DERTERMINANTS FOR ADOPTION OF SOIL FERTILITY MANAGEMENT TECHNOLOGIES AMONG SMALLHOLDER MAIZE-BASED PRODUCTION SYSTEMS IN EASTERN UGANDA AND WESTERN KENYA

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Reg No.: 2011/HD02/4721U

A THESIS SUBMITTED TO THE DIRECTORATE OF RESEARCH AND GRADUATE TRAINING IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE IN AGRICULTURAL AND APPLIED ECONOMICS OF MAKERERE UNIVERSITY

JANUARY 2017

DECLARATION

This thesis is my original work and it has not been presented in any university for the award of a degree or diploma.

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DEDICATION

To Mariah and Joseph Ethan.

ACKNOWLEDGEMENT

Firstly, I thank the almighty God for giving me life. He has been so generous to me; I will never be able to thank him enough. Secondly, I wish to thank the Department of Agribusiness and Natural Resource Economics, through the former head, Prof. Mugisha Johnny; for rendering me admission to this course.

Thirdly, my acknowledgement is to the Soil Health Programme (SHP 026) under Alliance for a Green Revolution in Africa (AGRA), Dr. Marie` Rarieya and Dr. Bashir Jama not forgetting the PI, Dr. Mulumba Lukman, who have sponsored and gave me a chance to pursue a higher degree in Agricultural and Applied Economics at Makerere University. In addition, thanks to SANREM-CRSP (Innovation Laboratory) supported by USAID for provision of the data used in this study free of charge.

My sincere regards go to my supervisors Prof. Bashaasha Bernard and Prof. Sserunkuuma Dick for continued assistance and guidance during the course of this research work, this thesis would not be as good without your assistance.

Last but not least, my classmates in the CMAAE (2012) cohort, for being ready to assist anyone in need so that we all succeed. Indeed, your efforts and contributions in my work cannot be exhausted especially during the third semester at University of Pretoria, South Africa, though God will reward you. Thank you.

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ACRONYMS

ACTA	African Conservation Tillage Network
AGRA	Alliance for a Green Revolution in Africa
AMITSA	Agricultural Input Market Information and Transparency System
AT-Uganda	Appropriate Technology Uganda
CA	Conservation Agriculture
CAPS	Conservation Agriculture Production Systems
CAN	Calcium Ammonium Nitrate
CBA	Cost Benefit Analysis
CIRAD	French Agricultural Research Centre for International Development
CIMMYT	International Maize and Wheat Improvement Center
CMAAE	Collaborative Masters in Agricultural and Applied Economics
CRSP	Collaborative Research Support Program
DAP	Diammonium Phosphate
DRC	Democratic Republic of Congo
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	Food and Agriculture Organization Statistics Database
FGDs	Focus Group Discussions
GDP	Gross Domestic Product
GEF	Global Environment Facility
HYVs	High Yielding varieties
IFAD	International Fund for Agricultural Development
IFDC	International Fertilizer Development Center

IFPRI	International Food Policy Research Institute
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
MLE	Maximum Likelihood Estimation
MT	Metric Ton
NCPB	National Cereals and Produce Board
NPK	Nitrate, Phosphate Potassium
NGOs	Non-Governmental Organizations
RATIN	Regional Agricultural Trade Intelligence Network
SAN	Sulphate of Ammonia or Ammonium Sulphate
SANREM	Sustainable Agriculture and Natural Resource Management
SEI	Stockholm Environment Institute
SDG	Sustainable Development Goals
SHP	Soil Health Programme
SSA	Sub-Saharan Africa
UBoS	Uganda Bureau of Statistics
UNEP	United Nations Education Programme
USAID	United States Agency for International Development

ABSTRACT

Increasing agricultural crop yields sustainably appears to be the only way out of the chronic decline in food availability in Sub-Saharan Africa given growing populations, shrinking farm sizes and rapidly degrading soil fertility. Although inorganic fertilizer use offers an option for increasing agricultural production, it does not provide the whole solution thus the need for complementary Conservation Agricultural technologies to enhance rural incomes and achieve food security. Thus, this study makes a contribution in terms of better understanding of the complementarity of CA and inorganic fertilizer use in Eastern Uganda and Western Kenya as soil fertility improvement technologies.

The study used secondary data collected for the SANREM-CRSP EA project. A two-stage stratified sampling procedure was employed in Tororo, Bungoma, Kapchorwa and Trans-Nzioa districts to sample 790 households. Data on socio-economic and demographic characteristics were used to characterize fertilizer and CA users and non-users. An Ordered Probit model was used to predict what factors determined adoption of these technologies; t-tests were used to measure any significant differences among farmer categories in Uganda and Kenya.

Overall, results show that respondents in Kenya were relatively older; more educated, received more extension services, more access to agricultural input and financial credit, participated more in farmer groups and in turn used more inorganic fertilizer and improved varieties of maize than their counterparts in Uganda. Respondents in Uganda travelled shorter distances to nearest input and output markets compared to Kenya counterparts. Main constraints to using inorganic fertilizer were the cost, transport and availability. However, for the use of CA, inadequate information was cited as the main constraint. Model results show that distance to input and output markets and use of improved maize varieties, country dummy and agro-ecology were significant factors for all the levels of adoption (*partial CA1 & CA2 full CA and total package).* Policy recommendations include the use of market-based approaches in bringing services nearer to farmers, the use of one-stop shops and farmer group mobilization.

Key words: Soil fertility management, Inorganic fertilizer, Conservation Agriculture, Ordered probit model

CHAPTER I

INTRODUCTION

1.0 Background

About one billion people are hungry in the world with 1/3 of children under 5 being stunted (Conway, 2012). Since the global food crisis began in 2008, a consensus has emerged regarding the need to increase agricultural production as the era of cheap food appears to be over (Minten *et al*. 2013). Some advocates go so far as to argue that the planet is running out of food because of under-investments in the agricultural sector. This issue is especially pertinent to Sub-Saharan Africa (SSA) where there is still a perceived potential for substantial agricultural productivity growth.

With growing population, shrinking farm sizes, and rapidly degrading soil, increasing crop yields sustainably appears to be the only way out of the chronic decline in food availability in SSA, (Paarlberg, 2010; Sanchez *et al*. 2009). This realization has triggered renewed attention to enhancing agricultural productivity growth in Africa since the early 2000s (Rashid *et al.* 2013). At least a doubling of agricultural yields is required over the coming decades (SEI, 2005) in economies where a majority of the populations depend on smallholder rain fed farming for their livelihoods. Improper agronomic practices have led to enhanced soil erosion, estimated in the order of 5-10t/ha/yr. (Shepherd *et al.* 2000). A major challenge is to reverse trends of soil fertility depletion and soil desiccation given that approximately 65% of agricultural land in SSA is subject to degradation (UNEP/ISRIC, 1991; GEF, 2003).

The conventional wisdom is that the most promising way to increase agricultural production in Africa is through widespread adoption of modern inputs such as chemical fertilizers and improved seed, as the adoption of these new technologies remains lower in Africa compared to the rest of the world (World Bank, 2008). Many of the farming systems in the region are far from their productive potential while accelerated economic growth in Africa now offers demand-side opportunities for agriculture (Montpellier Panel Report, 2013). To sustainably increase crop productivity, increased investments in nutrient additions to the soil are essential and globally agreed upon (Mapila *et al.* 2012). Agricultural productivity growth can be achieved through different means including the use of fertilizers (both organic and inorganic) and Conservation Agriculture (CA), which includes mulching, cover cropping and minimum/no tillage, among other options.

Numerous studies show that substantial agricultural productivity gains can be achieved in SSA by increasing the use of fertilizer and the efficiency of its utilization (Ersado *et al*. 2004; Tomich *et al*. 1995; Maiangwa, 2007). Experiences outside Africa also highlight fertilizer's key role in boosting agricultural productivity. Fertilizer was an integral part of the technological trinity; improved seed, irrigation, and fertilizer responsible for bringing about the green revolution in Latin America and Asia, and it contributed as much as 50 percent of crop yield growth in these regions (Mujeri *et al*. 2012; Duflo *et al.* 2003; Bumb & Baanante, 1996). This is the scenario where good seed, fertilizer and agronomic practices are adopted by the farmer.

However, despite the growing evidence, fertilizer application rates in SSA are still at around 10 kg/Ha whereas it has reached 222 kg/Ha in Asia, 160 kg/Ha in Oceania and 138 kg/Ha in South

America (Liverpool-Tasie *et al.* 2010). Even when compared with countries and crops in similar agro-ecological zones, fertilizer use intensity is much lower in SSA than in other developing regions and thus, crop yields are correspondingly lower (Liverpool-Tasie *et al.* 2010).
Although inorganic fertilizer use offers an option for increasing agricultural productivity, it does not constitute the whole solution. It is essential that complementary technologies are provided that will enhance rural incomes and achieve food security (Barrett, 2008; Wilchens, 2006; Crawford *et al*. 2005). These technology options include increased addition of organic matter, improved seed, soil and water management practices, expansion of irrigation and water resources and increased provision of extension services (Mapila *et al*. 2012).

Conservation Agriculture on the other hand, is being advocated for over conventional agriculture so as to enhance soil health and sustain long term crop productivity (Govaerts *et al*. 2009; Hobbs *et al*. 2008). Soil health has been summarized to involve increased organic matter, biological activity, soil structure and fertility (Shepherd *et al.* 2000). According to its promoters, the overall goal of CA is to make better use of agricultural resources through the integrated management of available soil, water and biological resources such that external inputs can be minimized (Garcı´a-Torres *et al*. 2003; FAO, 2001). CA revolves around three main principles: minimum soil disturbance; permanent soil cover, primarily by retaining crop residues as mulch; and crop rotation, especially with legumes (FAO, 2009). Proponents argue that the potential benefits of CA can be equally extended to Africa and Asia regions (FAO, 2009; Wall, 2007), largely dominated by smallholder farmers.

In practice, farmers have been found to not adopt all principles of CA due to various reasons such as limited access to inputs (herbicides, cover crop seeds), labor constraints, or insufficient resources to grow cash crops (Baudron *et al*. 2007; Shetto and Owenya, 2007; Kaumbutho and Kenzle, 2007). What farmers practice may therefore be quite different from the ‘ideal’ CA developed in on-station trials so that it is less certain what benefits are actually realized by farmers (Bolliger *et al*. 2006). Adoption of CA was, however, reported to be low mainly due to lack of training, poverty and land ownership issues (Kaumbutho and Kenzle, 2007).

1.2 Statement of the problem

Improving soil fertility management by smallholder farmers has been recognized as a major issue in reversing the declining trends in per capita food production in Africa; and a continued use of fertilizer has been an important factor in increasing crop productivity in many countries (Ade and Omiti, 2003). Fertilizer is one of the key inputs for increasing crop yields and its contribution to crop production is about 50-60 percent (Kafiluddin and Islam, 2008). In addition, CA is proposed as a panacea(solution) to agricultural problems in smallholder farming systems in the tropics (Hobbs et al. 2008), given the fact that these farmers are poor to afford buying fertilizer.

Although there has been some agricultural productivity growth in SSA during the past several decades, especially for cereals, current growth lags far behind that in other regions of the world and is well below what is required to meet food security and poverty reduction goals (AGRA, 2013). For example, studies in Western Kenya consistently reported that maize yields are lower than the expected yields based on research recommendations (Nambiro and Okoth, 2013), the annual maize yield in the region was 73% less than the potential yield (Salasya *et al*. 2007).

Sub-Saharan Africa has the greatest gaps between potential yields and actual yields for a number of crops, particularly maize and rice (Licker *et al.* 2010).

About four million households in Uganda survive on farming; which however, is characterized by nutrient mining. A study in 12 agro-ecological zones of Uganda found annual plot level nutrient depletion to be 97 kg of N, 31 kg of P, and 90 kg of K (Nkonya *et al*. 2008). To maintain agricultural yields, there is a need to replace the lost nutrients from external sources as soils have been mined for a long time.

Generally, based on literature review, determinants of farmers choice of soil fertility management technologies including CA were estimated in other countries/ areas but less information is known regarding the same subject in the study area and amongst smallholder farmers in Uganda and Kenya. Several studies in Uganda (for example; Okoboi, and Barungi, 2012; Kasule, 2009; Namazzi, 2008; and Kato, 2000), others in Kenya (for example; Nambiro, and Okoth, 2013; Ariga and Jayne, 2010; Kipsat, 2002), have been carried out to determine the factors affecting the use of inorganic fertilizers with little or no attention to CA practices. Therefore, this study is addressing the knowledge gap and determining factors influencing the choice of a combined use of both inorganic fertilizer and CA practices as soil fertility improving technologies to achieve food security in maize-based production systems.

1.3 Research objectives

The main objective of this study was to assess factors affecting the combined adoption of integrated soil fertility enhancing technologies in maize-based production systems in Eastern Uganda and Western Kenya.

Specific objectives were:

- To characterize users and non-users of fertilizer and CA in the maize-based production systems
- To identify drivers for the adoption of CA practices in the maize-based production systems
- To study determinants of choice of soil fertility management technological package among smallholder farmers in Eastern Uganda and Western Kenya

1.4 Hypotheses

Testable hypothesis in this study included the following;

1. Age and sex have significant effects on the choice of soil improvement package.
2. Maize variety planted significantly influence the choice to use CA practices.
3. Membership to farmer groups/associations significantly influence soil fertility improvement technologies adopted

1.5 Justification and scope of the study

One of the challenges of SSA governments is to modernize agriculture and achieve the objective of attaining food security and orienting producers towards market oriented production (commercialization). Modernizing agriculture is perceived to lead to increased farm productivity, increased farm yields and farm incomes.

For a realization of an African green revolution which is one of the main goals for AGRA, there is need for intensification of agriculture (increasing crop yields per unit of land through the use of improved farm technologies) and greater diversification into higher-valued crops (AGRA, 2013). Both of these strategies will doubtlessly require, among other things, increased use of fertilizers and sustainable CA practices as a package. Yet despite the crucial role of these technologies in raising agricultural productivity and rural incomes, their use and adoption is still limited in SSA.

A number of studies have been carried out on fertilizer use for maize production in Uganda and Kenya but there has not been a comprehensive analysis and comparison in Uganda and Kenya on the integrated usage of both inorganic fertilizer and CA. This study, seeks to inform policy makers and guide decision making on policies to enhance agricultural productivity growth and development by enabling smallholder farmers to choose the correct combination of soil improvement technologies.

Empirical evidence from this study will contribute to the achievement of the second Sustainable Development Goal (SDG) of ending hunger, achieving food security, improving nutrition and promoting sustainable agriculture (SDG toolkit, 2015). This is also consistent with AGRA’S goal of reducing food insecurity by 50% in at least 20 countries by 2020 (AGRA 2013). Besides, the study results will help contribute to the body of knowledge in soil improvement technologies to assist governments and Non-Government bodies to improve crop productivity and find solutions to other technical problems in smallholder agriculture in Eastern Africa.

1.6 Organization of the thesis

The rest of the thesis is organized as follows; chapter one gives an overview of the literature related to fertilizer input and CA use, objectives of the study and hypothesis. Chapter two reviews literature related to the study.

Chapter three presents the data and analytical methods used to analyze the data; results are presented and discussed in Chapter four including both descriptive and econometric results generated in STATA computer software packages and discussion of the results. And finally chapter five gives a summary of the study, conclusions and recommendations that policy makers, development partners and well-wishers can use to improve smallholder farming systems in the study area.

CHAPTER II

LITERATURE REVIEW

This chapter presents a review of literature from a number of studies relevant to this study and elaborates on the theoretical basis for the study. The section provides available literature on maize production and marketing, fertilizer consumption trends, CA practices in SSA and the factors that influence inorganic fertilizer and CA use in SSA.

2.0 Maize production in Uganda and Kenya

Maize (*Zea mays*) is an important food staple in both Uganda and Kenya. The first constraint in maize production is low soil fertility (Vanlauwe *et al*. 2010). In Kenya, almost 3.5 million farmers are engaged in maize production, where smallholder and large scale farmers account for 75 % and 25 % respectively of the total maize production (Tegemeo, 2013). Apart from inorganic fertilizer use, other soil fertility improvement practices promoted in Western Kenya are intercropping with leguminous plants and improved fallow rotations (Ehui and Pender 2005). While intercropping of maize and beans or groundnuts is common, farmers are reluctant to give up crop production in a field even for one season of improved fallow, due to land scarcity, even when total production over two seasons would significantly increase (Ehui and Pender 2005). Kenya average maize yields is estimated at 1.8 t/hectare compared to potential yield of over 6 t/hectares (FAOSTAT,
2010).

2.1 The case for inorganic fertilizer use in SSA

Within each country, fertilizer application has varied widely based on crop type, farm size, climate, and irrigation availability (FAO, 2006). For instance, fertilizer application throughout

SSA mainly concentrated on maize (26%) and sorghum (17%). Oil crops, such as groundnuts and cotton, which play major role as cash crops for smallholder farmers, also received significant amounts of fertilizer (Dittoh *et al.* 2013). Fertilizer proponents argue that there is need for substantial increases in the use of appropriate inorganic fertilizers, as they offer the most effective means of increasing crop productivity, especially in the short term (FAO, 2007; Wilchens, 2006; IFPRI, 2003; Weight & Kelly, 1998).

The green revolution led to increased incomes by increasing returns to land, and as a result between 1970 and 1995 real per capita income in many Asian countries almost doubled. In southern Africa, substantial accomplishments have also been made (AGRA, 2009). There have been tremendous improvements in farm incomes arising from programs that work towards improving seed systems, soil fertility, farmer organization and the functioning of markets (AGRA, 2009).

However, the adoption of modern inputs such as chemical fertilizer remains low in Africa compared to the rest of the world (World Bank, 2008). The reasons for low adoption include farmer's perceived profitability and motivation. Duflo *et al.* (2008, 2010) have shown that while modern fertilizer use in Kenya is highly profitable (a 70 percent return on an annualized basis), farmers' uptake of modern inputs has been limited due to procrastination issues. Interestingly, they also show some success with nudging practices (Duflo *et al.* 2010). To incentivize farmers to adopt, some advocates have suggested and some governments have used large subsidies to reduce market prices of modern inputs (Sachs 2004; Denning *et al.* 2009).

Others scholars argue that the low adoption of modern inputs is due to the lack of familiarity on the part of farmers with the new technologies. Researchers have studied institutional designs for stimulating changes in agricultural practices, the role that extension agents can play, and the type of extension systems that work best in leading to the sustainable adoption of modern inputs (Birner *et al*. 2009; Feder *et al.* 1985). The jury is still out on what the appropriate interventions may be. For example, although Davis *et al*. (2012) find that farmer field schools have a large impact on agricultural production in East Africa, Feder *et al*. (2004) are much more critical of them.

Increased use of fertilizers is expected to lead to higher economic growth and poverty reduction through increased agricultural productivity and output (Dethier and Effenberger, 2011). This is particularly more evident in SSA where agriculture is the primary sector and source of livelihood to the majority of the population (World Bank, 2008). Indeed, recent empirical evidence from Uganda (such as Senoga and Matovu, 2010) has demonstrated that increasing agricultural output and productivity leads to higher growth of the Gross Domestic Product (GDP) and accelerates poverty reduction. On the environmental front, agricultural intensification where a farmer gets more output from the same piece of land by using high yielding inputs including fertilizer, reduces forest cover loss and promotes biodiversity (Smaling *et al*. 2006). In Kenya the positive effect of fertilizer use has also been reported in other studies (Amaza *et al.* 2007; Ouma, 2011). In addition, adoption of inorganic fertilizer increases adoption of improved maize varieties (Doss and Morris, 2001)

2.2 Fertilizer consumption trends in East Africa

The total fertilizer consumption in East Africa (for example NPK fertilizer) remains at a low level: the 2010 annual consumption rates for Kenya, Uganda and Tanzania are 175,214, 13,746 and 86,533 tons respectively (AMITSA, 2011). Fertilizer use in Africa (4.3 million tons total in 2002, with 1.4 million tons for SSA) accounts for only three percent of world consumption, with SSA accounting for less than one percent (AMITSA, 2011). Contrary to conventional wisdom, fertilizer use in Africa has grown during recent decades (1970-2002), but at a slow average annual rate (2.3 percent overall and 3 percent in SSA). A substantial part of this growth resulted from supply- and subsidy-driven use in Nigeria during the 1970s and 1980s. While overall growth has been positive, the slow rate of annual growth during the 1990s (only 0.22 percent) compared to earlier periods (5.43 percent in the 1970s) has been a cause for concern, even though much of the slowing in growth was driven by subsidy removal in Nigeria. Also, the extremely slow growth in SSA compared to other developing regions of the world is worrisome.

During the 1960s and 1970s, growth in fertilizer use intensity in Africa kept pace with growth in other developing regions, but beginning in the 1980s it slowed sharply (Ariga *et al.* 2006). By the 1990s, fertilizer use per hectare actually declined in about one-half of all SSA countries. Nevertheless, there were some successes. For example, in Kenya most fertilizer use was already higher than in most other African countries, intensity increased by more than one-third during the 1990s (Ariga *et al.* 2006). It also rose in twelve other countries (including Uganda, Rwanda, Mozambique, Ethiopia, and Botswana), although most of these were starting from a much lower application rate than Kenya (Crawford *et al.* 2005).

The average intensity of fertilizer use throughout SSA is estimated to have been 8 kg/ha in 2002, representing only 8-10 percent of the application rates in other parts of the world. The number of nutrients consumed in the region is approximately 10 times the amount produced in the region and therefore, many SSA countries tend to be highly dependent on fertilizer importation (Hernandez & Torero, 2011).

2.3 The case for Conservation Agriculture

Conservation Agriculture is a set of cropping principles aiming at sustaining high crop yields with minimum negative consequences for the resource base – i.e. water, soil, and surrounding natural environment (Hobbs *et al.* 2008; Gowing and Palmer, 2008). It is defined as the simultaneous application of minimal soil disturbance, permanent soil cover through a mulch of crop residues or living plants, and crop rotations (www.fao.org/ca, 2014).

Conservation Agriculture has received increasing attention in SSA, as a means to increase food security and minimize environmental degradation, particularly in sub-humid and semi-arid areas that are characterized by frequent droughts and dry spells (Kassam *et al.* 2009). More specifically, CA enables early planting, as land preparation is simplified and can be carried out before the first effective rains (Haggblade and Tembo, 2003), which may result in more efficient use of rainfall, reducing the risk of crop failure when receiving below-average rainfall and stabilizing yields when rains are poorly distributed (Erenstein, 2002, 2003).

The yield levels of CA systems are comparable with and even higher than those under conventional intensive tillage systems, which means that CA does not lead to yield penalties. At the same time, CA complies with the generally acceptable ideas of ecological sustainability (Shaxson *et al*. 2008; Kassam *et al*. 2009, 2013, 2014)

A number of international organizations (FAO, CIRAD, CIMMYT, ICRISAT, The African Conservation Tillage Network-ACTN) actively promote CA with smallholder farmers in Africa (Kassam *et al.* 2009). Yet others have highlighted that mulching can be problematic for smallholders (Erenstein, 2002, 2003), that herbicides and fertilizers are often needed to realize the benefits of CA but are not readily available to smallholders (Gowing and Palmer, 2008), and that successful large-scale adoption of CA is rather rare among smallholders (Ekboir, 2003; Triomphe *et al*. 2007).

Smallholders are reluctant to adopt CA practices if they face increased demands for labor and inputs during the first years (Affholder *et al.* 2010). However, labor requirements are generally reduced by about 50% in the long run, which allows farmers to save on time, fuel and machinery costs (Satumino and Lander, 2002; Baker *et al*. 2007; Lindwell and Sontang, 2010; Crabtree, 2010). A recent review of the evidence from sub-Saharan African and South Asia finds that yield increases under CA are uncertain and are more likely to occur after a few years of implementation than immediately (Brouder & Gomez-Macpherson, 2014).

Corbeels *et al.* (2014) found that short-term yield responses to CA tend to be positive but variable, and that yield benefits of CA accumulate over time. Mkoga *et al.* (2010) found that CA plots have higher yield than conventional plots when rainfall is relatively low, but lower yield when rainfall is high. Mazvimavi *et al*. (2010) found that farmers in Zimbabwe who had practiced CA for at least five cropping seasons had a higher average maize yield in the 2009 harvest season. In eastern Uganda, CA was found to increase maize yields by over 1,000 kg/ha and reduce labor requirements by 11 to 19 family labor days per season (Bashaasha *et al*. 2013). The major attributes of CA include water conservation (Scopel *et al.* 2004), increased organic carbon in the surface soil (Dercon *et al*. 2010), reduction of erosion due to the maintenance of surface mulch (Schuller *et al*. 2007), saves on energy and mineral nitrogen use in farming thus reducing mineral gas emissions and enhances biological activity in soils (Farooq and Siddique, 2014). Birungi and Hassan (2007) report that 27.9% of farmers sampled throughout Uganda used traditional methods of enhancing soil fertility, such as mulching and cover cropping.

2.4 Factors influencing choice of soil fertility improvement technology

Adoption of soil-fertility improvement technology has been linked to a number of factors. These are broadly categorized into economic factors and non-economic factors. Economic factors mainly focus on price, costs and/or returns to factors of production while noneconomic factors include social, cultural, community, institutional and political factors. Few variables consistently explain why farmers adopt CA (Knowler & Bradshaw, 2007). Some variables explain adoption in specific studies. These include concern for environmental threats, the soil erosion rate and income. Others, such as level of education and steepness of slope, are frequently found to influence adoption. Some variables, such as farmer age and farm size, are positively correlated with adoption in some studies but negatively correlated in others. The promotion of CA thus should be tailored to individual locations rather than to people who fit a certain profile (Knowler & Bradshaw 2007).

2.4.1 Economic factors

Economic factors that influence fertilizer use among others include the price of fertilizer, price of other inputs that complement (for example, seed) or substitute fertilizer use, price of crop output, profit and opportunity costs associated with production and marketing risks. Empirical literature suggests that fertilizer use is sensitive to changes in its price as well as the price of crops to which it is applied (Griliches 1958; Roberts and Heady 1982; Ariga and Jayne 2010). In particular, demand for a particular type/brand of fertilizer (e.g. nitrogen) is derived demand, price elastic and influenced by the price of other types/brands of fertilizer (Acheampong and Dicks, 2012). The price and/or availability of other inputs that complement and enhance fertilizer productivity, for example, hybrid seed and irrigation, also play an important role in farmer's decision to use fertilizer. Similarly, the price and/or availability of other inputs that substitute a variety/brand of fertilizer as well influence its use (Acheampong and Dicks, 2012).

The wedge between the high price of fertilizer on the one hand and low price of output on the other, especially for farmers in SSA is one of the major factors that make them reluctant to use the input. Morris *et al.* (2007) observe that demand for fertilizer is often weak in Africa because incentives to use fertilizer are undermined by the low level and high variability of crop yields on the one hand and the high level of fertilizer prices relative to crop prices on the other. Smaling *et al*. (2006) indicate for example that farmers in Africa require 6 -11 kg of grain to purchase one kg of nitrogenous fertilizer compared with about 2- 3 kg of grain in Asia.

High fertilizer prices in SSA are mostly attributed to high transaction costs of fertilizer trade arising from high transportation costs, high interest rates and low volume of purchases (Gregory and Bumb, 2006). Lack of market information about the availability and cost of fertilizer and the inability of many farmers to raise the resources needed to purchase fertilizer in bulk is cited among other factors that make farmers pay more for fertilizer (Morris *et al.* 2007). Low farm-gate prices for crops on the other hand is mainly influenced by poor road infrastructure and lack of storage facilities as well as lack of market information (Torero and Chowdhury 2004; Morris *et al.* 2007).

2.4.2 Non-economic factors

Lanyintuo and Mekuria (2005) categorize non-economic factors that influence farmers' decisions to use agricultural improved inputs as: farmer characteristics, institutional factors and characteristics of the input. Farmer characteristics among others include sex, age, education, and household size while institutional factors include farm size, membership to association, access to information, access to credit, and access to infrastructure such as roads or storage. Characteristics of the factor input relate to the subjective attributes of the input as perceived by the farmer (Adesina and Zinnah 1993).

Sex plays an important role in farmer use of agricultural technologies. A recent study by Okoboi and Barungi (2012) and Nayenga (2008) indicate that use of agricultural inputs including inorganic fertilizer in Uganda, is more prevalent in male than female headed households. In Kenya, Karanja *et al.* (2010) also found differences in the proportion of men and women household heads in Nakuru's urban area using fertilizer though the result was not significant due to sample size. In Malawi where fertilizers are provided to farmers on subsidies irrespective of sex, no significant men/women differences have been observed with regard to use (Chirwa *et al*. 2011).

Lanyintuo and Mekuria (2005) argue for inclusion of sex in analysis of technology adoption by observing that extension services provision, which is important in use of improved inputs, is mainly conducted by men who are biased towards fellow men and yet women are the majority in African agriculture in particular small-scale agriculture. Additionally, inclusion of sex as one of the explanatory variables is important in the case of Uganda because women-headed households are relatively poor compared to male headed households (UBoS, 2010) and yet 72 percent of all employed women and 90 percent of all rural women work in agriculture (IFAD, 2000).

Studies that have examined the relationship between age and use of improved technologies in agricultural production have reported mixed results. Adesina and Baido-Forson (1995) reported a positive relationship between age and adoption of new sorghum and rice varieties in Burkina Faso and Guinea respectively. On the contrary, Kassie *et al.* (2010) found a negative relationship between age and use of compost manure and stubble tillage in Ethiopia.

In Nigeria, several authors (Akramov, 2009; Lawal and Oluyole, 2008; and Tabi *et al.* 2010) also reported a negative relationship between age and improved inputs use. Explanations offered for the mixed results regarding age and improved inputs use are that on one hand, young farmers may have lower income and wealth, limited access to credit and extension services, and face labor constraints, all of which may make them less prepared to adopt and use improved agricultural technologies than older farmers, hence age having a positive relationship with adoption. On the other hand, young farmers are sometimes more open to change and hence eager to try out new ways of doing things, thus a negative relationship between age and improved inputs use (Lanyintuo and Mekuria, 2005). Age is normally modeled both in its level (age) and quadratic form (age^2) for a better understanding.

The role of education in farmer use of agricultural technologies is widely discussed in literature. Educated farmers are believed to have higher ability to perceive, interpret and respond to new information about improved technologies than their counterparts with little or no education (Lanyintuo and Mekuria, 2005; Tabi *et al*. 2010). Relatively more educated farmers are more likely to access information and advice from extension workers, which influence their adoption and use of improved inputs. Moreover, education and the economic status of the farmer, which affects ability to buy and use improved inputs, are to a great extent positively correlated especially in developing countries such as Uganda (UBoS, 2010).

The ability of the farmer to actually buy the input is perhaps the most important characteristic, which hitherto is not well captured in the literature. According to Morris *et al*. (2007), even if farmers believe that fertilizer is profitable, they may be unable to purchase it if lack cash and/or cannot obtain credit. In agricultural households, the main sources of cash include earnings from salary/wage employment, sell of livestock, and trade. Besides, farm-household size and composition which has close links with labor supply as well as the income status of the household head, has both positive and negative implications on adoption of inputs. In case of labor intensive inputs such as production and use of organic fertilizer, availability of labor with minimum knowledge can encourage its use even in poor households (Mekuria, 2005).

On the other hand, if large households are disproportionately poor, then lower use of relatively expensive inputs such inorganic fertilizer is expected in households with large families. As such, the effect of family size and composition on agricultural technology adoption is not clear in adoption literature as both positive and negative relationships have been reported (Oluoch-Kosura *et al.* (2001).

The role of credit in financing farmer investments in improved technologies, particularly in developing countries where smallholder farmers are generally financially constrained cannot be overstated. Whereas most studies report a positive relationship between access to credit and use of improved technologies (Feder *et al.* 1985), a recent report by UBoS observes that access to credit in Uganda is a challenge (UBoS, 2010). An earlier study by Deininger and Okidi (2001) reported that capital constraints were a major obstacle to fertilizer use in Uganda.

Extension agents are some of the most important sources of agricultural information in many countries. Farmers' access to information on agricultural technologies through increased government investment in extension services is crucial in revealing the opportunities of using such technologies, thereby reducing the subjective uncertainty on one hand and fostering increased adoption on the other (Strauss *et al.* 1991; Lanyintuo and Mekuria, 2005). Indeed, a number of studies (Strauss *et al.* 1991; Deininger and Okidi, 2001; and Akromov, 2009), report a positive relationship between extension services access and use of improved technologies in general and fertilizer in particular. Ouma *et al*. (2014) reports a positive and significant association between extension visits and adoption of improved agricultural technologies.

Nonetheless, the provision of extension services is dominated by men who have little or no gender awareness training (Opio, 2003). According to Nambiro and Okoth (2013), the number of contacts a farmer had with an extension agent in a year also had a positive and significant influence on the use of inorganic fertilizer, reflecting the role played by access to information on adoption decision.

Availability of and easy access to infrastructures such as roads, storage and irrigation facilities are critical in agricultural production processes. Roads, for example, ease access to input and outputs market; while storage facilities help to maintain the quality of harvested crops and postpone immediate sale. A number of studies including Jansen *et al.* (1990) and Ransom *et al.* (2003) reported that availability of and access to such infrastructure increases the likelihood of use of improved technologies. In Bangladeshi, Ahmed and Hossain (1990) found that improved rural infrastructure tremendously increased the intensity of use of modern agricultural technologies including fertilizer, high yielding varieties and irrigation, in villages with developed infrastructure than in underdeveloped villages.

According to Morris *et al.* (2007), factors that influence the intensity of soil improvement technologies use depend on farmers' perceptions of the potential profitability of soil improvement technology use which in turn depend on the characteristics of the input, including productivity of (crop response to) fertilizer as well as the perceptions that farmers may hold against fertilizer. Vanlauwe and Giller (2006), for example, catalogue several myths surrounding soil nutrient balances, and organic and inorganic fertilizers use in SSA, which the authors note that potentially limit soil fertility management if not adequately demystified.

Farmers are also reluctant sometimes to use especially inorganic fertilizers and herbicides because of fake products on the market. For example, Ashour *et al.* (2015) found limited use of high-quality inputs, with only 9.7%, 33%, and 10.2% of the sampled households (N=2,378) using hybrid maize seed, glyphosate herbicide and inorganic fertilizer, respectively in the first cropping season of 2014. Among the few households that purchased any agricultural inputs, four out of five purchased them in retail shops which suggests a high risk of purchasing counterfeits.

Forty percent of households purchasing hybrid maize seed believed that all or most of the hybrid maize seed is either counterfeited or adulterated (Ashour *et al.* 2015). Yet another study by Bold *et al.* (2015) found low quality inputs to be rife in the local retail markets in Uganda; and the adoption of modern inputs purchased from these markets was found to be unprofitable. The low quality of inputs in the local market substantially reduces the economic returns to adoption of modern inputs.

From the foregoing literature, it is clear that both economic and non-economic factors influence farm-household decisions either positively or negatively with regard to use of agricultural technologies. The question pertinent to this study therefore is: which among these factors have a strong bearing on the likelihood of farmers in Eastern Uganda and Western Kenya to adopt an integrated inorganic fertilizer and CA technology package.

2.5 Methods for identifying adoption choice determinants

The majority of adoption studies have incorporated Maximum Likelihood Estimation (MLE) techniques. Among the more commonly used estimation techniques are Tobit, Logit and Probit. These models are more appropriate than Ordinary Least Squares (OLS) for analyzing the decision to use a new technology (Ouma *et al.* 2006). Many studies (Okoboi and Barungi, 2012; Omamo *et al.* 2002; Makokha *et al*. 2001; Ouma *et al*. 2006) have investigated the factors that influence farmer's decision to use a new technology using either Probit or Logit models.

In a study by Kipsat (2002), the probit model was rejected on grounds that it leads to inefficient estimators and that the estimated probabilities are not constrained to lie between the (0, 1); a range demanded by probability theory. A logistic regression, however, enables a researcher to predict a discrete outcome such as group membership, from a group of variables that may be continuous, discrete or dichotomous (Nzomoi *et al*. 2007). Evidence shows that economists prefer Probit whereas statisticians use the Logistic regression.

However, for this study an ordered probit model is chosen for analysis given the ordinal nature of the dependent variable; with the soil fertility improvement components examined including mulching, minimum tillage, crop rotation and inorganic fertilizer. The ordered logit/ probit have come into fairly wide use as a framework for analyzing such responses (Zavoina and McElvery, 1975). It is an alternative to the multinomial logit if we consider the household choices unambiguously ordered.

2.6 Empirical agricultural technology adoption studies

Teshome *et al*. (2015) studied household level determinants of Soil and Water Conservation (SWC) adoption in North-Western Ethiopian Highlands using ordered Probit model. The study examined the drivers of different stages of adoption of SWC technologies in Ethiopia based on a detailed farm survey among 298 households in three watersheds. The dependent variable had different outcomes showing different phases of adoption; dis-adoption/non-adoption (18.5%), initial adoption (30.5%), actual adoption (20.1%), and final adoption (30.9%). Model results show that farm labor, parcel size, ownership of tools, training in SWC, presence of SWC program, social capital (e.g., cooperation with adjacent farm owners), labor sharing scheme, and perception of erosion problem have a significant positive influence on actual and final adoption phases of SWC. In addition, the final adoption phase of SWC is positively associated with tenure security, cultivated land sizes, parcel slope, and perception on SWC profitability.

Gachango *et al.* (2015) examined factors for the adoption of voluntary water-pollution reduction technologies and water quality perception among Danish farmers using the ordered probit model. Using data from 267 farmers, and two ordered probit models on adoption and perception, adoption of these technologies was still low despite the introduction of a number of incentives to do so. The adoption of voluntary nutrients reduction technologies is significantly explained by the variables on farm slope, farmers' age, farmers' attitude to subsidies, farm size and farmers' awareness of existence of the constructed wetland funds. None of the personal and attitude variables are found to be significant in determining perceptions of water quality.

Damisa and Yohanna, (2007) used the ordered probit model to the study the role of women in farm management decision making process in Nigeria. Data was collected in 10 areas of decision making depending on importance for agricultural development. They discovered that the socio-economic characteristics of the women farmers' significantly affected their decision making in agriculture. Model results showed that the age group, education, wealth status and tenancy variables were significant factors on the level of women participation in farm management decision making.

CHAPTER III

METHODOLOGY

This chapter presents the model; theoretical and empirical, data and sources, study area, survey design and data collection methods employed for this research. The chapter also presents data analysis techniques and *a priori* expectations.

3.1 Theoretical and empirical model

3.1.1Theoretical model

The farmers' decision to adopt has been widely studied since the publication of Griliches (1958) pioneering work on the adoption of hybrid corn in the United States. The major body of the existing economic research on technology adoption has been concerned with the question of what determines the decision of a farmer to adopt or reject an innovation (Genius *et al*. 2006). However, there is a relative dearth of empirical research in addressing the choice of which soil-fertility improvement technology package to adopt. This is important given the increased need for sustainable land management in the face of shrinking per capita land, and the increasing awareness of the harmful effects of inorganic fertilizers on soil health.

Traditionally, inorganic fertilizer use and CA practices namely; mulching, minimum tillage and crop rotation have been treated and analyzed as mutually exclusive soil fertility management options yet in reality a number of farmers do practice them in a complementary manner. This research makes a contribution in terms of understanding this complementarity.

The ordered probit model was used to achieve objectives two and three of the study. Adoption choice in this research entailed ordered responses which were captured during a cross sectional household survey. Farmers have adopted or declined the use of particular soil improvement technologies, given differing resources, education, aims and utility preferences (Bogdan and Bilken, 2009). Maximum Likelihood Estimation (MLE) models are appropriate for such discrete scenarios.

Following Greene (2003), the ordered Probit model is built around a latent regression in the same manner as the binomial Probit model. For this study, respondents have their own choice of which soil improvement package to adopt which depend on certain measurable factors **x** and certain unobservable factors, ε, then,

$$y* = x'\beta + \varepsilon \quad (1)$$

As usual $y*$ is unobserved, what is observed is

$$y = 0 \quad \text{if} \quad y* \leq 0,$$

$$= 1 \text{ if } 0\mu 0 < y* \leq \mu_1,$$

$$= 2 \text{ if } \mu_1 < y* \leq \mu_2,$$

.

.

$$= J \text{ if } \mu_{j-1} \leq y*, \quad (2)$$

which is a form of censoring. The μ_s are unknown parameters to be estimated with $\boldsymbol{\beta}$. The ancillary parameters/threshold values vary with the individual respondents. Respondents with similar socioeconomic characteristics and communication behavior are expected to have similar ancillary parameters. This is because according to the central limit theorem the ancillary parameters are normally distributed (Chen *et al*. 2006; Maddala 1983). The error term, ε, is assumed to be normally distributed across observations, and the mean and variance of ε are normalized.

The probability of the respondents choosing a specific ranking can be expressed as (Chen *et al.* 2006, Greene, 1993);

$$Prob\ (y = 0|\ X) = \Phi(-x'\beta),$$
$$Prob(y = 1|\ X) = \Phi\left(\mu_1 - x'\beta\right) - (-x'\beta),$$
$$Prob\ (y = 2|\ X) = \Phi\left(\mu_2 - x'\beta\right) - \Phi(\mu_1 - x'\beta),$$
.
.
$$\text{Prob} y = J|\ X) = 1 - \Phi(\mu_{j-1} - x'\beta) \quad (3)$$

For all probabilities to be positive, we must have

$$0 < \mu_1 < \mu_2 \ldots\ldots.. < \mu_{j-1}$$

where Φ is the cumulative probability function of a standard normal distribution function. However, the marginal effects of the regressors **x** are not the coefficients, thus for the three probabilities above, marginal effects are usually calculated to determine how much each explanatory variable increases or decreases the likelihood of respondents in each of the 3 categories of the dependent variable;

$$\frac{\delta\ \text{Prob}\ (y{=}0|\ x)}{\delta\ x} = -\phi\left(x'\beta\right)\boldsymbol{\beta},$$
$$\frac{\delta\ \text{Prob}\ (y{=}1|\ x)}{\delta\ x} = \phi\ [\left(-x'\beta\right) - \phi\ \mu - x'\beta)]\ \boldsymbol{\beta},$$

$$\frac{\delta\ \text{Prob}\ (y{=}2|\ x)}{\delta\ x} = \phi\left(\mu - x'\beta\right)\boldsymbol{\beta}, \quad (4)$$

The marginal effects should sum to zero by cancelling one another out across the response categories.

3.1.2 Justification for use of ordered probit model for choice analysis

The ordered probit model has previously been used to measure adoption and diffusion of no-tillage practices in Southern Spain olive groves (Franco and Calatrava, 2008), it has also been used to analyze information acquisition and adoption of organic farming practices (Genius *et al*. 2006). It has also been used to determine the extent to which selected socioeconomic characteristics and communication behavior influenced adoption of maize in Kahramanmara’s province of Turkey (Boz and Akbay, 2005).

Wollni *et al*. (2010) also used the ordered probit to model CA, participation in organic markets and collective action in the Honduran hillsides. The results indicated that besides supply-oriented policy measures, such as the provision of technical assistance and extension, demand-related factors are likely to play an important role in sustainable soil management.

The ordered response models recognize the indexed nature of various response variables; in this application, the components of soil fertility improvement technologies are the ordered responses. Underlying the indexing in such models is a latent but continuous descriptor of the responses. The ordinal nature of the dependent variable motivates the use of an ordered probit model (Daykin and Moffatt, 2002; Greene, 2008).

In contrast to ordered response models, multinomial logit and probit models neglect the data's ordinality, require estimation of more parameters (in the case of three or more alternatives, thus reducing the degrees of freedom available for estimation), and are associated with undesirable properties, such as the Independence of Irrelevant Alternatives (IIA), in the case of a multinomial logit (Ben-Akiva and Lerman, 1985)) or lack of a closed-form likelihood (in the case of a multinomial probit (Greene, 2000). The ordered probit can be estimated via several commercially available software packages and is theoretically superior to most other models for the data analyzed in this work.

3.1.3 Empirical model

Regarding soil improvement technology adoption, farmers rarely adopt the total package. As observed by Giller *et al*. (2009), CA is considered to be a complex set of crop management practices whose adoption is believed to be incremental in nature. In this present study, three CA practices namely; mulching, minimum tillage and crop rotation practices and inorganic fertilizer use are being investigated. Farmers usually adopt one CA practice for example mulching, two or all the three CA practices and a few take up the total package including inorganic fertilizers.

For purposes of this analysis, we separate the total package into a number of categories: ***benchmark or base category*** (farmers who do not use any of the soil improvement management practices), ***partial CA1*** [farmer adopts any one of the three CA practices], ***partial CA2*** [farmer adopts any two of the CA practices], ***full CA*** [farmer adopts all the three CA practices; mulching, minimum tillage and crop rotation] and ***total package*** [when all three CA practices and inorganic fertilizer are adopted by the farmer]. There are possibilities of other combinations, for example, farmers adopting any one or two CA practices with fertilizer, however, these are not considered in this study.

Considering the fact that some farmers adopt various components of soil fertility improvement, adoption is categorized into four main components. Based on these categories and the fact that adopters had various factors influencing their choices, an ordered probit model was used to analyze the data. The empirical model that was estimated is specified as follows;

$$y_i^* = \boldsymbol{\beta_0} + \boldsymbol{\beta_1} AGE_i + \boldsymbol{\beta_2} Gender_i + \boldsymbol{\beta_3} EDU_i + \boldsymbol{\beta_4} HHS_i + \boldsymbol{\beta_5} INLAND_i + \boldsymbol{\beta_6} EXT_i + \boldsymbol{\beta_7} INCRDT_i + \boldsymbol{\beta_8} DIST_i + \boldsymbol{\beta_9} OFFINC_i + \boldsymbol{\beta_{10}} MEG_i + \boldsymbol{\beta_{11}} HRDLBR_i + \boldsymbol{\beta_{12}} MVP_i + \boldsymbol{\beta_{13}} Ctry\ dummy_i + \boldsymbol{\beta_{14}} DstrctAZ_i + \varepsilon_i$$

where;

y_i^* = unobserved soil fertility improvement technology

y_i = component of soil fertility improvement technology

$y_i = 0$ if $y^* \leq 0$, indicating did not take up any technology, the benchmark category

$y_i = 1$ if $0 \leq y^* < \mu_1$, indicating farmer used ***partial CA1*** practices (any of the three CA practices; mulching, minimum tillage or crop rotation)

$y_i = 2$ if $\mu_1 \leq$ y* $< \mu_2$, indicating the farmer used ***partial CA2*** (any two of the three CA practices)

$y_i = 3$ if $\mu_2 \leq y^*$, indicating the farmer adopted the ***full CA*** package (all the three CA practices)

$y_i = 4$ if $\mu 2 \leq$ y* $< \mu_2$, indicating the farmer adopted total package (***full CA*** and inorganic fertilizer)

β_1----β_{14}= Parameters to be estimated and ε_i= error terms

Table 3.1: Description of explanatory variables

Variable	Variable name	Description of the variable	Expected sign
X1	AGE	Age of the household head in complete years	-/+
X2	GENDER	Sex of household head, 1=male, 2= female	-/+
X3	FS	Size of the household	+/-
X4	EDU	continuous, completed years in school	+/-
X5	LAND	Total land owned by the household in acres	+/-
X6	EXTA	Access to agricultural extension agents, 1=yes, 0= no	+
X7	INCRDT	Access to input credit, 1=yes, 0=no	+
X8	DIST	Distance to input and output markets in km	-
X9	OFFINC	Household earns some income outside farm activities e.g salary from employment	+ +
X10	MEG	Membership to farmer associations/groups, 1=yes, 0=no	
X11	HRDLBR	Household hires labor for farm activities, 1=yes, 0= no	+
X12	MVP-IMP	Planted improved maize variety, 1= yes, 0=no	+/-
X13	CTRY	Country dummy, Uganda=0, Kenyan =1	+
X14	Agro-ecology	Agro-ecology dummy Tororo and Bungoma=0, Kapchorwa and Trans-Nzoia=1	+

Regression diagnostics were conducted to ensure that the model was correctly specified and in line with the assumptions of MLE.

3.2 Data and sources

3.2.1 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.

3.2.2 Survey design and data collection

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 (USA), 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-Nzioa 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. The second stage of sampling involved constructing a list of all households in each stratum, with help from local administrators. In total, 790 households were sampled, including 202 households from Tororo district, and 200, 188 and 200 households from Kapchorwa, Bungoma and Trans-Nzoia districts, respectively.

Structured questionnaires were used to collect data. They were administered through face-to-face interviews with household heads, or in their absence, other adult household members who were present. The 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 questionnaire, 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.

3.3 Data analysis

Primary data were entered and analyzed in STATA 11. Descriptive statistics in form of percentages, means and standard deviations were generated to identify socio-economic characteristics of farmers. Comparison of socio-economic characteristics across the region and districts was made using t-tests for continuous variables and percentages for categorical variables. To determine factors influencing the choice of soil fertility improvement technologies, an ordered probit model was used.

Table 3.2: Objectives, method of analysis and variables

Objectives	**Method of analysis**	**Variables used**
1. To characterize users and non-users of fertilizer and CA in the study area	t-tests, frequencies generated using STATA	Demographic and socio-economic characteristics and institutional factors
2. To identify drivers for the adoption of CA practices in the study area	Ordered probit model	Listed in table 3.1
3. To study determinants of choice of soil fertility management technological packages among smallholder farmers in the study area	Ordered probit model	Listed in table 3.1

CHAPTER IV

RESULTS AND DISCUSSION

4.0 Results and discussion

This chapter presents the findings of the research, their implications and interpretations. Related empirical studies are also highlighted in this section to further support findings or show a contrast between study results and those of past studies. Descriptive statistics and model marginal effect estimates are also presented and discussed in this section.

4.1 General descriptive statistics

In the traditional agricultural production system practiced by food crop farmers in SSA, the farmers' socio-economic characteristics are important factors that could affect the use or non-use of soil fertility improvement technologies on the farm. The summary description of farmers by their socio-economic characteristics and adoption pattern are provided in Tables 4.1 and 4.2 respectively.

Respondents in Kenya were on average older (49 years) than respondents in Uganda (45 years) and the difference was significant (P=0.000), the combined mean age being 47 years. Generally, respondents in the study area were on average 47 years and actively involved in farming. The mean family size (FS) in Kenya was comparatively larger (with 8 members) as compared to Uganda with 7 members. The average number of household members actively involved in crop production (FMLBR) was slightly higher for Uganda. This shows that almost half of the family household members worked on the farm in both countries. When more labor is available for crop production, farmers are more likely to use and adopt soil fertility technologies and also provide labor to other activities because of abundant supply of labor.

Table 4.1: Summary statistics by country

Variable	Unit	Mean			Significance
		Uganda (n=388)	Kenya (n=402)	Total (N= 790)	
AGE	Years	44.79 (14.92)	49.16 (12.21)	46.94 (13.82)	0.000***
HHS	number	7.25 (3.14)	7.55 (3.39)	7.39 (3.27)	0.169
LAND	acres	3.08 (2.09)	3.82 (2.16)	3.39 (2.13)	0.000***
FMLBR	number	3.50 (2.49)	3.23 (2.12)	3.44 (2.65)	0.000***
EXP	years	2.3 (0.9)	2.40 (0.9)	2.4 (0.9)	0.598
DIST	Km	1.17 (1.0)	3.33 (2.18)	2.23 (2.19)	0.000***
			Percentages		
EDU	1=yes, 0=no	28.1	57.22	42.66	0.000***
EXT	1=yes, 0=no	20.4	26.29	23.29	0.050**
INCREDIT	1=yes, 0=no	11.19	39.95	25.32	0.000***
MEG	1=yes, 0=no	32.84	61.60	46.96	0.000***
HRDLBR	1=yes.0=no	41.54	56.70	48.99	0.000***
USECA	1=yes, 0=no	57.71	56.96	57.34	0.008**
MVP-IMP	1=yes, 0=no	58.46	90.21	77.47	0.000***

*Figures in parentheses are standard deviations, *, **, ***Represents significance at 10% 5% and 1% levels respectively, Source: Survey data 2010*

Farmers in Kenya were more educated than those in Uganda; education influences adoption of agricultural technologies for example inorganic fertilizer and herbicide use. Educated farmers are believed to have higher ability to perceive, interpret and respond to new information about improved technologies than their counterparts with little or no education. The education level of the spouse is also very crucial in adoption of agricultural inputs given that most females carry out the weeding, planting and application of agricultural inputs.

Access to extension services (EXT) is higher for Kenyan respondents, which reflects an advantage over their Ugandan cohorts in terms access to information on adoption decision. Farmers' access to information on agricultural technologies through increased government investment in extension services is crucial in revealing the opportunities of adopting agricultural technologies. Farming experience is equally the same for the two groups though not significant.

Access to financial credit (CRDT) is very crucial for access to the most crucial agricultural inputs for example inorganic fertilizer and farm implements. Forty three percent of the respondents in Western Kenya reported having access to credit compared to only 29% in Eastern Uganda. In addition, access to input credit (INCRDT) is lower in Uganda (11%) compared to western Kenya (40%). Input credit in form of agricultural inputs like inorganic fertilizer, seed, farm implements and machinery are also crucial components in increasing agricultural productivity and attaining food security.

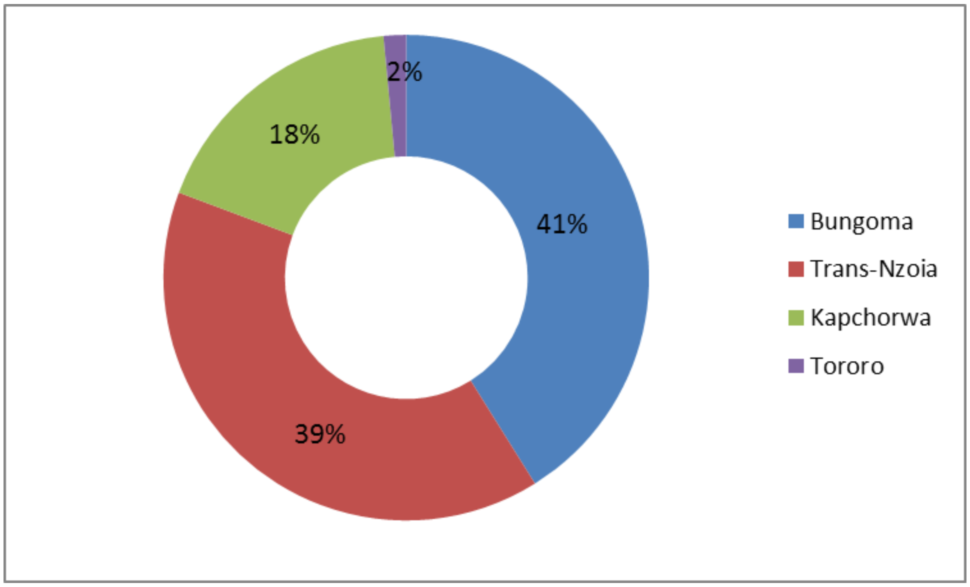
Though 87% of farmers in Eastern Uganda compared to 67% in Western Kenya reported crop production (CRP PDN) as their main occupation, they are using less hired labor (HRDLBR) compared to their counterparts in Western Kenya. Hired labor is important in the adoption of some of the technologies especially CA because they are labor intensive. Given the smaller number of family members actively engaged in farming, household heads find themselves almost engaged in farming as their main occupation.

Use of inorganic fertilizer (INOFERT) is more prevalent in Western Kenya at 81% compared to Eastern Uganda at 19%. This is attributed to the favorable policy environment by the Government of Kenya which recognizes inorganic fertilizer as the most important input for improving soil fertility (Nambiro and Okoth, 2013). A similar argument was echoed by the June 2006 International Fertilizer Summit which resolved that soil nutrients from both organic and inorganic sources are strategic inputs for raising agricultural productivity in Africa, but emphasized increased use of mineral fertilizers because of low levels of soil nutrients in Africa (IFDC, 2006). This goes hand in hand with use of improved maize varieties to achieve better yields. Ninety percent of farmers in Kenya reported the use of improved maize varieties (MVP-IMP) compared to only 58% in Uganda. However, the use of CA practices (USECA) was about the same in both countries at 58% in Uganda and 57% in Kenya. The use of CA is very important because modern inputs like fertilizer are still very expensive for the smallholder farmers in SSA.

4. 2 Comparison of soil fertility improvement technology adopters in Kenya and Uganda

4.2.1 Fertilizer use by district

As noted from Table 4.1, over 80 percent of the respondents in Kenya used inorganic fertilizer compared to 19% respondents in Uganda. Figure 1 shows a comparison of fertilizer use by district. Tororo district barely had any fertilizer users (2%) compared to Kapchorwa with 18%. The reasons for very low use of fertilizer in Uganda are the high transportation and marketing costs due to the fact that it is landlocked and depends on Kenya to get fertilizer, in addition to having poor road infrastructure. The two districts in Kenya show a high proportion for fertilizer use due to the fact that Kenya historically use more fertilizer due to the supportive policies that have existed long before compared to Uganda (Waithaka *et al*. 2007).



Source: survey data 2010

Figure 1: Proportion of inorganic fertilizer use by district

In addition, Kenya's nearness to Mombasa port facilitates a steady flow of imports at a lower price than for Uganda. According to Nambiro and Okoth (2013), inorganic fertilizer was used in maize production by approximately 70% of the households in Western Kenya, which is consistent with the results of this study.

4.2.2 Sources of fertilizer used in the study area

Respondents who used fertilizer both in Uganda and Kenya reported six main sources of fertilizer. As shown in Table 4.2, the main source was the local input dealers at 44%. Local input dealers play a very crucial role in bringing fertilizer to users. This is attributed to liberalization of the market and a subsequent increase in the number of agro input dealers in the study region. Farmer's knowledge of various aspects of fertilizer usage is very essential in improving crop yield. For example in Kenya, Freeman and Omiti (2003) concluded that market reform has stimulated fertilizer use by smallholder farmers in Kenya, mainly by improving farmers' access to inputs through the expansion of private retail networks. In addition, input dealers play an extension role by providing and sharing agricultural knowledge, technologies, information and also linking the famer to other sectors in the economy (NASEP, 2007) thus promoting household food security and poverty reduction.

According to Makhoka *et al.* (2001), adopters of inorganic fertilizer obtained it from stockists (64.1%), the local market (23.1%), or the co-operative society (12.8%), which concurs with the study findings as shown in Table 4.2. Local markets (40.2%) are also very important sources of fertilizer especially when farmers gather for market days. Farmers also access fertilizer via extension agents (8%) for example Operation Wealth Creation (OWC)/NAADS in Uganda and other Non-governmental organizations in the study region.

Table 4.2: Sources of fertilizer in the study region

Source	**Frequency (n=393)**	**Percentage**
Input dealer	172	43.8
Local market	158	40.2
Extension/NAADS/ Govt	30	7.6
Farmer retained	12	3.1
NGO	9	2.3
Research organizations	6	1.5
From other farmers	6	1.4

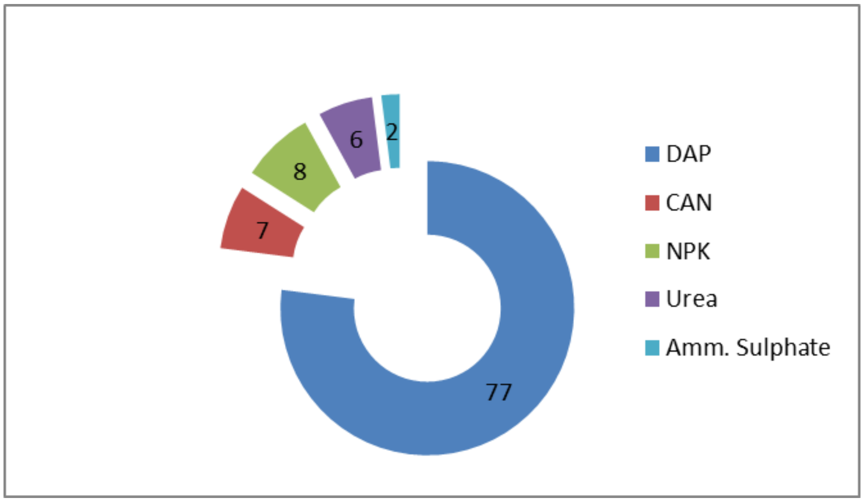
Source: Survey data 2010

Farmers also have a tendency of saving some fertilizer from previous seasons in case they fail to get resources for next season’s purchases, this accounts for 3% as shown in Table 4.2, in addition to getting from friends and neighbors to meet their season’s fertilizer needs.

4.2.3 Type of fertilizer used in the study region

There are various types of inorganic fertilizer that can be used in maize production. These include Diammonium Phosphate (DAP), Calcium Ammonium Nitrate (CAN), Nitrogen Phosphate, Potassium (NPK), UREA and Sulphate of Ammonia (SAN) among others. Farmers who used fertilizer reported the use of mostly DAP (77%) in their maize fields, followed by NPK (8%), CAN (7%) and Urea at 6% in that order as shown in Figure 2.

These results mirror those of Makokha *et al.* (2001) who found out that of the farmers who used inorganic fertilizer, 90.5% used DAP, 4.8% used NPK, and 4.8% used CAN in maize production. Meanwhile adopters of both manure and inorganic fertilizer used DAP (94%) and NPK (5.9%) in Kiambu district. Makokha *et al.* (2001) further noted the advantages of using fertilizers in general, given by adopters to include lower labor requirement (40.7%) and improved yields (37%) and overall 77.3% of respondents preferred inorganic fertilizer compared to manure.



Source: Survey results 2010

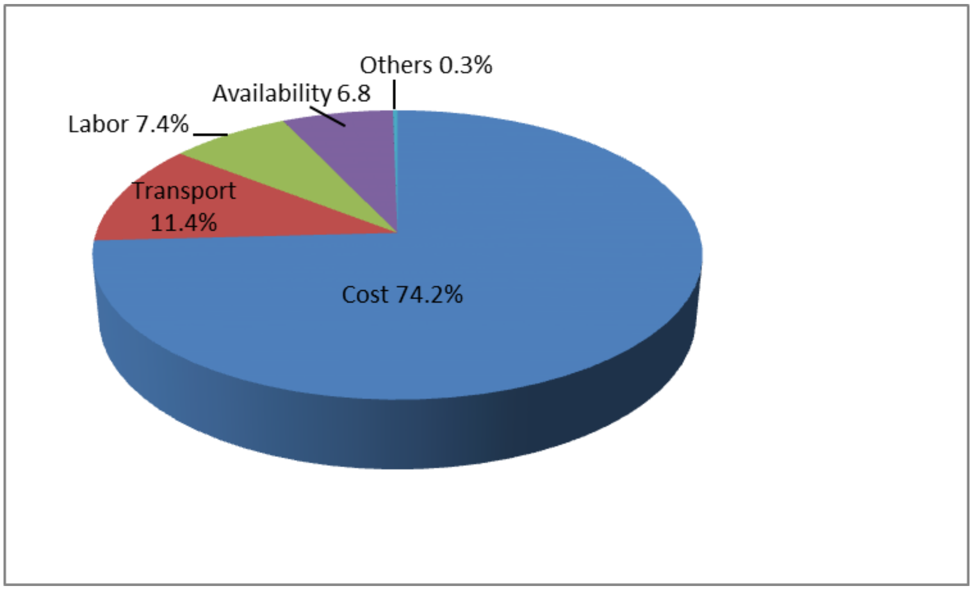
Figure 2: Proportion of fertilizer types used in the study region

As reported by Nambiro and Okoth (2013), the main type of mineral fertilizer used in maize production in all sub-locations was DAP (18:46:0) which was mainly applied at planting, followed by CAN and Urea (46:0:0) mainly for top dressing. According to the panel survey by Matsumoto and Yamano (2009), DAP is the most commonly used fertilizer in Uganda and Kenya. According to Waithaka *et al.* (2007), farmers' preference for DAP could be due to historic reasons. Diammonium Phosphate has been more readily available in Kenya than TSP or calcium phosphate.

4.2.4 Constraints to using inorganic fertilizer

Figure 3 shows that the main constraint to using fertilizer is its cost (74%), which corroborates Nambiro and Okoth (2013) who found that over 70% of the surveyed farmers admitted that if it were not for the high cost of the inorganic fertilizer, they would be willing to apply more fertilizer ha^{-1} since they were aware of its importance. Nambiro and Okoth (2013) reported that subsistence farmers have accepted and are willing to adopt inorganic fertilizers in their farming system; but are constrained by affordability and accessibility.

Fertilizer cost is followed by transportation costs which are very high in the region due to poor infrastructure, as reported by Guo *et al.* (2009). Distance itself is a major cause of high marketing costs for some countries, where farms are very far from the nearest port. The high transport costs are a result of low volume of fertilizer traded, especially in Uganda, so traders use smaller and less efficient trucks with higher per unit costs. In addition, Makhoka *et al.* (2001), reported the major constraint to fertilizer use include its high price (44.6%), lack of the right fertilizer package size (17.9%), and lack of credit (17.9%).



Source: Survey data 2010

Figure 3: Major constraints to using fertilizer in the study region

Availability of fertilizer is another constraint to increased use of inorganic fertilizer, often unavailable at the right time and place as shown in Figure 3. Factors limiting fertilizer supply include unfavorable business environment, poor transport and communication infrastructure (Dittoh *et al.* 2013). Moreover, the absence of fertilizers and high fertilizer prices cause farmers to resort to adulterated fertilizers that enter markets through unofficial channels or are intentionally or that are unintentionally distributed after re-bagging into smaller packages (Turuka and Kilasaru, 2002).

Other constraints to increased fertilizer use include labor costs, inadequate knowledge on the part of farmers about usage and fear of acquiring adulterated inorganic fertilizers, dependence on rainfall which has fluctuated in SSA over the years and low prices for maize crop output.

4.2.5 CA practices used in the study region

There are three main CA practices used in the study area, namely mulching, minimum tillage/ cover cropping and crop rotation, with crop rotation being the most commonly practice, followed by minimum tillage and then mulching. A higher proportion of respondents in Kenya reported use of mostly minimum tillage (26.9%) than their cohorts in Uganda (10.9%), while the prevalence of mulching in Kenya (17.3%) was not different from that of Uganda (17.2%). Crop rotation on the other hand was significantly more prevalent in Uganda (65.4%) than Kenya (38.1%) as shown in Table 4.3. This confirms that specific components of a CA system can thus be very different across broad locations and types of farmers (Erenstein *et al*. 2012; and Scopel *et al.* 2013).

Table 4.3: CA practices used by farmers in study region

Variables		**percent**			
		Total	**Uganda**	**Kenya**	**p-value**
CA practices	Minimum tillage	18.8	10.9	26.9	0.000
	Mulching	17.2	17.2	17.3	0.979
	Crop rotation	50.2	65.4	38.1	0.000

Source: Survey data 2010

Results of this study are consistent with Giller *et al. (*2009) who noted that crop rotation forms a central pillar of CA and that many approaches highlight the use of cereal-legume rotations. The most widely grown legumes in the farming systems of SSA are the grain legumes including groundnut (*Arachishypogaea L.*), cowpea (*Vignaunguiculata* (*L.) Walp*.) and common bean (*Phaseolus vulgaris L.*). These crops have the advantage over other legumes in that they provide a direct economic yield for food or for sale. Yet unless there is a ready market for the grain, farmers tend to grow grain legumes on only a small proportion of their land, and certainly not sufficient to provide a rotation across the farm.

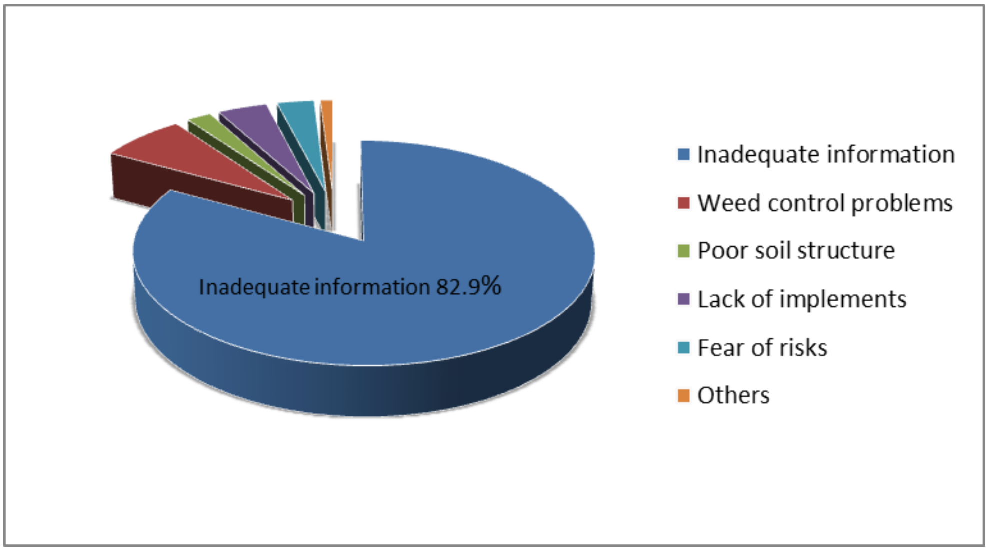
In addition, the nitrogen derived through Biological Nitrogen Fixation (BNF) (about 43 percent in *Mucuna)* contributes to the nitrogen requirements at moderate levels of output under favorable conditions (Giller *et al.* 1997). Other crops used as cover crops, either at planting or during fallow periods include *Sesbania sesban* (L), *Leucaena leucocephala* (cv Cunningham) and *Cajanus cajan* (Pigeon pea).

4.2.7 Reasons limiting CA practice in the study area

Given site specific production constraints that can limit adoption of CA practices, farmers gave a variety of reasons for not practicing CA even when they have heard about these practices from extension workers, fellow farmers, media and field days. Figure 4 shows that lack of information (83%) regarding the use of CA is still the major limiting factor in the study area; information concerning use, management and advantages that arise from the adoption of CA technologies is very minimal as such information has not been disseminated widely to farming communities. In addition, the low adoption of CA in parts of SSA is due to the fact that CA is often promoted as a package, without proper fine-tuning of technologies and adaptation to local circumstances (Tittonell *et al*. 2012).

Respondents also cited weed control problems in adoption of CA technologies at 7% as shown in Figure 4. For example, when practicing minimum tillage, perennial weeds infest and they can only be controlled using conventional means like use of herbicides. With evidence from one of the few long-term assessments of conservation tillage practices in SSA, Vogel (1995) found that

CA systems subjected to continuous maize production led to unacceptable infestation with perennial weeds within 6 years. This is limiting the adoption of these technologies since they cannot be used for large scale production for example staple crops like maize.



Source: Survey data 2010

Figure 4: Reasons for not practicing CA technologies in the study region

In addition, figure 4 also shows that poor soil structure (2%), lack of implements (4%), fear of risk (3%) and other problems (1%) were also cited by farmers as impediments to adoption of CA technologies. Implements needed for minimum tillage for example, the jab planter, ox or donkey-driven rippers are unavailable and inaccessible in the remote areas of East Africa. Smallholder farmers are also known to be risk-averse and late adopters of new technologies; they are never early adopters of technologies even when they are aware that the technologies lead to better yields and incomes.

4.3 Factors influencing choice of any technological package adopted

Ordered probit analysis was performed using STATA 11 software to establish the factors that affect choice of the soil fertility improvement technological package. The dependent variable was choice of combinations of soil fertility management practices among four alternatives namely ***partial CA1, partial CA2, full CA*** and ***total package***. ***Partial*** *CA*1 includes farmers who adopt any one of the three CA practices, ***partial CA2*** includes adopters of any two of the CA practices, ***full CA*** includes adopters of all the three CA practices and ***total package*** includes farmers who practice all the three CA practices and use inorganic fertilizer. The choice of explanatory variables was guided by their presumed theoretical importance to adoption of soil fertility improvement technologies. The coefficients of the model are not readily interpretable, so the interest is in the marginal effects of changes in the regressors on the response probabilities; these are presented in Table 4.4.

The χ^2 results show that the likelihood ratio statistics are highly significant (P=0.0000) suggesting that the model has strong explanatory power. A very low log likelihood ratio (-392.56) implies that the penalty is low for any variable specified in the model. LR χ^2 (14) = 77.39 imply that the null hypothesis that all coefficient are simultaneously zero is rejected.

As CA is considered to be a complex set of crop management practices, adoption is often believed to be incremental in nature (Giller *et al*. 2009). When farmers take on only some CA components this is generally referred to as partial uptake. Farmers may either gradually expand their area under CA, and/or adopt different CA components and inorganic fertilizer in a stepwise manner. Based on results in Table 4.4, factors that significantly affected partial adoption included total land owned by the farmer (acres) (INLAND), access to input credit (INCRDT), off-farm income (OFFINC), use of hired labor (OFFINC), maize varieties planted previous season (MVP), country dummy (CTRY) and district agro-ecology dummy.

All other variables held constant relative to not using any soil fertility improvement technology, farmers who own more land (INLAND) are positively associated with adoption of at least one of the CA practices (CA1) at 4.9%, or any combination of two of the CA practices (CA2) at 4.6%. This is because the availability and ownership of land is a pre-requisite for farming.

All other variables held constant relative to not using any soil fertility improvement technology, household size (HHS) was positively associated with adoption of the full CA technological package (*Full* CA). The results of the marginal effects suggest that bigger households that are actively involved in farming are 5% more likely to adopt all the three CA practices. The result suggests that a unit increase in household size is associated with a 5% higher probability of adopting full CA, compared to farmers who do not use any soil improvement technology.

Holding all other independent variables constant, number of visits by agricultural extension agents (EXT) to a farmer is positively associated with adoption of at least two CA practices by 7.8%, compared to farmers who do not use any soil improvement technology. This shows the role of agricultural extension agents in guiding and providing technical information to farmers; thus creating awareness and motivation for farmers to invest in CA practices. Acquisition of knowledge through access to extension services was found to play a significant role in improving land and soil management practices (Desta, 2012). Nkonya *et al*. (2005) found the use of inorganic fertilizer more likely where access to technical assistance programs was greater. Knowledge about the existence of soil management technologies enables the farmer to make optimum use of it. Therefore, farmers exhibit knowledge and skills on the correct use of soil technologies thus demanding greater quantity of fertilizer utilized (*Udoh* and Umoh, 2011).

Table 4.4: Model estimates of factors affecting choice of soil fertility improvement technologies: Dependent variable: Non-adopters (benchmark), *partial CA1, partial CA2, full CA and total package*

Variables	***Partial CA1***		***Partial CA2***		***Full* CA**		***Total* package**	
	δy/δx	p-value	δy/δx	p-value	δy/δx	p-value	δy/δx	p-value
AGE[a]	0.035	0.628	0.034	0.565	0.069	0.301	0.056	0.090*
GENDER	0.060	0.370	0.059	0.281	-0.003	0.860	0.032	0.283
EDU	-0.004	0.828	0.002	0.863	0.002	0.738	-0.011	0.169
HHS	0.004	0.580	0.007	0.212	0.046	0.046**	0.001	0.658
INLAND[a]	0.049	0.059*	0.046	0.031**	-0.001	0.980	-0.014	0.207
EXT	-0.026	0.570	0.001	0.978	0.078	0.064*	-0.015	0.456
INCRDT[a]	-0.063	0.178	0.069	0.088*	-0.021	0.301	0.433	0.026**
DIST[a]	-0.020	0.361	-0.022	0.224	0.095	0.088*	-0.003	0.728
OFFINC	0.749	0.196	0.063	0.076*	-0.007	0.787	0.055	0.082*
MEG	-0.005	0.855	-0.003	0.884	0.106	0.012**	-0.007	0.559
HRDLBR	0.137	0.002**	0.059	0.075*	0.244	0.000***	0.092	0.000***
MVP	0.223	0.000***	-0.012	0.805	1.689	0.000***	0.238	0.000***
CTRY	0.724	0.000***	0.474	0.000***	0.430	0.000***	0.092	0.061**
DISTRICT (agro-ecology)	0.313	0.000***	0.166	0.000***	0.174	0.000***	0.111	0.000***

Number of observations = 775
LR χ^2 (14) = 118.91
Prob> χ^2 = 0.0000
Log likelihood = -386.81
Pseudo R^2 = 0.1597

a = Logarithm, *, ** ,***Represents significance at 10% 5% and 1% levels respectively, in parenthesis are standard errors

Source: Survey data 2010

All other variables held constant relative to not using any soil fertility improvement technology, farmers who have access to input credit (INCRDT) were positively associated with adoption of at least two CA practices and the *total* technological package. The value of marginal effects suggest that farmers who had access to input credit were 6.9% and 43% more likely to use at least two CA practices and all the four technology practices respectively, compared to those who do not use any soil improvement technology. Input credit is useful for any agricultural venture to succeed; credit in form of seed, fertilizer, pesticides and herbicides facilitates farmers' adoption of new soil improvement technologies. Farmers are more likely to adopt if they have access to such credit. Akramov (2010) found farm households that had access to input credit to be 1.3 times more likely to use fertilizer than those who did not have access to input credit. This is consistent with a study by Makokha *et al*. (2001) where most of farmers who obtained credit from cooperatives used it for fertilizer purchases.

Holding all other variables constant, distance to input and output markets (DIST) is associated with higher adoption of the full CA technology package compared to farmers who do not use any soil improvement technology. Market access is vital for farmers not only for market search but also information sharing with colleagues which also facilitate adoption. Farmers with shorter distances to markets were 9.5% more likely to access the required inputs for example herbicides required for minimum tillage compared to those were located so far away from trading centers. Roads, for example, ease access to input and output markets, while storage facilities help to maintain the quality of harvested crops and postpone immediate sale. Ahmed and Hossain in Banghladeshi found that improved infrastructure tremendously increased the intensity of use of modern agricultural technologies including fertilizer, high yielding varieties and irrigation, in villages with developed infrastructure than the undeveloped villages. This is also consistent with Ranson *et al*. (2003) who reported that availability and access to such infrastructure is associated with use of improved soil technologies.

Holding other variables constant, age of the farmer is associated with a higher likelihood of adoption of all the four soil improvement technologies (*Total* package) by 5.6% compared to farmers who do not use any of the technologies. Younger farmers are believed to be late adopters because they have low income and wealth, limited access to credit and extension services, and face labor constraints compared to older farmers. All such challenges make younger farmers less prepared to adopt and use soil-fertility improvement technologies. These results mirror Adesina and Baido-Forson (1995) who reported a positive relationship between age and adoption of new sorghum and rice varieties in Burkina-Faso and Guinea, respectively.

All other variables held constant, off-farm income (OFFINC) is associated with a higher likelihood of adoption of any two CA practices and the *Total* package as shown in Table 4.4. The value of the marginal effects suggest that farmers who had other sources of income are likely to adopt at least any two of CA practices by 6.3% and *Total* package by 5.5% compared to non-adopters. Access to other sources of income for example through professional employment and being involved in other business ventures by farmers makes them more likely to invest in agriculture in terms of buying farm inputs and paying laborers.

In addition, all other variables held constant, membership to farmer groups/ associations was significant and positive, and thus associated with a higher likelihood of adopting CA practices compared to non-members/non-adopters. Farmers with group membership are 10.6% more likely to adopt *all* CA technologies (*Total* package) due to the benefits gained in such organizations for example information and experiences shared which positively influence adoption behavior of farmers. This mirrors results of Wollni *et al*. (2010), who found that households that participate in farmers' groups are 24% more likely than non-participants to apply more than one CA practice on their land. This observation could be because group members monitor each other and can suggest improvements in farm management, perform activities together, reduce costs of production or even bail out a fellow member.

All other variables held constant, the use of hired labor (HRDLBR) was significant and positive, thus associated with a higher likelihood of adoption of all the four soil technological packages. The values of marginal effects in Table 4.4 confirm that farmers who hired labor are 13.7%, 5.9%, 24% and 9% more likely to adopt at least one CA practice, at least two CA practices, *full* CA package and the *Total* soil-fertility package respectively. This shows the importance of investing in agriculture and being able to afford hired labor on the farm. This can be explained by the fact that labor inputs constitute one of the largest cost factors for CA and its use overcomes labor related constraints which in some cases hinders the use of agricultural technologies. According to Mugisha *et al.* (2012), farmers who used hired labor were expected to supplement family labor and cope with the labor requirements of new agricultural technologies particularly in labor intensive agricultural technologies for example CA. Likewise Ouma *et al.* (2002) found that hiring labor increased the amount of inorganic fertilizer used.

Holding other factors constant, the use of improved maize varieties is associated with a likelihood of adopting at least one CA by 22%, adoption of the *full* CA package by 168.9% and adoption of all the four practices by 23.8% when compared to farmers not using any soil fertility improvement technology. This is attributed to the responsiveness of the improved maize seed to improved soil fertility management technologies, making it an important catalyst for the adoption of these technologies (Morris and Byerlee, 1998). This is because improved seed is found to have a higher response to fertilizers and CA management practices compared to local seed. Therefore with the use of fertilizers, CA and improved seed, higher yields are attained compared to the use of local seed and poor agronomic practices. Ariga *et al.* (2008) found households who planted hybrid or open pollinated varieties of maize seed to have a 25-percentage point higher probability of purchasing fertilizer than those planting local seed maize. Farmers appeared to be aware of some synergy between these technologies. However, it is not clear why choice of maize variety decreases the likelihood of adopting any two of the CA practices.

All other variables held constant, living in Kenya is associated with a higher likelihood of adopting all the four soil improvement technological packages. The marginal effects values indicate that farmers in Kenya are more likely to adopt any one of the CA practices by 72%, adopt any two of the CA practices by 47%, all the three CA practices by 43% and the total package by 9.2% respectively than their cohorts in Uganda and those who are not using any practice. This shows that Kenya farmers are more availed with the necessary information and the favorable policy environment thus more willing to invest in agriculture compared to Uganda farmers.

All other variables held constant, agro-ecology (highland location) is associated with a higher likelihood of adopting the partial and total soil improvement technological package compared to not using any soil fertility technology. The marginal effect values indicate that farmers who were located in highland locations (Kapchorwa and Trans-Nzoia) are more likely to adopt any one of the CA practices by 31%, any two of the CA practices by 16.6%, all the three CA practices by 17% and all the four technological practices by 11.1% respectively when compared to farmers who are not using any soil improvement technology, and in low-land ecology. This shows the role of rainfall and favorable weather in smallholder farming in encouraging adoption of CA practices and inorganic fertilizer. This mirrors results in a study by Uaiene (2007) that indicated that households in areas with high rainfall and better soils were more likely to adopt new agricultural technologies, particularly improved seeds, than regions with poor and erratic rainfall and predominately sandy soils. The agro-ecological zone/farming system in terms of the soils and climate was found to significantly influence land management practices (Nkonya *et al.* 2005).

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.0 Summary, Conclusions and Recommendations

5.1 Summary and conclusions

About one billion people are hungry in the world with 1/3 of children under 5 being stunted. Food insecurity is especially rampant in SSA where there are growing populations, shrinking farm sizes and rapidly degrading soils. At least a doubling of agricultural yields is required over the coming decades especially in economies where populations depend on smallholder rain fed farming for their livelihoods. Although inorganic fertilizer use offers an option for increasing agricultural production, it does not provide the whole solution thus the need to complement it with Conservation Agricultural (CA) technologies to achieve food security.

It was on this basis that this study was undertaken to better understand the complementarity of CA and inorganic fertilizer use in Eastern Uganda and Western Kenya as soil fertility improvement technologies. The study used secondary data to establish socio-economic factors to characterize fertilizer and CA adopters and non-adopters in both regions. Descriptive statistics like frequencies, cross tabulations and independent samples test were generated to establish the characteristics. In the study, the established socio economic and demographic characteristics of farmers who used any of the soil improvement technology in Western Kenya and Eastern Uganda were age, education level of the household head, land size, household size, access to input credit, and hired labor, membership to farmer groups and availability of any off-farm sources of income. Descriptive statistics show that over 80% of farmers in Kenyan used inorganic fertilizer compared to 18% in Uganda. Kenya farmers also had greater access to input credit by 39.9%, extension services by 26.3%, higher membership to farmer groups by 61.6%, and planted improved varieties of maize by 90.2% compared to their cohorts in Uganda, with only 20% accessing extension services, 32.8% membership to farmer groups and 11.2% access to input credit. These results suggest greater efforts among Kenyan farmers than their cohorts in Uganda towards enhancing agricultural productivity and food security.

The results show that Bungoma (41%) and Trans-Nzoia (39%) in Kenya had the highest proportion of fertilizer users, Kapchorwa (18%) and Tororo (2%) followed in that order. For fertilizer users, DAP is commonly used at 77%, NPK at 8%, CAN at 7% and urea at 6%, while for those who used CA, crop rotation prevailed in both countries with an average of 50.2% adopters. In addition the main reasons limiting fertilizer use included high transport costs (11.4%) and the high cost of chemical fertilizers (74.2%). The main sources of fertilizer are input dealers (43.8%), local markets (40%) and extension or government personnel (7.6%). On the other hand, inadequate information (82.9%), weed control challenges, poor soil structure and lack of appropriate implements were major reasons for not using CA practices.

Factors associated with the adoption of soil fertility management technological packages were determined using the ordered probit model. Model results revealed that membership to farmer groups/ associations, planting of improved maize varieties and access to input credit were factors associated with the likelihood of adoption of both partial and full CA practices in Western Kenya and Eastern Uganda. Planting improved maize varieties, membership to farmer associations, distance to input and output markets and access to input credit were the factors positively associated with the use of the total soil fertility improvement technological package, which includes mulching, minimum tillage, crop rotation and chemical fertilizers.

Kenya respondents are fairly better than Uganda farmers in terms of adoption of the considered soil improvement technological package mainly because of the favorable policy environment by the Kenyan government.

5.3 Policy recommendations

Based on the study findings, the following are recommended;

Access to input credit is associated with a higher probability of use of recommended technologies; implying the need to improve the quality and coverage of agricultural input finance. This will not only look at financial institutions but also the infrastructure linking to these areas has to be improved to enable access, availability and affordability. Appropriate services or packages should also be provided for example animal and crop insurance given that agriculture is very risky and farmers always suffer losses from drought and floods. Also the development of farmer credit and input packages must be based on, and take into account, the socio-economic status of the farmers in terms of country and agro-ecological locations.

Membership in farmer groups was significantly associated with technology use. To increase the probability of using fertilizer and CA technologies by smallholder farmers, policy should support formation of farmer groups as a vehicle for farmers to easily access the tools needed to adopt CA and inorganic fertilizer packages. With such groups in place, farmers will have better access to both financial and input credit because most financial institutions prefer providing credit to farmers in groups than individual farmers in order to minimize administrative costs and defaulting. In addition, they gain from implement- hiring agencies for hiring implements for example: tractors jab planters and manure spreaders.

Distance to inputs and output markets or trading centers was associated with the use of soil fertility improvement technologies. Policies for scaling out of agro-input shops to bring private sector services nearer to farmers would encourage the use of agricultural inputs for example fertilizer-both organic and inorganic. The use of market-based approaches for example the one-stop shop strategy which has been adapted in Rwanda and community input shops which can be financed under community based organizations should also be encouraged. Such agents based nearer farmers would encourage the adoption of technologies most especially in Uganda where fertilizer use is still lowest.

There is need to design location-specific polices based on agro-ecology given highland areas are significantly different from the lowland areas. For example, irrigation should be suggested and provided for in the lowland areas that receive minimal rainfall. In addition, the Ugandan government should draw lessons from what the Kenyan government is doing in promoting the use of recommended soil fertility improvement technologies. There is also need to be a co-action between soil scientists and plant breeders to develop fertilizer recommendations which are adjusted to different agro-ecological zones.

5.4 Suggestion for future studies

One major area for further research should be Cost Benefit Analysis (CBA) to generate more scientific evidence especially on the economic viability and benefits of the various soil fertility management technological packages. There is need to assess the nutrient levels within each agro-ecological zone. Knowing the nutrient content in each zone can increase agricultural input use efficiency through recommending the right inputs for each zone.

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Appendix 1- Marginal effects after ordered probit

Ordered probit regression

Number of obs	=	775
LR chi2(14)	=	118.91
Prob > chi2	=	0.0000
Pseudo R2	=	0.1597

Log likelihood = -386.81463

CA2	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
lnage	-.0947608	.1956487	-0.48	0.628	-.4782252	.2887036
gender	-.1615443	.1802408	-0.90	0.370	-.5148097	.1917211
educ	.0102365	.0470396	0.22	0.828	-.0819595	.1024325
hh_siz	-.0100184	.0181017	-0.55	0.580	-.045497	.0254602
lnland	.1317826	.0697651	1.89	0.059	-.0049544	.2685197
extvst	.0716301	.1269315	0.56	0.573	-.1771511	.3204113
inpt_cr	.1729521	.1306523	1.32	0.186	-.0831217	.4290258
lntc	.0547809	.05991	0.91	0.361	-.0626406	.1722023
oc_sal	-.1971819	.1499737	-1.31	0.189	-.4911251	.0967612
hh_org	.0140117	.0765435	0.18	0.855	-.1360109	.1640343
hire_labor	.3668389	.1189334	3.08	0.002	.1337336	.5999441
mz_vard	.5730311	.1731956	3.31	0.001	.2335741	.9124882
ktry_cod	-1.944454	.2915095	-6.67	0.000	-2.515802	-1.373106
dst_code	.8394386	.1264922	6.64	0.000	.5915184	1.087359
/cut1	7.568839	1.347139			4.928496	10.20918
/cut2	9.783997	1.368471			7.101844	12.46615

Marginal effects after oprobit
y = Pr(CA2==0) (predict)
= .35504156

variable	dy/dx	Std. Err.	z	P>|z|	[95%	C.I.]	X
lnage	.0352802	.07283	0.48	0.628	-.107467	.178028	3.80301
gender	.0601441	.06711	0.90	0.370	-.071387	.191676	1.11509
educ	-.0038111	.01751	-0.22	0.828	-.038137	.030515	2.38113
hh_siz	.0037299	.00674	0.55	0.580	-.009479	.016939	7.50377
lnland	-.0490637	.02597	-1.89	0.059	-.099957	.001829	1.29937
extvst*	-.0264761	.04656	-0.57	0.570	-.117736	.064784	.241509
inpt_cr*	-.0634309	.04712	-1.35	0.178	-.155777	.028915	.292453
lntc	-.0203953	.0223	-0.91	0.361	-.064112	.023322	.338978
oc_sal*	.0749074	.0579	1.29	0.196	-.038572	.188387	.177358
hh_org	-.0052167	.0285	-0.18	0.855	-.061073	.05064	.779245
hire_l~r*	.1377363	.04477	-3.08	0.002	-.225492	-.04998	.603774
mz_vard*	.2227315	.06779	-3.29	0.001	-.355589	-.089874	.869811
ktry_cod	.7239346	.10838	6.68	0.000	.511514	.936356	1.56981
dst_code	□.3125292	.04706	-6.64	0.000	-.404766	-.220292	12.6642

(*) dy/dx is for discrete change of dummy variable from 0 to 1

□
= .85127048

variable	dy/dx	Std. Err.	z	P>|z|	[95%	C.I.]	X
Cropro~n*	.0552589	.0411	1.34	0.179	-.0253	.135818	.486792
lnage	.0336448	.05848	0.58	0.565	-.080969	.148259	3.80301
gender	.0594639	.05521	1.08	0.281	-.048748	.167676	1.11509
educ	.0024409	.01414	0.17	0.863	-.025267	.030149	2.38113
hh_siz	.0068193	.00547	1.25	0.212	-.003901	.01754	7.50377
lnland	-.0456886	.02118	-2.16	0.031	-.087203	-.004174	1.29937
extvst*	.0010085	.03669	0.03	0.978	-.070909	.072926	.241509
inpt_cr*	.069361	.0407	-1.70	0.088	-.149135	.010412	.292453
lntc	-.0223794	.01841	-1.22	0.224	-.058461	.013702	.338978
oc_sal*	.0626268	.03525	1.78	0.076	-.006464	.131718	.177358
hh_org	-.0032631	.02238	-0.15	0.884	-.047132	.040605	.779245
hire_l~r*	.0599364	.03366	-1.78	0.075	-.125906	.006034	.603774
mz_vard*	-.0121826	.04935	-0.25	0.805	-.108897	.084532	.869811
ktry_cod	.4739885	.10442	-4.54	0.000	-.678647	-.26933	1.56981
dst_code	.1659904	.04373	3.80	0.000	.080289	.251691	12.6642

(*) dy/dx is for discrete change of dummy variable from 0 to 1

```
. mfx

Marginal effects after oprobit
      y  = Pr(CA3==0) (predict)
         =  .30750542
```

variable	dy/dx	Std. Err.	z	P>|z|	[95%	C.I.]	X
lnage	.0689336	.06671	1.03	0.301	-.061806	.199673	3.81107
gender	.0542019	.0606	0.89	0.371	-.064577	.172981	1.11885
educ	-.0028005	.0159	-0.18	0.860	-.033966	.028365	2.40164
hh_siz	.0020748	.0062	0.33	0.738	-.010085	.014235	7.52664
lnland	-.0462749	.02315	-2.00	0.046	-.091648	-.000902	1.32153
extvst*	-.0010751	.04299	-0.03	0.980	-.085326	.083176	.245902
inpt_cr*	-.078233	.04219	-1.85	0.064	-.160929	.004463	.282787
lntc	-.0208897	.02018	-1.04	0.301	-.060439	.018659	.358822
oc_sal*	.0948032	.0555	1.71	0.088	-.01397	.203576	.17623
hh_org	-.006952	.02577	-0.27	0.787	-.057456	.043552	.743852
hire_l~r*	-.1055685	.04207	-2.51	0.012	-.188034	-.023103	.614754
mz_vard*	-.24444	.06551	-3.73	0.000	-.372843	-.116037	.862705
ktry_cod	.4300899	.09963	4.32	0.000	.234817	.625362	1.55328
dst_code	-.1736676	.0427	-4.07	0.000	-.257348	-.089987	12.6598

(*) dy/dx is for discrete change of dummy variable from 0 to 1

```
. mfx

Marginal effects after oprobit
      y  = Pr(TECHNOLOGY==0) (predict)
         =  .10174685
```

variable	dy/dx	Std. Err.	z	P>|z|	[95%	C.I.]	X
lnage	.0563601	.03328	1.69	0.090	-.008874	.121594	3.81107
gender	.0320172	.02985	1.07	0.283	-.026482	.090516	1.11885
educ	-.0108541	.00789	-1.38	0.169	-.026312	.004604	2.40164
hh_siz	.0013515	.00305	0.44	0.658	-.004631	.007334	7.52664
lnland	-.0144755	.01146	-1.26	0.207	-.036937	.007986	1.32153
extvst*	-.0149507	.02004	-0.75	0.456	-.054238	.024336	.245902
inpt_cr*	.0432576	.01938	-2.23	0.026	-.081249	-.005267	.282787
lntc	-.0034434	.00991	-0.35	0.728	-.022871	.015985	.358822
oc_sal*	.0551558	.03167	1.74	0.082	-.006915	.117227	.17623
hh_org	-.0074496	.01274	-0.58	0.559	-.032418	.017519	.743852
hire_l~r*	.0920649	.02442	-3.77	0.000	-.139929	-.044201	.614754
mz_vard*	.2381029	.05517	-4.32	0.000	-.346231	-.129974	.862705
ktry_cod	.0921618	.04924	1.87	0.061	-.004351	.188675	1.55328
dst_code	.110509	.02291	-4.82	0.000	-.155413	-.065605	12.6598

(*) dy/dx is for discrete change of dummy variable from 0 to 1