social pressure for farmers to use inputs and practices advocated by extension agents and avoid those that the agents do not support. It could, therefore, be true that public extension agents in the study area do not actually advocate for CA as a soil and water management practice in their training curricular for smallholder farmers.

Experimentation with new technologies

A higher percentage of HHs that experimented with any form of farming technology or tool in the past adopted CA compared to those that did not (table 10). This is indicative of the direction of influence that participating in trials or experimentation with new farming practices and technologies has in influencing HH's technology adoption decision making. Previous studies on adoption of new farming technologies have shown that local participation in technology trials is an important factor in both technology development and its future adoption (Thangata and Alavalapati 2003). Likewise involvement of farmers in technology trials provides

them with a chance to experiment for themselves and understand the usefulness of the new farming techniques.

Table 10: Experimentation with new technology

Have you experimented with new technology		Non-Adopters	Adopters	Total
No	Count	129	97	226
	Expected Count	124.2	101.8	226.0
	% within Adoption of CAPS	97.0%	89.0%	93.4%
	% of Total	53.3%	40.1%	93.4%
Yes	Count	4	12	16
	Expected Count	8.8	7.2	16.0
	% within Adoption of CAPS	3.0%	11.0%	6.6%
	% of Total	1.7%	5.0%	6.6%
Total	Count	133	109	242
	Expected Count	133.0	109.0	242.0
	% within Adoption of CAPS	100.0%	100.0%	100.0%
	% of Total	55.0%	45.0%	100.0%

Pearson Chi-Square value= 6.212, Asymp. Sig. (2-sided) =.013, N of Valid Cases=242

Use of hired labor

Farm labor constraints are a major deterrent to adoption of CA, many farmers resort to hiring farm labor to meet labor requirements for activities such as planting, weeding and harvesting which often coincides with periods of peak labor demand. It was hypothesized that a higher number of HH members who provide farm labor positively influences HH's likelihood of adopting CA.

Table 11: Use of hired labor

HH used hired labor		Non-Adopters	Adopters	Total
No	Count	50	62	112
	Expected Count	61.4	50.6	112.0
	% within Adoption of CAPS	35.0%	52.5%	42.9%
	% of Total	19.2%	23.8%	42.9%
Yes	Count	93	56	149
	Expected Count	81.6	67.4	149.0
	% within Adoption of CAPS	65.0%	47.5%	57.1%
	% of Total	35.6%	21.5%	57.1%
Total	Count	143	118	261
	Expected Count	143.0	118.0	261.0
	% within Adoption of CAPS	100.0%	100.0%	100.0%
	% of Total	54.8%	45.2%	100.0%

Pearson Chi-Square value =8.154, df =1, Asymp. Sig. (2-sided) = .004, N of Valid Cases =261

A higher percentage of non-adopters of CA were found to have hired labor for farm activities compared to adopters of CA. Correlation analysis reveals a high and positive relationship between HH size and active labor and an insignificant positive relationship between active labor and use of hired labor by HH (table 12). This suggests that adoption of CA either reduces labor requirements and therefore the need for hiring additional labor or that having many active members of a HH providing farm labor influences adoption of CA.

Table 12: Correlations between household size, active labor, and use of hired labor

		HH size	Active_labor[a]	HH used hired labor
HH size	Pearson Correlation	1	.584**	.102**
	Sig. (2-tailed)		.000	.004
	N	789	668	789
Active_labor	Pearson Correlation	.584**	1	.023
	Sig. (2-tailed)	.000		.555
	N	668	669	669
HH used hired labor	Pearson Correlation	.102**	.023	1
	Sig. (2-tailed)	.004	.555	
	N	789	669	790

[a] Number of adult HH members that provide labor for farm work
** Correlation is significant at the 0.01 level (2-tailed)

Fertilizer use

A smaller proportion of CA-adopters use inorganic fertilizer compared to non-adopters (table 13). Similarly, a smaller proportion of CA-adopters use hired farm labor compared to non-adopters. These two differences are statistically significant. There was no significant difference, however, in the use of tractors for tillage by adopters versus non-adopters of CA practices. These findings suggest that HHs that are already using fertilizers and hired labor in their crop production systems may have a lower incentive to adopt CA practices, especially if yield improvement is their primary concern.

Table 13: Fertilizer use

Inorganic FertilizerUse		**Non-Adopters**	**Adopters**	**Total**
No	Count	72	73	145
	Expected Count	79.4	65.6	145.0
	% within Adoption of CAPS	50.3%	61.9%	55.6%
	% of Total	27.6%	28.0%	55.6%
Yes	Count	71	45	116
	Expected Count	63.6	52.4	116.0
	% within Adoption of CAPS	49.7%	38.1%	44.4%
	% of Total	27.2%	17.2%	44.4%
Total	Count	143	118	261
	Expected Count	143.0	118.0	261.0
	% within Adoption of CAPS	100.0%	100.0%	100.0%
	% of Total	54.8%	45.2%	100.0%

Pearson Chi-Square value= 3.472, df= 1, Asymp. Sig. (2-sided) = .062 N of Valid Cases =261

Household location and duration of land use

The proportion of HHs that adopted CA did not differ significantly across the four districts. Likewise, the proportion of HHs that used their land for different time periods was not significantly different between adopters and non-adopters of CA practices (table 14).

Table 14: Household location and duration of land use

Variable	Description	Non-Adopters N=149	Adopters N=118	Probability (significance)[a/]
District	Tororo	41	28	0.759
	Kapchorwa	40	34	
	Bungoma	29	28	
	Trans-Nzoia	39	28	
Year of cultivation on HH maize plot	< 5 years	35	19	0.183
	2 to 20 years	75	54	
	20 to 30 years)	22	24	
	>30 years	17	21	

[a/]Calculated from a Pearson chi-square statistic assuming 1 degree of freedom. If probability is less than 0.05 (5% level of significance) then the null hypothesis of 'no significant difference between adopters and non-adopters' is rejected (Howell, 2010).

Farming practices and technologies

Improved conservation practices such as crop rotations, use of cover crops, and minimum tillage, have been promoted in both eastern Uganda and western Kenya by development agencies like Africa 2000 Network (in Tororo) and SACRED Africa (in Bungoma). The baseline survey used in this study suggests, however, that less than one third (29%) of HHs practiced different forms of conservation agriculture technologies (table A1).

Logistic regression model results

Table 15 shows results from the binary logistic regression analysis, in which HHs that learned about CA in the past are the subset of observations included in the regression. The dependent variable is a binary variable representing whether or not the HH actually practices CA (0 = does not practice CA; 1 = does practice one or more elements of CA). The dependent variable is regressed against select independent variables that represent household, socio-economic and biophysical factors.

Identification and correction of multi-collinearity

A multivariate correlation analysis was conducted to identify the nature of correlation between independent variables. For variables that had correlation coefficients of 0.5 and above, and served similar functional purposes (e.g., alternative measures of wealth), all but one of those

variables were excluded from the model (Paudel and Thapa 2004). High correlation between explanatory variables was considered a warning-sign of multi-collinearity. Removal of such variables was presumed to help reduce potential negative effects of multi-collinearity. Distance from nearest urban center, ox ownership and use of ox-traction were excluded from the model because they were highly correlated with other explanatory variables included in the model.

Interpretation of logistic regression results

The estimated coefficients (B; also known as the log-odds), and their corresponding odds ratios (i.e., Exp(B)), are shown in table 10. Log-odds are difficult to interpret, so I focus on odds-ratios instead. An odds ratio greater than 1.0 reflects a positive effect of the explanatory variable on the dependent variable. For example, the odds-ratio on EDUCATION (i.e., a HH-head has post-primary education) is 1.133, which implies someone who has post-primary education is 13.3% more likely [(1.133 – 1.00)*100% = 13.3%] to adopt CA than someone who does not have post primary education (although this effect is not statistically significant).

Alternatively, for every 1 HH that does not have post-primary education but does adopt CA, there are 1.133 HHs that do have post-primary education and do adopt CA. An odds-ratio less than 1.0 reflects a negative effect of the explanatory variable on the dependent variable. For example, the odds ratio on GENDER (i.e., 0 = HH head is male; 1 = HH head is female) is 0.943, which implies that only 0.943 females adopt CA for every 1 male who adopts CA. That is, a female head of household's odds of adopting CA are only 0.943 times as large as a male head of household's odds. Alternatively, this odds ratio can also be interpreted as females having 5.7% less chance of adopting CA than males [(0.943 – 1.00)*100% = -5.7%]. Note, this effect of gender on adoption is not statistically significant. Summary of the omnibus test for the regression

is presented below table 10. Test statistics show that the model is significantly better than the intercept only model at 5% level.

Table 15: Parameter estimates of the logistic regression model

Variable[a/]	B	Standard error	Exp(B)
AGE	-.019	0.015	0.982
GENDER (MALE)	-.059	0.625	0.943
HOUSE_TYPE[b/]			
Temporary	-.565	0.658	0.568
Semi-permanent	-.592	0.487	0.553
FERTILIZER	-.844	0.505	0.430**
SEED	.861	0.476	2.365**
EDUCATION (1=post-primary; 0 if not)	.125	0.381	1.133
TENURE	.049	0.041	1.050
HIRE_LABOR	-1.043	0.431	0.352**
MANURE	-.504	0.377	0.604
TRACTOR	-.708	0.796	0.493
EXPERIENCE	.487	0.224	1.628**
ACTIVE_LABOR	.056	0.164	1.058
RESOURCE	.163	0.442	1.177
GROUP	-.565	0.362	0.568
EXTENSION	-.198	0.384	0.820
LOCATION[c/]			
TORORO	-1.780	0.864	0.169**
KAPCHORWA	-.644	0.847	0.525
BUNGOMA	.846	0.978	2.330
FERTILITY[d/]			
Decreasing	-.116	0.481	0.890
Staying the same	.310	0.617	1.364
CONSTANT	1.029	1.454	2.797

[a/]The dependent variable is 0 if a household had knowledge of conservation agriculture but does not practice it, and 1 if a household had knowledge of conservation agriculture and does practice it.
b/ Permanent is the reference house type
c/ Trans-Nzoia is the baseline or reference location.
d/ Increasing is the reference soil fertility trend.
Note: All reference categories are dropped to avoid perfect-collinearity between the levels of categorical variables.
**Statistically significant at 5% level
Initial step -2log likelihood =279.060, step one (model) -2log likelihood = 240.188. Chi-square statistic = 38.872, Sig. 0.015

The binary regression model predicts that two factors have positive significant influence on a HH's adoption of conservation agriculture practices: use of improved seed, and duration of time the HHs used their land. The model predicts three factors that have negative significant influence on adoption: location of HHs in Tororo district of eastern Uganda, use of hired labor, and use of inorganic fertilizers. Other characteristics, like education level of HH head, wealth (HOUSE_TYPE), AGE, institutional factors, and biophysical factors, did not significantly influence HHs' decision to adopt conservation practices.

Household characteristics

Education level of the HH head was found to have a positive but insignificant influence on adoption of CA. Higher level of education was hypothesized to lead to a better understanding of new farming technologies when reviewing different extension materials, which enhances adoption of improved technology. Positive effects of education on adoption of improved soil conservation technology have been reported in other studies (Lapar and Ehui, 2004; Mbaga-Semgalawe and Folmer, 2000; Sheikh et al., 2003).

Households in Tororo district are significantly less likely to adopt CA than HHs not in Tororo district, even after controlling for house type (a proxy of wealth), access to extension services, education, and several other characteristics. Only 0.169 households in Tororo district adopt CA for every 1 household in some other district that adopts CA, assuming the two households are identical in all other characteristics included in the model.

Keep in mind, all HHs included in this regression reported knowing about CA, so all HHs have had some past exposure to the idea. However, the baseline survey did not measure the depth of a community's knowledge of CA, or the extent to which CA education efforts were made in the community, or the length of time that has passed since they were made. The Tororo variable

might therefore be picking up a lack of in-depth CA educational efforts in that community compared to efforts in other communities. The Tororo variable could also be a proxy for maize yield, which is not included in the regression, and which tends to be much lower in that district, compared to yields in other communities. On the other hand, variables such as 'use of inorganic fertilizer' and 'use of improved seeds' might also proxy for variability in maize yield.

Age of the household head had a negative but statistically insignificant influence on adoption of CA. The odds-ratio for age is 0.982, which suggests that, for every additional year of age, a HH head is 0.982 less likely to adopt CA than someone who is a year younger, holding all other characteristics constant. Age was hypothesized to negatively influence CA adoption because older HH-heads were expected to be more risk averse and have a higher discount rate than younger HH heads. Findings from this study are in agreement with results from Lapar and Pandey (1999) in the Philippines, and Bekele and Holden (1998) who reported a negative influence of age on adoption of soil conservation practices in Ethiopia.

Membership in farmer producer groups and access to public extension services

Household membership in producer and marketing groups, and access to public extension services had negative but insignificant influence on a HH's likelihood of adopting conservation practices. This result, although not statistically significant, is counter to my initial hypothesis and some findings in the existing literature. A study by Adesina et al., (2000), for example, reported a positive and significant influence of HH membership in farmers' associations in Cameroon on adoption of soil conservation technologies.

Producer and market groups provide smallholder farmers with a forum for sharing farming experiences and market information. Most farmer groups in villages were created by NGOs and government agencies as a means of increasing the speed of information transfer to

rural farmers. Farmers in such groups might therefore feel pressured to disseminate information on technologies that are promoted by NGOs and agencies, and shun agricultural practices that are not. The lack of a significant impact of group membership on adoption could imply numerous conclusions: there may simply be limited discussion of CA among such groups; there may be mixed opinions among farmers about the net benefits of CA; individual farmers might discount the opinions of their fellow group members; or some HHs might be members of a group but not participate in it very actively.

Farming practices and perceptions of soil

The effect of various farming practices, such as length of time a plot had been used, use of improved seeds, fertilizers, hired labor, and tillage systems, on adoption of CA were explored. Effect of a HH's perception of their soil's fertility on the likelihood of adopting CA practices was also explored. Results show that the duration (years) that HHs have used their land, and use of improved seed had a positive influence on HH's likelihood of adopting CA. Use of inorganic fertilizers, however, had a negative influence on their likelihood of adopting CA.

Results from cross-tabulation reveal similar insights as logistic regression results. Many of the factors that had positive correlation and influence on CA adoption in cross tabs were also predicted to have similar direction of influence in the logistic regression model. For example the cross-tabs and logistic regression predict that use of inorganic fertilizer and hired labor have a significant negative influence on likelihood of CA adoption and significant negative relationship with CA adoption respectively.

CHAPTER FIVE

Conclusions and recommendations

Cross-tabulation (combined with the chi-square test statistic) and a logistic regression model reveal several factors that have significant effects on adoption of CA. The result of the logistic regression analysis showed that the length of time a HH had used its land and use of improved seed significantly increases a HH's decision to adopt CA practices. Use of inorganic fertilizers, use of hired labor, and location in Tororo district, in contrast, significantly decreased adoption of CA practices. Cross-tabulations also revealed significant differences between adopters and non-adopters of CA, including the proportion of HHs with access to off-farm employment and experimentation with new technologies, which were higher among adopters. A higher proportion of non-adopters had contact with public extension service providers, used hired labor and inorganic fertilizer than adopters.

These finding have important practical and policy implications for adoption of the SANREM/CRSP East Africa team's CAPS by smallholder farmers in the study area. Summary statistics of the baseline survey data reveal several important differences between smallholder farmers in the four districts. Farmers perceive different causes of their problems in different districts. This will affect their willingness to adopt different components of CAPS (as will their other characteristics). Results from cross-tabulation and logistic regression reveal that HH who are wealthy enough to afford hired labor and inorganic fertilizer are not very interested in adopting CA practices. Although they are the ones who can presumably most easily afford to adopt CAPS, they are also the ones who have relatively high maize yields already, and therefore have the smallest additional yield to gain. They are not terribly concerned about their long-term

yields because they can afford to buy the external inputs necessary to keep yields high. These HHs are mainly located in Trans-Nzoia district.

Next, we turn to HHs in Tororo, who have the longest history of land-use, lowest maize yield, the lowest ability to purchase external inputs to boost yields, and therefore have the most at stake, or the most to potentially gain (or lose because they can't afford to take much risk) from adopting CAPS. Results from my regression analysis indicate that HHs in Tororo are much less likely to adopt CA than HHs in other areas, perhaps because they lack the resources necessary to purchase herbicides, improved seeds, and other inputs, and cannot afford to leave residue in the field. Correlation analysis results presented in the appendix shows that proxies for wealth (house type) are positively correlated with inorganic fertilizer, herbicide and improved seed use. So, the fact that Tororo uses very little of these inputs suggests it might be because they are less wealthy than other districts.

The SANREM/CRSP East Africa CAPS team is promoting and advocating the following three practices:1) minimum tillage (which requires special tillage equipment that involves draft animals or tractors, which are not currently used in Tororo);2) increased crop residue to be left on the surface (which my correlation analysis in the appendix suggest are negatively correlated with hand-weeding, and positively correlated with house-type, which implies it will be difficult for HHs in Tororo to increase crop residue); and 3) crop rotations(HH's rating of the statement that 'crop rotation is always a best practice in farming' did not significantly differ across districts; a majority of HHs strongly agreed with the statement. This could be indicative of HHs' willingness to continue using or up-scaling the practice in Tororo and all other districts).

Lastly, we have the 'moderate' districts: Kapchorwa and Bungoma. HHs in these districts have a degree of uniqueness in their characteristics that might have influenced their

adoption of CA in the past, and their incentives to adopt SANREM/CRSP's CAPS in the future. Evidence suggests that they are more wealthy than Tororo, but less wealthy than Trans-Nzoia. This means some HHs might be able to afford to adopt CAPS, if they have not done so already.

Kapchorwa perceives erosion as a major problem, and they have relatively high maize yields right now, so they might sense they have a lot to lose if they do not take action soon to conserve soil fertility and curb erosion. They make more use of animal and tractor traction, so they have the ability to adopt our CAPS' no-till practice. They have higher levels of our proxies for wealth, so they are in a better position to purchase herbicides and leave more crop residue. Kapchorwa might, therefore, be more easily induced to adopt CA than Tororo or Trans-Nzoia. The benefits of adoption might be quite high too because of the large erosion problem.

Bungoma on the other hand, lies at the borderline between the wealthy and poor, has the lowest number of active HH members providing farm labor, has relatively high level of both animal traction and tractor use, use more fertilizer than Tororo and Kapchorwa, but has lower yields and poor soils. Many of these unique characteristics might make CAPS more appealing to HHs in Bungoma than HHs in Tororo. Regression analysis results showed that HH location in Bungoma (not Trans-Nzoia) increases its likelihood of adopting CA by a factor of 2.3 as opposed to location in Tororo or Kapchorwa. Being wealthier than HHs in Kapchorwa and Tororo, having higher level of access to animal draft power and tractors enables Bungoma HHs to afford the use both inputs and tillage equipment recommended for CA. Likewise, low yields and high levels inorganic fertilizers increases their gains from adopting CA.

The SANREM/CRSP East Africa CAPS project is designed to facilitate active participation of smallholder farmers in the design, implementation, and evaluation of improved CAPS. Cross-tab analysis suggests that farmers who experimented with new technologies in

their own farms were more likely to adopt the technology than those that did not. The team should thus continue to encourage and facilitate participation of farmers in the on-farm implementation and evaluation process. The team will also need to actively promote the use of inputs that are important components of the CAPS being developed, such as improved seed, no-till equipment, herbicides, and specialty seeds for cover crops. After all, my results suggest that certain districts are more or less likely to purchase these inputs. Wealth does not appear to have a strong influence on adoption, but it might be a side effect of the definition of the dependent variable 'adoption' which comes in different degrees, but I broadly define it as 0 versus 1 on the basis of use of at least one of the three recommended practices for adopters.

Because this study reveals significant differences between the four study sites despite similarities in agro-ecological zones and altitude between some if the cites, including differences in crop yields, tillage systems and farming practices, blanket recommendation of uniform conservation agriculture practices for all CAPS locations should never be done. Instead such recommendations should be based on outcomes from CAPS trials in each site and they should be targeted to the specificity of each location.

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Appendix 1: Summary of SANREM/CRSP East Africa project's baseline survey in 2010

Table A1.1: Characteristics of all households surveyed

		Uganda		Kenya		
Variable	**Description**	**Tororo**	**Kapchorwa**	**Bungoma**	**Trans-Nzoia**	**Overall**
HH head	Male (%)	84.5	95.0	91.0	80.5	87.6
Gender	Female (%)	15.8	5.0	9.0	19.5	12.4
HH head AGE	Average male (years)	47.4	42.2	47.3	50.8	46.8
HHSIZE	No. of people in the HH	6.6	7.9	7.4	7.8	7.4
HH head EDUCN	Primary and below (%)	78.2	64.5	48.4	37.5	57.3
	Post primary (%)	21.8	35.5	51.6	62.5	42.7
ActiveN	No. of people actively involved in Ag. Production	3.2	3.8	1.8	3.2	3.0
DIST_TC	Average distance to urban center (Kms)	1.3	1.1	2.9	4.0	2.3
Primary occupation	Crop production (%)	85.5	90.5	75.9	61.0	70.6
	Salaried work (%)	14.4	9.0	19.1	30.0	18.1
Animal draft access	Access draft power (%)	0	50.5	28.7	0.5	19.7
Tractor access	Access to tractor (%)	1	10.5	29.8	41.0	20.4
Total land access	Total land accessed (acres)	4.7	3.9	3.5	9.3	5.3
LN cultivated	Total land cultivated (acres)	3.4	2.8	2.6	5.9	3.7
Maize plot	Maize plot size (acres)	0.9	2.0	1.8	3.8	2.3
Seed_type	Use improved seed (%)	37.6	79.5	97.0	89.5	74.1
Fertilizer	Use inorganic fertilizer (%)	0.00	27.0	78.7	78.5	45.4
Extension access	Visited by extension agent at least once in the season (%)	20.3	20.5	26.1	26.5	23.3
CA knowledge	Has ever learned/heard of CA (%)	34.3	37.0	32.8	33.5	34.5
Hired labor	HH hired labor for farmwork in 2010 main season (%)	27.7	55.5	42.0	70.5	49.0
Type of residence	Temporary house (%)	32.2	35.0	14.4	0	20.5
	Semi-permanent house (%)	48.5	62.0	71.8	56.5	59.5
	Permanent house (%)	18.8	1.5	11.7	42.5	18.7
Maize yield	Average maize yield (kg/ha)	263	2500	997	4641	2113
Group membership	Actively involved in producer group (%)	32.7	25.5	80.3	31.5	41.9
Years of cultivation on household's land	< 5 years (%)	15.1	25	14.8	12.7	16.9
	5 to 20 years (%)	41.2	43.9	43.8	58.4	46.9
	20 to 30 years (%)	19.1	23.5	20.5	17.3	20.1
	>30 years (%)	24.6	7.7	21.0	11.7	16.1
Shared resource access	Pasture (%)	38.6	7.5	27.9	7.0	20.2
	Forest (%)	63.2	6.0	22.7	3.0	17.0
	Water (%)	96.0	85.0	83.5	36.2	75.0

Data source: SANREM/CAPs Baseline survey 2010

Appendix 2: Correlation coefficients (to narrow the list of variables) and cross-tabulations

Table A2.1: Correlation statistic for selected variables

		Area cultivated	No. of oxen owned	Maize yield	Type of house	Method of land prep	HH members actively in Ag.	HH adopted CA	Hand weeding	Herbicide use	Fertilizer use	Improved seed	% of crop residue
Area cultivated	Pearson Cor	1	.093*	.034	.184**	.181**	.007	-.025	-.050	.252**	.098**	.077*	-.058
	Sig. (2-tailed)		.019	.416	.000	.000	.854	.687	.170	.000	.007	.035	.240
	N	758	637	584	749	635	621	258	758	758	758	758	414
No. of oxen owned	Pearson Cor		1	.158**	.071	.124**	-.010	.134*	-.147**	.045	.076*	.189**	.048
	Sig. (2-tailed)			.000	.068	.004	.806	.047	.000	.245	.049	.000	.357
	N		666	488	658	534	551	220	666	666	666	666	373
Maize yield	Pearson Cor			1	.070	.315**	.023	-.077	-.267**	.096*	.154**	.190**	.047
	Sig. (2-tailed)				.088	.000	.611	.266	.000	.019	.000	.000	.360
	N			601	593	596	472	211	601	601	601	601	389
Type of house	Pearson Cor				1	.352**	.066	.012	-.117**	.163**	.251**	.136**	.120*
	Sig. (2-tailed)					.000	.097	.850	.001	.000	.000	.000	.014
	N				780	646	639	263	780	780	780	780	421
Method of land preparation	Pearson Cor					1	.031	-.022	-.814**	.201**	.377**	.174**	.120*
	Sig. (2-tailed)						.488	.739	.000	.000	.000	.000	.014
	N					654	516	232	654	654	654	654	421
HH members actively in Ag.	Pearson Cor						1	.046	.000	.065	.112**	.106**	.094
	Sig. (2-tailed)							.504	1.000	.101	.004	.007	.067
	N						644	213	644	644	644	644	379
HH adopted CA	Pearson Cor							1	-.038	-.068	-.122*	.032	.131
	Sig. (2-tailed)								.539	.269	.047	.598	.111
	N							267	267	267	267	267	150
Hand weeding	Pearson Cor								1	-.041	-.156**	.032	-.131**
	Sig. (2-tailed)									.248	.000	.362	.007
	N								790	790	790	790	427
Herbicide use	Pearson Cor									1	.112**	.095**	-.020
	Sig. (2-tailed)										.002	.007	.684
	N									790	790	790	427
Fertilizer	Pearson Cor										1	.476**	.155**
	Sig. (2-tailed)											.000	.001
	N										790	790	427
Improved seed	Pearson Cor											1	.113*
	Sig. (2-tailed)												.020
	N											790	427
% of crop residue	Pearson Cor												1
	Sig. (2-tailed)												
	N												427

* Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed). a. Cannot be computed because at least one of the variables is constant

Table A2.2: Correlations between number of oxen owned, use of own oxen and use of animal traction

		No. oxen owned	Use own oxen	Use of ox traction
No.of oxen owned	Pearson Cor.	1	.677**	.569**
	Sig. (2-tailed)		.000	.000
	N	666	471	666
Use own oxen	Pearson Cor.		1	.890**
	Sig. (2-tailed)			.000
	N		473	473
Use of animal traction	Pearson Cor.			1
	Sig. (2-tailed)			
	N			790

** Correlation is significant at the 0.01 level (2-tailed).

Table A2.3: Correlations between number of oxen owned, use of ox traction and type of house

		No. of oxen owned	Use own ox for plowing	Use of ox plow	Type of house
No. of oxen owned	Pearson Cor.	1	.677**	.569**	.071
	Sig. (2-tailed)		.000	.000	.068
	N	666	471	666	658
Use own ox for plowing	Pearson Cor.		1	.890**	.062
	Sig. (2-tailed)			.000	.179
	N		473	473	468
Use of ox plow	Pearson Cor.			1	-.099**
	Sig. (2-tailed)				.006
	N			790	780
Type of house	Pearson Cor.				1
	Sig. (2-tailed)				
	N				780

** Correlation is significant at the 0.01 level (2-tailed).

Table A2.4: Correlation between household size and number of adult members that provide farm labor

		HH size	Active HH labor
HH size	Pearson Cor.	1	.305**
	Sig. (2-tailed)		.000
	N	789	644
Active HH labor	Pearson Cor.		1
	Sig. (2-tailed)		
	N		644

** Correlation is significant at the 0.01 level (2-tailed).

Table A2.5: Correlation between fertilizer use, tractor use and herbicide use

		Fertilizeruse	Tractor use	Herbicide use
Fertilizer use	Pearson Correlation	1	.389**	.112**
	Sig. (2-tailed)		.000	.002
	N	790	790	790
Tractor use	Pearson Correlation		1	.276**
	Sig. (2-tailed)			.000
	N		790	790
Herbicide use	Pearson Correlation			1
	Sig. (2-tailed)			
	N			790

**. Correlation is significant at the 0.01 level (2-tailed).

Table A2.6: Correlation between fertilizer use, herbicide use, use of improved seed and hand weeding

		Fertilizer use	Herbicide use	Improved seed	Hand weeding
Fertilizer use	Pearson Cor.	1	.112**	.476**	-.156**
	Sig. (2-tailed)		.002	.000	.000
	N	790	790	790	790
Herbicide use	Pearson Cor.		1	.095**	-.041
	Sig. (2-tailed)			.007	.248
	N		790	790	790
Improved seed	Pearson Cor.			1	.032
	Sig. (2-tailed)				.362
	N			790	790
Hand weeding	Pearson Cor.				1
	Sig. (2-tailed)				
	N				790

** Correlation is significant at the 0.01 level (2-tailed).

Table A2.7: Fertilizer use and type of house cross-tabulation

Fertilizer use		Type of house the households resides in			Total
		Temporary	Semi-Permanent	Permanent	
No	Count	127_a	240_b	58_c	425
	% within Fertilizer	29.9%	56.5%	13.6%	100.0%
	% within Type of house	78.4%	51.1%	39.2%	54.5%
	% of Total	16.3%	30.8%	7.4%	54.5%
Yes	Count	35_a	230_b	90_c	355
	% within Fertilizer	9.9%	64.8%	25.4%	100.0%
	% within Type of house	21.6%	48.9%	60.8%	45.5%
	% of Total	4.5%	29.5%	11.5%	45.5%

Each subscript letter denotes a subset of 'Type of house the households resides in' whose column proportions do not differ significantly from each other at the .05 level.

Table A2.8: Correlation between area cultivated, number of oxen owned, use of own oxen, maize yield and type of house

		Area cultivated	No. of oxen owned	Use own oxen for plowing	Maize Yield	Type of house
Area cultivated	Pearson Cor.	1	.093*	.085	.034	.184**
	Sig. (2-tailed)		.019	.070	.416	.000
	N	758	637	453	584	749
No. of oxen owned	Pearson Cor.		1	.677**	.158**	.071
	Sig. (2-tailed)			.000	.000	.068
	N		666	471	488	658
Use own oxen for plowing	Pearson Cor.			1	.155**	.062
	Sig. (2-tailed)				.005	.179
	N			473	327	468
Maize Yield	Pearson Cor.				1	.070
	Sig. (2-tailed)					.088
	N				601	593
Type of house	Pearson Cor.					1
	Sig. (2-tailed)					
	N					780

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

Table A2.9: Fertilizer use and education level of household-head cross-tabulation

Fertilizer use		Education level of HH								
		None	Pre primary	Primary	O level or Jr.Cert	A level or Sr. Cert	Tertiary	Non-Formal	Other	Total
No	Count	76_{a}	$38_{b, c}$	$183_{b, c}$	88_{d}	17_{d}	24_{d}	$4_{a, c}$	$0_{b, d}$	430
	% Within fertilizer use	17.7%	8.8%	42.6%	20.5%	4.0%	5.6%	.9%	.0%	100.0%
	% within Education level	80.9%	62.3%	62.9%	37.9%	34.0%	43.6%	100.0%	.0%	54.5%
	% of Total	9.6%	4.8%	23.2%	11.2%	2.2%	3.0%	.5%	.0%	54.5%
Yes	Count	18_{a}	$23_{b, c}$	$108_{b, c}$	144_{d}	33_{d}	31_{d}	$0_{a, c}$	$2_{b, d}$	359
	% within Fertilizer use	5.0%	6.4%	30.1%	40.1%	9.2%	8.6%	.0%	.6%	100.0%
	% within Education level	19.1%	37.7%	37.1%	62.1%	66.0%	56.4%	.0%	100.0%	45.5%
	% of Total	2.3%	2.9%	13.7%	18.3%	4.2%	3.9%	.0%	.3%	45.5%

Each subscript letter denotes a subset of Education level of HH categories whose column proportions do not differ significantly from each other at the .05 level.

Table A2.10: HH occupation * Adoption of CAPS Cross tabulation

HH occupation		Non-Adopters	Adopters	Total
Crop production	Count	103	97	200
	Expected Count	110.1	89.9	200.0
	% within Adoption of CAPS	72.5%	83.6%	77.5%
Livestock	Count	6	1	7
	Expected Count	3.9	3.1	7.0
	% within Adoption of CAPS	4.2%	0.9%	2.7%
Crop pdt marketing	Count	2	1	3
	Expected Count	1.7	1.3	3.0
	% within Adoption of CAPS	1.4%	0.9%	1.2%
Livestock marketing	Count	6	0	6
	Expected Count	3.3	2.7	6.0
	% within Adoption of CAPS	4.2%	0.0%	2.3%
Petty trading	Count	8	2	10
	Expected Count	5.5	4.5	10.0
	% within Adoption of CAPS	5.6%	1.7%	3.9%
Salaried worker	Count	14	14	28
	Expected Count	15.4	12.6	28.0
	% within Adoption of CAPS	9.9%	12.1%	10.9%
Other	Count	3	1	4
	Expected Count	2.2	1.8	4.0
	% within Adoption of CAPS	2.1%	0.9%	1.6%
Total	Count	142	116	258
	Expected Count	142.0	116.0	258.0
	% of Total	55.0%	45.0%	100.0%

Chi-Square Test: Value=12.188, df=6, Asymp. Sig. (2-sided) =0.058, N of Valid Cases= 258, 9 cells (64.3%) have expected count less than 5. The minimum expected count is 1.35.

Table A2.11: Frequency of interaction with extension agents* Adoption of CAPS Cross tabulation

How often do you interact		Non-Adopters	Adopters	Total
Never	Count	14	3	17
Weekly	Count	4	3	7
Biweekly	Count	5	4	9
Monthly	Count	9	8	17
Seasonally	Count	29	7	36
Yearly	Count	1	5	6
Total	Count	62	30	92

Chi-Square Test: Pearson Chi-Square value = 14.119, df=5, Asymp. Sig. (2-sided) = .015 N of Valid Cases = 92, 5 cells (41.7%) have expected count less than 5. The minimum expected count is 1.96.

Table A2.12: HH is a member of a producer association * Adoption of CAPS Cross-tabulation

HH is a member of a producer association		Non-adopters	adopters	Total
No	Count	80	65	145
	Expected Count	79.4	65.6	145.0
	% within Adoption of CAPS	55.9%	55.1%	55.6%
	% of Total	30.7%	24.9%	55.6%
Yes	Count	63	53	116
	Expected Count	63.6	52.4	116.0
	% within Adoption of CAPS	44.1%	44.9%	44.4%
	% of Total	24.1%	20.3%	44.4%
Total	Count	143	118	261
	Expected Count	143.0	118.0	261.0
	% within Adoption of CAPS	100.0%	100.0%	100.0%
	% of Total	54.8%	45.2%	100.0%

Chi-Square Test: Likelihood Ratio value = .019, df = 1, Asymp. Sig. (2-sided) =0.889, N of Valid Cases = 261

Appendix 3: T-test of sample comparisons

Table A3.1: t-Test: Two-Sample Assuming Unequal Variances in age of householdheads

	Adopters	Non-Adopters
Mean	46.211	45.783
Variance	235.707	198.002
Observations	118	143
Hypothesized Mean Difference	0	
df	240	
t Stat	0.233	
P(T<=t) one-tail	0.408	
t Critical one-tail	1.651	
P(T<=t) two-tail	0.816	
t Critical two-tail	1.970	

Table A3.2: t-Test: Two-Sample Assuming Unequal Variances in number of active household members

	Adopters	Non-Adopters
Mean	3.381	3.077
Variance	7.058	4.761
Observations	118	143
Hypothesized Mean Difference	0	
df	226	
t Stat	0.997	
P(T<=t) one-tail	0.160	
t Critical one-tail	1.651	
P(T<=t) two-tail	0.320	
t Critical two-tail	1.970	

Table A3.3: t-Test: Two-Sample Assuming Unequal Variances in household size

	Adopters	Non-Adopters
Mean	7.576	7.274
Variance	10.383	9.562
Observations	118	142
Hypothesized Mean Difference	0	
Df	245	
t Stat	0.765	
P(T<=t) one-tail	0.222	
t Critical one-tail	1.651	
P(T<=t) two-tail	0.445	
t Critical two-tail	1.970	

Table A3.4: t-Test: Two-Sample Assuming Unequal Variances in size of land owned by households

	Adopters	Non-Adopters
Mean	4.504	3.674
Variance	38.676	17.301
Observations	118	140
Hypothesized Mean Difference	0	
df	198	
t Stat	1.235	
P(T<=t) one-tail	0.109	
t Critical one-tail	1.653	
P(T<=t) two-tail	0.218	
t Critical two-tail	1.972	