DETERMINANTS OF CROP AND LAND MANAGEMENT PRACTICES AND EFFECTS ON PRODUCTION RISKS UNDER VARIABLE CLIMATIC CONDITIONS IN EASTERN UGANDA

BY

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DECLARATION

I **Kansiime Monica Kagorora** declare that this thesis is my original work and has not been presented for the award of a degree in any other university or any other award.

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Supervisors' approval

We confirm that the work reported in this thesis was carried out by the candidate under our supervision and has been submitted with our approval as University supervisors.

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DEDICATION

To my husband Charles Owuor

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LIST OF ABBREVIATIONS AND ACRONYMS

AEZ	Agro-ecological Zone
ANOVA	Analysis of Variance
ASAL	Arid and Semi-Arid Land
ASARECA	Association for Strengthening Agricultural Research in Eastern and Central Africa
CAADP	Comprehensive Africa Agricultural Development Program
CGCM	Coupled General Circulation Model
CIMMYT	International Maize and Wheat Improvement Center
CV	Coefficient of Variation
ENSO	El Nino Southern Oscillation
FAO	Food and Agriculture Organization of the United Nations
FEWSNET	Famine Early Warning System Network
FGD	Focus Group Discussion
FGLS	Feasible Generalized Least Squares
GCM	General Circulation Models
GDP	Gross Domestic Product
GIS	Geographical Information System
GOU	Government of Uganda
GRID	Global Resource Information Database
IFOAM	International Federation of Organic Agriculture Movements
IFPRI	International Food Policy Research Institute
IPCC	Intergovernmental Panel on Climate Change
MDG	Millennium Development Goals
MNL	Multinomial Ligit model
MNP	Multinomial Probit model
NAADS	National Agricultural Advisory Services
NAPA	National Adaptation Programme of Action
OECD	Organization for Economic Cooperation and Development
OLS	Ordinary Least Squares
PCA	Principal Component Analysis

PCM	Parallel Climate Model
SD	Standard Deviation
SDA	Stochastic Dominance Analysis
SPSS	Statistical Program for Social Scientists
SSA	Sub-Saharan Africa
TLU	Total Livestock Unit
UBOS	Uganda Bureau of Statistics
UGX	Uganda Shillings
UNDP	United Nations Development Programme
UNISDR	United Nations International Strategy for Disaster Reduction
UNFCCC	United Nations Framework Convention on Climate Change
UNWD	Uganda National Water Development
USD	United States Dollar
VIF	Variance Inflation Factors
VOP	Value of Production
WDR	World Development Report

ABSTRACT

This study aimed to establish the effects of various crop and land management practices in reducing production risks under variable rainfall regimes in Eastern Uganda. An approach that integrated both rainfall variability and agricultural production was used, through yield functions. The following specific objectives were addressed based on knowledge and methodological gaps identified in literature review: i) establishing the extent and pattern of variation of annual and seasonal rainfall over a 40-year period, ii) determining factors that influence farmers' decisions to adopt management practices, iii) evaluating the effect of farmer-preferred management practices on the mean and variance of crop production in variable rainfall regimes, and iv) assessing farmers' perceptions of the effectiveness of the various management practices in mitigating against rainfall variability-induced production risks. Data for this study were obtained from 315 households, 9 focus group discussions and 23 key informants drawn from Mbale, Pallisa and Sironko districts. Study results showed an increasing trend in annual and ASON rainfall, and decreasing trend for MAMJ rainfall, with ASON exhibiting higher variations than MAMJ. Farmers employed a number of crop and land management practices strategically in response to perceive seasonal variations in climatic conditions, majorly influenced by their perception of rainfall adequacy. Most of the farmer-preferred management practices showed significant positive mean impacts on yield but had different risk-reducing effects on yield. Changing sowing dates and crop varieties, soil bunds, compost manure, cover crops, crop rotation and intercropping showed significant ($p \leq 0.05$) risk-reducing effects on yield. Their effects varied across agro-ecological zone, except soil bunds and compost manure whose use consistently exhibited both yield-increasing and risk-reducing effects across all the agro-ecologies. Study results have the following implications: First, the changing scenario in variability of rainfall will affect cropping patterns in the study districts thus requiring introduction of crops or varieties best suited to the patterns such as early maturing crops for MAMJ and more water tolerant crops for ASON. Second, the effectiveness of technologies in reducing production risks is location-specific thus the need to develop and disseminate location specific adaptation approaches, instead of blanket recommendations of similar adaptation measures across locations. Lastly, the need to focus not only on the technical aspects of technologies, but also the social dimensions such as perceptions of smallholder farmers of technology effectiveness, if adoption and retention of management practices is to be increased. Development and research organizations promoting adaptation options should involve farmers in technology evaluation so as to recommend the most feasible options given farmers' situations and local perceptions.

CHAPTER ONE

INTRODUCTION

1.1 Introduction

In this introductory chapter the background to the study is presented. The chapter also presents the statement of the problem, research questions, objectives and significance of the study. Also presented in this chapter is the study conceptual framework and operational definitions of terms and concepts used in this study.

1.2 Background of the Study

Agriculture is often characterized by high variability of production outcomes, that is, by production risk. Unlike most other entrepreneurs, agricultural producers cannot predict with certainty the amount of output their production process will yield, due to external factors such as weather, pests, and diseases. The agricultural sector in Sub Saharan Africa (SSA) continues to be confronted with multiple shocks and crises, threatening the endowment of the sector, and impeding efforts at attaining the targets of the millennium development goals (MDGs) and the core Comprehensive African Agriculture Development Programme (CAADP) pillars (Chuku and Okoye, 2009; World Development Report, 2009).

Rainfall variability influenced by large scale inter-seasonal and inter-annual variability resulting in frequent extreme weather events is among the major risk factors affecting agricultural production and food security in the sub region (Christensen *et al*., 2007; Easterling *et al*., 2007; Haile, 2005). This variability in rainfall has also been directly linked to the decline in economic activities in most SSA countries (Brown *et al*., 2010). Managing climate induced risk is important in agriculture not only for the direct impact that climate has on production, but also for the tendency of most farmers to be risk averse (Cabrera *et al*., 2009).

Ruttan (1996) indicates that impacts of climate variability on crop yields depend on both technological considerations and farmers' response to changing environmental conditions. Appropriate technologies and management practices present ample opportunities to bridge yield gaps, thereby increasing productivity as well as improving management of climate induced risk in agriculture (Goddard *et al*., 2001; Hansen, 2005). An increasing body of observations has emphasized the importance of managing climate risk to the optimization of crop/varietal choice especially in marginal areas (Di Falco *et al*., 2006; Kurukulasuriya and Mendelsohn, 2006a), and farm income (Jones *et al*., 2000; Kumar *et al*., 2004). Kassie *et al*. (2009) and Kato *et al*. (2009) demonstrated the importance of organic farming, and soil and water conservation techniques respectively as adaptation strategies to climate variability, in specific farming systems.

Based on this evidence of technological responses to changing climatic conditions, researchers and development agencies have relied on the ability of technology and management practices to provide farmers with needed strategic options for handling uncertainties related to future climate variability and change (Ausubel, 1995; Rosenberg, 1992). Several technological and management options have been developed and promoted including; soil and water conservation, new crop varieties, management adjustments, reforestation in fragile landscapes, down-scaled forecasting, and investment in low level irrigation infrastructure in watersheds (Goddard et al., 2001; Iglesias, 2005; Nzuma *et al.*, 2010).

There have also been efforts to generate and disseminate seasonal climate forecasts, particularly in developing countries (Goddard *et al.*, 2001). Availability of such information is useful to show direction of change in climate in order to inform farmers' decisions of what type of adaptation actions to take. However, for such information to effectively inform farming decisions, it should be precise (Thornton *et al.*, 2008).

Climate risks to agriculture vary according to location, type of enterprise, and the effectiveness of risk management (Iglesias *et al.*, 2006; Kassie *et al.*, 2009), thus the need for local level analyses that take into account both the biophysical and socio-economic characteristics of the farming system. However, a major challenge facing most agriculture-climate evaluations is the inclusion of both biophysical and socioeconomic aspects in the methodology (Iglesias and Quiroga, 2007). Most assessments of regional climate risk provide only probabilistic information on climate (Hansen and Indeje, 2004).

Some studies have used agricultural simulation models to capture these complex interactions. A range of methods for linking crop simulation models to seasonal climate forecast models have been advanced in Africa, Australia and USA (Cabrera *et al.*, 2009; Hansen & Indeje, 2004; Hansen *et al.*, 2006).

Multiple regression models have been developed to represent process-based yield responses to these environmental and management variables (for example, Cabas *et al.*, 2010; Di Falco *et al.*, 2006; Iglesias and Quiroga, 2007; Iglesias *et al.* 2000; Pender and Gebremedhin, 2006; Sileshi *et al.*, 2010), and could be used to estimate the risk associated with climate variability.

Local level analyses of rainfall in Uganda have focused on magnitudes of monthly and seasonal rainfall (FEWSNET, 2012; Kigobe *et al.*, 2011) and the occurrence of dry and wet spells (Bamanya, 2007; FEWSNET, 2012; Osbahr *et al.*, 2011), with limited focus on the variability of rainfall within the year and seasons. Yet crop production is sensitive not only to annual changes but also to the seasonal distribution of precipitation (Mukiibi, 2001; Ogallo *et al.*, 2000). There is no study so far in Uganda that has been conducted to understand the effects of various management practices promoted by government, research, extension and development agencies in reducing production risks under variable rainfall regimes.

As the role of technology continues to become more ingrained in strategic thinking of agricultural adaptation to climate variability and change (Smithers and Blay-Palmer, 2001), there is a need for systematic, location specific fine-tuning of the technologies to improve adoption by farmers through unravelling their effectiveness to risk reduction, constraints, opportunities and synergies. This will lead to better understanding of their risk effects on agricultural production and facilitate decisions on which technologies to promote and where in particular. There is also need to ensure more integrated approaches that include probabilistic information on the system at risk, thus boosting the relevance of results to risk management (Botterill and Wilhite 2005).

1.3 Statement of the Problem

Climate variability is among the major risk factors affecting agricultural production and food security of smallholder farm households in SSA. Variability of rainfall both within and between seasons makes it difficult for farmers to plan for agricultural activities, and frequently leads to crop failure. This uncertainty discourages beneficial investment decisions required from a wide range of agricultural stakeholders, when the returns to investment appear so unpredictable from season to season. In the context of sustainable development and adaptation, several technological and management options have been developed and disseminated intended to adapt agriculture to changing and variable climate. However, information is still lacking on their effect on production risks under variable rainfall in rain-fed farming systems. In addition, knowledge of within-season characteristics and magnitude of rainfall variability remain scarce in most parts of Africa with previous research emphasizing on annual averages. This study therefore used an integrated approach to assess the effect of various farmer-preferred technological and other responses employed by farming households in three distinct agro-ecological zones in Eastern Uganda in reducing climate-induced production risks.

1.4 Research Questions

The following questions guided this study:

i. Is there a discernible and significant pattern in the variation of annual and seasonal rainfall in Eastern Uganda that has affected crop production over the period 1971-2010?

ii. What factors influence farmers' decisions to adopt crop and land management practices for reducing production risks under rainfall variability in Eastern Uganda?

iii. What are the effects of farmer-preferred crop and land management practices on crop production risk under variable rainfall regimes?

iv. What is the perception of farmers regarding the success of different crop and land management practices in reducing rainfall variability-induced production risks?

1.5 Objectives of the Study

The general objective of the study was to contribute to development of evidence-based decision support system to determine the most effective production risk-reducing management practices given variation in rainfall and farm household socio-economic characteristics in Eastern Uganda. Specifically, the study aimed to:

1. Establish the extent and pattern of variation of annual and seasonal rainfall in Eastern Uganda that has affected crop production over the period 1971 to 2010;

2. Determine factors that influence farmers' decisions to adopt crop and land management practices for reducing rainfall variability-induced production risks;
3. Evaluate the effects of farmer-preferred crop and land management practices on the mean and variance of crop production in variable rainfall regimes; and
4. Assess farmers' perceptions of the effectiveness of different crop and land management practices in mitigating against rainfall variability-induced production risks.

1.6 Significance of the Study

Empirical evidence generated from this study helps to improve targeting of technological and management innovations by policymakers, extension agents, nongovernmental organizations, and other development agencies as part of an effort to promote adaptation to climate variability at the farm level. Currently, the Government of Uganda is in the process of finalizing climate change adaptation policy and implementation strategy. Results from this study are important in informing the adaptation planning and even future reviews of the policy. In addition, farm households will use the information to inform their decision making of what technologies to employ to reduce production risks under variable rainfall regimes. The study findings also contribute to literature linking various technological innovations to production risks under variable rainfall patterns in particular and climate in general. A greater understanding of the application of the analytical tools for measuring the success of adaptation innovations in reducing production risks will be created amongst researchers, development organizations, extension personnel and policy makers, to enhance continuous assessment of technological options in order to promote the most effective ones given future variations in rainfall and other climate extremes.

1.7 Theoretical Framework

The study aimed to establish the effects of various crop and land management practices in reducing production risks under variable rainfall regimes. In this case, production risk is considered a function of crop and land management practices. Production may increase due to introduction of new technologies or farming practices, or production may remain the same with lower level input due to the introduction of a new technology. A farmer adopts an innovation if its output will increase from given resources or if input decreases for a given output.

This study assumed that the production by household h on plot p (y_{hp}) is determined by crop and land management practices (T_{hp}). Farming practices employed by farmers may either have risk increasing or risk reducing effects on production (Kato et al., 2009). If they are risk increasing, it means they have a positive influence on the variance of crop production, thus considered ineffective in addressing climate variability-induced production risks.

It is also assumed that the true effectiveness of farming practices on crop production can be obtained if other moderating variables are controlled for, for example rainfall variables (RF_{hp}) (mean annual rainfall for the 40-year period, deviation of rainfall from its 40-year average, rainfall satisfaction index), use of purchased inputs (IN_{hp}), the household's endowment of physical capital (PC_h) (land, livestock), human capital (HC_h) (education, age, and gender of household head, size of household), and financial capital (FC_h) (household income, off farm income); village-level factors that determine local comparative advantages (X_v) (agro-ecological conditions, access to markets and infrastructure, and population density); and random factors (u_{yhp}) (Equation 1.1).

$$y_{hp} = y(T_{hp}, RF_{hp}, IN_{hp}, PC_h, HC_h, FC_h, X_v, u_{yhp}) \qquad (1.1)$$

On the other hand, choice of crop and land management practices is determined by rainfall variables; the household's endowment of physical, human and financial capital at the beginning of the year, as well as the local agro-ecology. Access to information and institutional support services such as extension (ET_{hp}) and use of credit (CR_{hp}), weather information (WI_{hp}) and access to markets (MK_{hp}) (input and output markets) affect adoption of technologies, and only have intervening effects on the value of crop production (Equation 1.2).

$$T_{hp} = T(RF_{hp}, PC_h, HC_h, FC_h, ET_{hp}, CR_{hp}, WI_{hp}, MK_{hp}, X_v, u_{hp}) \qquad (1.2)$$

The effect of rainfall variables particularly the subjective index is assumed to play a critical role in technology adoption, and is affected by a number of factors that potentially affect adoption of management practices. It is assumed that a farmer will adopt a production risk reducing practices, only if they notice or perceive change in rainfall variables. As such perception of rainfall variability is affected by the household's endowment of physical, human and financial capital at the beginning of the year; access to weather information and extension services; and local agro-ecology (Equation 1.3).

$$RF_{hp} = RF(PC_h, HC_h, FC_h, ET_{hp}, WI_{hp}, X_v, uRF_{hp}) \tag{1.3}$$

Most of the determinant factors in equations 1.2 and 1.3 are either exogenous to the households, for example local agro-ecology or state variables that are predetermined at the beginning of each year (e.g. natural capital of the plot, physical capital, human capital and financial capital). Use of credit on the other hand may be wholly or partially determined in the current year and hence potentially affected by current decisions about crop and land management technologies. In the econometric analysis (discussed in section 3.10), the study used predicted use of credit as an instrumental variable to address this potential endogeneity bias. Access to credit may depend on the household's endowment of physical (land) and human capital, and village-level factors affecting local comparative advantage (Equation 1.4).

$$CR_{hp} = CR\ (PC_h, HC_h, X_v, u_{CRhp}) \tag{1.4}$$

Finally, plot-level characteristics (e.g. plot-level biophysical characteristics, soil, slope and presence of land investments); pests and diseases; and temperature are potential independent variables, affecting both technology adoption and crop production. Since this study is being conducted in three distinct agro-ecological zones, plot-level characteristics (slope, soil type, fertility levels) have been assumed to be homogeneous across agro-ecological zones, thus the study undertook to explain agro-ecology specific rather than plot level characteristics. Pests and diseases and temperature were also considered as control variables, majorly for the reason of difficulty in acquiring this information.

1.8 Operational Definition of Terms and Concepts

A number of terms and concepts have been used in this study. In the following, operational definitions are given, based on how they are used in this study. Some of the definitions are based on citable definitions of terms:

1. **Adaptation:** Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPCC, 2007).
2. **Agricultural production risk:** The probability of an undesirable outcome in an agricultural enterprise (yield loss, low profit or economic loss, environmental damage).
3. **Climate change:** Any change in climate over time, whether due to natural variability or as a result of human activity (IPCC, 2007).

4. **Climate variability:** The disparities in the mean state and other statistics (standard deviation, occurrence of extreme events) of climate on all time scales beyond that of individual weather events. Variability may be due to natural processes within the climate system or to variations in natural or anthropogenic external forcing. In this study, rainfall variability is used as a proxy for climate variability.
5. **Management practices:** Refer to operations and methods of carrying out agri-business such as production methods, land use, land topography, irrigation and timing of operations. In this study, management practices refer to crop and land adjustments employed by farmers in response to rainfall variability.
6. **Technological options:** Refer to all agricultural-related technologies and innovations which encompass the production to consumption continuum; e.g. new varieties, management practices, agronomic practices, post-harvest practices, techniques for natural resources management and biodiversity conservation (ASARECA, 2010).

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter reviews literature related to the research topic and objectives. The key concepts in the study problem are climate variability, technological and management options, and production risk reduction. While it is generally agreed that impacts of climate variability on crop yields depend on technological considerations and farmers' response to changing environmental conditions, there is need to make reference to other studies conducted in areas related to these concepts specifically, and the study problem in general.

In this chapter, discussion is made of such related literature under three themes; extent of climate variability and its impacts on agricultural production; agricultural production risk management; and the role of technologies and management practices in reducing agricultural production risks. The review further assesses the various analytical methods that have been applied in previous studies related to this study, further identifying knowledge and methodological gaps and how they have been filled by this study.

In addition, current government of Uganda policy frameworks that relate to climate change adaptation and agricultural risk reduction are explored. This is intended to place this study and results into context of national climate risk management.

2.2 Extent of Current Climate Variability

Evidence is emerging that climate change is increasing rainfall variability and the frequency of extreme events such as drought, floods, and hurricanes (IPCC, 2007). Boko et al. (2007) predicted that Africa is likely to warm across all seasons during this century with annual mean surface air temperatures expected to increase between 3°C and 4°C by 2099, roughly 1.5 times average global temperatures. Projections in East Africa suggest that increasing temperatures due to climate change will increase rainfall by 5 - 20% from December to February, and decrease rainfall by 5-10% from June to August by 2050 (Hulme et al., 2001; IPCC, 2007). Analyses from General Circulation Models (GCM's) indicate an upward trend in rainfall under global warming over much of Burundi, Kenya, Rwanda, southern Somali and Uganda (van de Steeg et al., 2009).

In Uganda, there is a general lack of scientific consensus on the trend and distribution of annual and seasonal rainfall. McSweeney et al. (2008) reported an annual rainfall decrease of 3.5% since the 1960s, with annual rainfall due to decline further. McSweeney et al. (2008) further suggested that rains during the March to May rainy season are falling by 4.7% per decade. This result is corroborated by FEWSNET (2012) where it is reported that both spring and summer rains have decreased in Uganda during the past 25 years, with significant declines in west and northwest regions.

However, according to climate analysis in the Ugandan Government's National Adaptation Programme of Action (NAPA), published in December 2007 (GOU, 2007), the wetter areas of Uganda, around the Lake Victoria basin and the east and northwest are tending to become wetter, indicating an increase in rainfall in these areas. Also, temperature and rainfall simulations by Goulden (2008) indicated high percentage increases in rainfall for historically dry seasons for many parts of Uganda.

On the seasonal scale, GOU (2007) reported increasing erratic onset and cessation of rainfall seasons across the country in recent years; coupled with increasing frequency of droughts. It has also been observed that falls are heavier and more violent. Non-governmental organizations working in Uganda also reported that farmers recognize an increasingly erratic rainfall pattern in the first March to May rainy season, causing drought and crop failure, but also more intense rainfall, especially in the second rains at the end of the year, causing flooding and erosion (Oxfam, 2008). The spatial variability has been attributed to the complex topography and existence of large inland water bodies (Bamanya, 2007), La Niña and El Niño phenomena, with La Niña years tending to bring significant drying and El Niño years heavy rains (GOU, 2009).

In their study on modelling rainfall in Uganda, Kigobe et al. (2011) indicated variations in the amounts of rainfall in the south and northern parts of the Lake Kyoga basin. Kigobe et al. (2011) further indicated that during the early part of the year, the north is typically dry while the south is moderately wet. During the period March–May (MAM), the south eastern parts of the basin receive moderately higher rainfall amounts compared to other areas.

Komutunga and Musiitwa (2001) in their study on characterising drought patterns for approppriate development and transfer of drought resistant cultivars in Uganda, showed high rainfall variability in season two as compared to season one in most parts of Uganda. Also, the start of season one varied by location with a deviation of up to two weeks.

The studies above conducted in Uganda, have been based on the magnitudes of monthly and seasonal rainfall, the on set and ceasation of rainfall, and the occurrence of dry and wet spells, with limited focus on the variability of rainfall within the seasons. Yet crop production is sensitive not only to annual changes but also to the seasonal distribution of precipitation (Mukiibi, 2001; Ogallo et al., 2000).

General Circulation Model scenarios provide no better information as they are insufficiently precise in terms of spatial resolution or scale of assessment and fail to reasonably differentiate spatiality (Thornton et al., 2008). Therefore, little can be said yet about changes in climate variability or extreme events in Africa (Sivakumar et al., 2005; Christensen et al., 2007).

Considering that previous studies have also been generalized over Uganda (and East and Central Africa for the case of GCM's) with no focus on specific region or agro-ecology, such information cannot be reasonably used to inform decision making at local level, due to lack of understanding of what the local-level impacts of climate change are likely to be, hence need for research to address this uncertainty (Bradshaw et al., 2004). This study addressed this knowledge gap by providing empirical evidence of the extent of annual and seasonal rainfall variability in Eastern Uganda, focusing on three distinct agro-ecologies in the region. Clarity on variability by specific agro-ecology is essential to support vulnerable communities to adapt their farming systems to emerging climate variability realities.

2.3 Effects of Climate Variability on Agricultural Production

An extensive literature has been developed on the impacts of climate change and variability on agriculture, with the earliest focusing primarily on the vulnerability of the sector (for example Kurukulasuriya et al., 2006b; Kurukulasuriya and Mendelsohn, 2008; Mendelsohn et al., 1996; Seo and Mendelsohn, 2006). The general message from this literature is that the degree of vulnerability of the agricultural sector to climate variability and change is contingent on a wide range of local environmental and management factors: biological conditions such as soil content, type of crop, extent of knowledge and awareness of expected changes in climate, type and objectives of the management regimes prevalent in agriculture, the extent of support from government and other agencies, and the ability of key stakeholders to undertake the necessary remedial steps to address climate concerns (Kurukurasuriya and Rosental, 2003).

Hulme et al. (2001) described four ways in which climate would have a physical effect on crops: i) Changes in temperature and precipitation will alter the distribution of agro-ecological zones; ii) Carbon dioxide effects are expected to have a positive impact due to, for example, greater water use efficiency and higher rate of photosynthesis; iii) Water availability (or runoff) is a critical factor in determining the impact of climate change in many places, particularly in Africa; and iv) Agricultural losses resulting from climatic variability and the increased frequency of extreme events such as droughts and floods or changes in precipitation and temperature variance.

Climate variability and change are likely to affect land degradation processes by altering rainfall averages, variability and extremes and by increasing evaporation and transpiration of water from soils, vegetation and surface waters (ASARECA, 2009). In North Africa and the Sahel, increasing drought, water scarcity and land overuse could lead to a loss of 75% of arable, rain-fed land. The Nile Delta, for example, is at risk from both sea-level rise and salinization in agricultural areas with estimates of 12 to 15% loss of arable land by 2050 affecting 5 million people (Boko et al., 2007). Shisanya et al. (2011) demonstrate the continued effect of climate variability on the vegetation condition and consequently crop production in Arid and Semi-Arid Lands of Kenya.

In a recent study of rain-fed cereal potential under different climate change scenarios and varying rainfall, losses of rain-fed production potential in the most vulnerable developing countries was predicted under most scenarios. Losses were estimated at 10%–20% of production area, with some 1–3 billion people possibly affected in 2080 (Fischer et al., 2002). These findings are corroborated by Boko et al. (2007) and Brown and Crawford (2007) who predicted decreases in crop yields from Africa's rain-fed farm production as a result of changes in climatic conditions. Model based maize yield changes due to climate change in dry land ecosystems in Tanzania predicted average country yield decrease of 33%, but could be as high as 84% in some regions (Agrawala et al., 2003). In Kenya, during the 1999–2000 drought, the country lost about 26 percent of its livestock resulting into losses to a tune of Kenya shilling 5.8 billion (approx. $77 million) (Mogaka et al., 2005).

Like most of SSA, agricultural productivity in Uganda is being adversely constrained by climate variability manifested through irregular rainfall patterns and erratic onset and cessation of rains, which have increased the intensity of drought and brought about changes in growing seasons (Nkonya et al., 2008). In particular, climate variability and change is likely to mean increased food insecurity; soil erosion and land degradation; flood and landslide damage to infrastructure and settlements and shifts in the productivity of agricultural and natural resources (GOU, 2009).

Climate variability has been reported as having a significant impact on rural livelihoods in Uganda (Apuuli et al., 2000; GOU, 2007; James, 2010). Farmers claim increasingly unpredictable weather has led to poor yields, a reduction in pastures, poor animal health, rangeland related conflicts, greater expense and labour, food insecurity and reduced incomes leading to poverty (Osbahr et al., 2011; Oxfam, 2008). Oxfam, further reported an increase in the frequency of droughts, with for example seven droughts experienced between 1991 and 2000 alone.

This variability in rainfall has increased losses both at household and national levels. At national level, economic losses resulting from climate related disasters destroy annually an average of 800,000 hectares of crops making economic losses in excess of USD 65 million (UNWD, 2005). A shift in the viability of coffee growing areas could potentially wipe out USD 265.8 million or 40% of export revenue as a result of climate variability and change (GOU, 2009). At household level, many parts of the country especially in the North and North East are experiencing significant increases in hunger and malnutrition (GOU, 2009). An increase in the intensity and frequency of heavy rains, floods and landslides in the highland areas such as Bududa and areas around Mt. Elgon as well as outbreaks of associated waterborne diseases, has also been observed. Table 2.1 shows land mark climate related disasters in Uganda and the extent of damage caused to various sectors.

With only 0.1% of land irrigated, changes in rainfall greatly impact the rain-fed agricultural sector as well as the ability to achieve broader development objectives in Uganda and targets of the MDGs (GOU, 2009; James, 2010). The increased uncertainty of climate effects represents an additional problem to farmers that translates into production risks associated with crop yields (World Bank, 2009).

Table 2.1 Landmark Climate Change-Related Disasters in Uganda

Year	Nature of Disaster	Impacts
1961/1962	El Niño rains	Extensive floods experienced in many parts of the country. Roads, bridges, houses, crops and property, worth millions of dollars (actual loss not established) destroyed; Drastic rise in the water level of Lake Victoria (by 2.5 metres, submerging all major infrastructure along the lake shores.
1993/1994	Drought and famine	Over 1.8 million people affected due to lack of food, water, and inadequate pasture for livestock.
1997/1998	El Niño rains	53 people killed in landslides and over 2,000 people displaced; Roads, bridges, houses, crops, and property, worth more than US$20 million destroyed.
1999	Drought and famine	Over 3.5 million people in 28 districts affected by lack of food and a large number of livestock suffered from inadequate pasture and water.
2007	Flash floods	Over 718,045 people affected by lack of food due to flooded farm lands, destroyed crops, limited access to markets, and livestock disease outbreaks.
2008, 2009, & 2011	Drought	Over 750,000 people affected by lack of food and cattle suffered from inadequate pasture and water.
2009, 2010, 2011 & 2012	Floods and mudslides	Mudslides caused by heavy rains left over 6,400 people in need of urgent re-settlement, 14 injured and 21 dead. Floods destroyed food crops.

Source: Adopted and modified from Relief Web http://reliefweb.int, accessed December 20, 2012.

2.4 Agricultural Production Risk Management

Many definitions of risk exist in literature. For example, Székely and Pálinkás (2009) defined risk as "the potential deviation between the expected and the real outcomes resulting from an economic decision where, from a practical point of view, a negative outcome has greater importance, and constitutes the one actually considered by most decision makers". Harwood et al. (1999) described risk as the possibility of adversity and refer to it as the "uncertainty that matters". Among the many definitions of risk in literature, three properties emerge as common factors; (1) the chance of a bad outcome, (2) the variability of outcomes, and (3) the uncertainty of outcomes.

In agriculture, the major risks are business risk (including production, market, personal and institutional risk) and financial risk (issues related to financing business operations) (USDA, 1997). Among these risks faced by agricultural stakeholders, production or yield risk is the most important (Chuku and Okoye, 2009). This occurs because agriculture is subject to uncontrollable events usually related to climate such as changes in precipitation, floods, hail, insects, diseases etc.

Rainfall variability, both within and between seasons creates risk and uncertainty of farm production as well as for the potential impact of innovations for crop, soil and livestock management practices (Cooper and Coe, 2010). Overlaid on this challenge is the IPCC prediction that whatever happens to future greenhouse gases, we are locked into global warming and inevitable changes to climatic patterns which are likely to exacerbate existing rainfall variability in SSA and further increase the frequency of climate extremes (IPCC, 2007). Considering that African agriculture is primarily rain-fed and is entirely dependent on rainfall that is both seasonal and highly variable, there is a need to manage the associated risks. Without effective intervention, projected increases in climate variability can be expected to intensify the cycle of poverty, natural resource degradation, vulnerability and dependence on external assistance (Jarvis et al., 2011).

Risk management is the range of strategies and instruments applied to avoid or minimize losses and to utilize opportunities (Moschini and Hennessy, 2001). A number of options for risk management in agriculture have been cited in literature. Among them are, integrated planning of land and water resources at plot and watershed scales, soil fertility improvement, diversifying agriculture with crops and varieties that can perform better under various climatic stresses, developing sound risk management strategies including safety nets and risk insurance, and adaptive management that disseminates timely climate information to farmers and tailors techniques to shifting climatic conditions (Eakin, 2005; Iglesias, 2005; Nzuma et al., 2010; Muchena and Iglesias, 1995; Organization for Economic Co-operation and Development [OECD], 2009; Rao, 2011; Reid and Vogel, 2006).

Chuku and Okoye (2009) generally group the various agricultural risk coping and management strategies into four main categories that are not mutually exclusive: (1) Income/asset management, (2) Government programmes and insurance, (3) Farm production practices, and (4) Technological development.

2.4.1 Income and Asset Management

Income and asset management are intended to spread exposure to risks by farmers, and reduce vulnerability to shocks and crises (Chiotti et al., 1997; Mahul and Vermersch, 2000). Income and asset management options include crop insurance, crop shares, options and futures, and asset smoothing. Insurance against crop loss is receiving increased attention as a means to cover losses from extreme events such as flooding and droughts and enhance the resilience to shocks.

Crop insurance schemes are well established in developed countries where farming is practiced by large commercial farmers, but are new to developing countries where farming is mainly of subsistence nature that generates very little marketable surplus. In addition there are also problems associated with accurate assessment of risks in financial terms and high transaction costs due to involvement of large number of farmers over small areas. Index based insurance is one approach that appears to be of considerable promise in the countries where agriculture is predominantly smallholder in scale. Formal insurance requires innovation in designing products and services that are appropriate in terms of coverage, timeliness, accessibility and affordability.

Informal crop insurance systems have been observed in Nigeria (Udry, 1994), Mozambique (Eriksen and Silva, 2009; Osbahr et al., 2008), and Uganda (Asiimwe and Mpuga, 2007). Informal insurance mechanisms used include; diversification to livestock enterprises, social safety nets such as village savings schemes, maintaining food stocks and participation in off-farm income generating activities.

2.4.2 Government Programmes and Insurance

Government programmes and support strategies include among others, governments subsidy and transfers, governments insurance and natural resource management programs (Smit and Skinner, 2002). These represent adaptation strategies at an aggregate scale and can be considered as prerequisite actions for effective and sustainable risk management in agriculture.

2.4.3 Farm Production Practices

Farm production practices include; diversification of crop and livestock varieties, the substitution of plant types, land use and topography, innovations in natural resource management, altering the composition of chemical (fertilizers and pesticides and synthetic inputs) and timing of operations (Chiotti et al., 1997; Cooper et al., 2008; Nzuma et al., 2010; Skoufias, 2003; Smit and Skinner, 2002).

Innovations in natural resource management such as broad scale water resource management address the risk of water (moisture) deficiencies or surpluses associated with shifting precipitation patterns and the proximity of more frequent floods and/or droughts (Smit and Skinner, 2002). At the community or individual farm-levels, resource management innovations could take the form of the development of integrated drainage system, land contouring, and alternative tillage systems (Smit and Skinner, 2002). Changing the timing of operations, for example rescheduling planting, spraying, fertilizing and harvesting has the potential to maximize farm productivity during the growing seasons and to avoid heat stresses and moisture deficiencies during times of increased climate perturbations (Chiotti et al., 1997; de Loë et al., 1999; Smit and Skinner, 2002).

Sustainable land management (SLM) practices such as conservation tillage, cover cropping, improved livestock practices, water harvesting, agroforestry, and enhanced water and nutrient management can improve soil carbon sequestration (SCS), increase yields, and enhance resilience to climate change (Thornton and Herrero, 2010). There may also be tradeoffs between increasing farm productivity and profitability, adaptation to climate change, and mitigation of greenhouse gases (GHGs).

Other production practices employed mostly in Mali, Niger and Burkina Faso involve building of anti-erosion small dykes to allow for sedimentation and particle deposits upstream of the dykes to reduce run-off and increase water percolation; the "*zai*" technique, which is also applied in the Sahelian zone, involves planting of crops in small, circular pits perpendicular to the slope to capture rainwater and retain soil moisture (Akponikpè et al., 2010; Brown and Crawford, 2007); and improved land clearing technique which involves leaving of tree stumps and trimmed shrubs and small trees to facilitate fast re-growth (Brown and Crawford, 2007).

2.4.4 Technological Development

The Association for Strengthening Agricultural Research in Eastern and Central Africa [ASARECA] (2010) defines agricultural technologies as agricultural-related innovations which encompass the production to consumption continuum. A variety of technological innovations have been developed to better accommodate farming to spatial variations in climate. Smithers and Blay-Palmer (2001) identify two basic types of technological options – mechanical and biological.

Some of the mechanical technologies that are associated with managing climate-induced production risks are; irrigation, conservation tillage and development of integrated field drainage systems. The development of effective irrigation systems, particularly drip systems, has facilitated both more intensive agricultural activity and a broader range of activities than local climatic resources would otherwise permit.

Similarly, conservation tillage involving improvements in alternative tillage systems, along with associated planting and harvesting technologies, have facilitated greater usage of reduced tillage systems. In addition to soil conservation benefits, these systems reduce the number of field operations that expose soil to evaporation while leaving a vegetation cover that further retards moisture loss (Rosenberg, 1981). The development of integrated drainage systems and field drainage technologies has enabled farmers to cope with excess moisture during the growing season, and especially during harvest, when field activities are constrained by the presence of standing water.

On the other hand, biological technologies include the development of crop varieties with higher yield potential or those that are better suited to the temperature, moisture and other conditions associated with a particular ecology (Smithers and Blay-Palmer, 2001). This is most clearly reflected in the development of hybrids for many major field crops, thus permitting their introduction and/or expansion into regions where climate had previously been a limiting factor.

The technological components that are suggested under these strategies are mainly aimed at sustainable intensification which is the key to ensure food security especially in countries where good scope for increasing current levels of productivity exists. The development of information systems capable of forecasting weather, climate and market conditions associated with agricultural production over a long period of time to farm holders has also been proposed as a technological option.

2.5 Farming Practices and the Management of Production Risks

It is generally agreed that in the medium and longer term, as climate change becomes more obvious farmers need to adapt their farming practices to a new set of weather-induced risks and opportunities (Cooper and Coe, 2011). Against this background, a wealth of information has emerged over the decades in SSA that has identified a broad range of tested and proven innovations that farmers can adopt to reduce production risks as a result of changes in the local climate. For example, there have been many success stories of productivity increases in irrigated systems in Africa (Karukulasuriya and Mendelsohn, 2006b). Studies in Ethiopia showed that soil and water conservation and sustainable agriculture technologies have significant impacts on reducing production risk (Kassie et al., 2008; Kato et al., 2009; Shiferaw and Holden, 1999). Di Falco et al. (2006) show that variety richness increases farm productivity. Simulations with estimated parameters illustrate how planting more diverse durum wheat varieties on multiple plots contributes to improving farmer's welfare.

Other studies have related technology effects on crop production to climate change adaptation. For example, Kassie et al. (2009) and Kurukulasuriya and Mendelsohn (2006a) demonstrated that adoption of organic farming techniques, and crop selection are important adaptation strategies to climate variability respectively, in specific farming systems.

However, as noted by Cooper and Coe (2010), the adoption of such innovations remains low. One contributing reason is noted as unavailability of information to farmers and their support agents with regard to the climate-induced risk associated with these innovations and the extent to which such innovations might mitigate or exacerbate such risk. Such information is considered essential if risk-averse farmers are to make better informed and more profitable decisions, and their support agents to more effectively promote innovative farming practices.

Further, it's generally agreed from literature that climate-induced risks to agriculture vary according to location, type of enterprise, and the effectiveness of risk management (Iglesias *et al*., 2006; Kassie *et al*., 2009), thus the need for local level analyses that take into account both the biophysical and socio-economic characteristics of the farming system.

This study therefore, aimed to develop an evidence base addressing this knowledge gap by assessing effectiveness of various production practices and technologies employed by farmers in reducing climate-induced production risks. The study was conducted in the context of Eastern Uganda focusing on three distinct agro-ecological zones in the region. The inclusion of local level rainfall information in the analysis strengthens the results and recommendations made by this study. There is no specific study that has been conducted in Uganda analysing impacts of technology on crop production, given rainfall variability.

2.6 Understanding and Evaluating Production Risks

Several types of economic approaches have been used to estimate the potential impacts of climate change on agricultural production. Economic models are based on the goal of maximizing economic returns to inputs. These have been used extensively in the context of climate change (Antle and Capalbo, 2001). They are designed to simulate the decision-making process of farmers regarding methods of production and allocation of resources. Most commonly used approaches have been the Ricardian approach, multiple regression analysis and yield functions.

The Ricardian approach measures the relationship between net revenues from crops and climate using cross sectional evidence (Kurukulasuriya et al. 2006; Kurukulasuriya and Mendelsohn 2008). The

Ricardian studies generally capture endogenous adaptation measures that farmers actually take to adjust to climate change. However, the model's weakness lies in the need to control for many variables in addition to climate. The Ricardian approach does not deal with the process of adaptation and how it occurs, nor those factors that may retard or hasten the process of adaptation (Maddison, 2007).

Multiple regression models have also been developed to represent process-based yield responses to environmental and management variables (for example, Cabas *et al*., 2010; Di Falco *et al*., 2006; Iglesias and Quiroga, 2007; Iglesias *et al*. 2000; Pender and Gebremedhin, 2006; Sileshi *et al*., 2010), and could be used to estimate the risk associated with climate variability.

Yield function approach relates per unit area yield to a set of explanatory variables, such as levels of input use, type of technology and environmental factors. A production function is specified in its general form as in equation 2.1:

$$Y = f(X, Z, T, \beta) + \mathcal{E} \qquad (2.1)$$

Where: Y is the per hectare output, X a vector of variable input levels, Z a vector of environmental factors, T a vector of management practices, β a vector of coefficient to be estimated, and $\mathcal{E}$ a random error term. From equation 3.6, the impact of innovation Ton profit π at output price p and holding other inputs constant can be expressed as in equation 2.2:

$$\Delta\pi = (\delta Y / \delta T)\, p \qquad (2.2)$$

The advantages of the production function approach are; regression model is capable of statistically isolating the individual effects of production factors, interactions among technologies and inputs can be tested statistically, and the data used to estimate the production function are taken from farmers themselves, rather than from controlled experiments.

Crop production functions can be used to optimise the technological inputs as an adaptation response to climate variations. Climate risk can be managed by altering decisions before and during the growing season, such as the level of inputs (low levels of fertilizers in dry seasons versus high levels to take advance of good seasons), irrigation regimens, or insurance planning. Cobb-Douglas and translog production functions are also commonly cited forms in the literature. Translog profit function can also be applied to farm level data (Sidhu and Baanante, 1981). Logistic regression model can also be used to analyze the impact of a technology.

However, in the estimation of production functions, ignoring risk considerations can cause inefficient estimates, whilst biased parameter estimates arise in the presence of sample selection. For example studies by Kassie et al. (2008), Kassie et al. (2009), Kurukulasuriya and Mendelsohn (2006 a & b), and Sileshi et al. (2010) on the effect of technology adoption on production risk estimated mean crop yield alone. Inference based on the mean alone can be misleading if the variance around the mean, and hence the probability distribution of the risk is not known.

Just and Pope (1977, 1978) suggest a production function where inputs have both an effect on levels of production and on output variability, as production risk is related to the variance of output and is assumed to have an additive form. Model specification allows the differentiation of impact of input on output and risk, and has sufficient flexibility to accommodate both positive and negative marginal risks with respect to inputs. This approach has been applied in a number of studies for example; Cabas et al. (2010), Di Falco et al. (2006), Gardebroek et al. (2010), Kato et al. (2009), Kelbore Z. G. (2012), Pender and Gebremedhin (2006), Poudel and Kotani (2013). These studies analyze production risks considering both the mean and variance of yield.

Although different methods of impact assessment have been used to depending on the objective of the study, the objective of this study was to measure effect of technologies on production risk given variations in rainfall regimes in a way that allows making comparisons between different agro-ecological zones. Identified knowledge and methodological gaps in the existing studies relate to failure to include both biophysical and socioeconomic variables in the analyses; inference of results based on mean rainfall alone and not its variability; and analysis of both the mean and variance of yield, thus the risk distribution. Appendix 1 summarises the key studies reviewed in respect to this study problem, their objectives, results and identified knowledge and methodological gaps.

This study therefore complemented the existing economic analyses by using an approach that integrated both rainfall variability and agricultural production through yield functions. The potential impacts quantification was evaluated by empiric models to find the relations between yield, rainfall variability and production using cross sectional data. The statistic tool used was the Just and Pope stochastic production framework.

2.7 Policy and Institutional Framework for Climate Change Adaptation in Uganda

Uganda has committed to the adoption and implementation of policies and measures designed to mitigate climate change effects and adapt to its impacts. At the international level, Uganda has signed and ratified both the United Nations Framework Convention on Climate Change (UNFCCC) adopted in 1993 and the Kyoto Protocol that came into force in 2006. These frameworks oblige Uganda to put in place appropriate mitigation and adaptation measures to address the cause and effects of climate change as well as undertake education and awareness programmes. At the regional level, the climate change policy for the East African Community (EAC) urges member countries to develop consistent national policies to ensure harmonised action.

In conformity with UNFCCC, Uganda developed and submitted its National Adaptation Programmes of Action (NAPA) to UNFCCC in 2007, with a list of nine priority projects (GOU, 2007) many of which are yet to be rolled out and implemented (GOU, 2012). Uganda's five-year (2010 – 2015) National Development Plan (NDP) already recognises that addressing the challenges of climate change is crucial to enhancing sustainable economic and social development (GOU, 2010).

Uganda has also recently developed a draft National Climate Change Policy and Implementation Strategy (GOU, 2012) that will enable the country to fulfil its obligations under the conventions. The Climate Change policy is grounded on the fact that a policy response to climate change in Uganda is crucial for reducing the country's vulnerability to climate change, and it is the most appropriate way to adjust to and cope with the projected impacts of climate change on the nation. Actions on climate change undertaken in Uganda have tended to be scattered and uncoordinated, with no appropriate institutional framework to ensure effective coordination (GOU 2009). The policy also acknowledges the multi-sectoral nature of climate change and provides direction for key sectors to facilitate adaptation and strengthen efforts towards building an overarching, more resilient national development process.

The Uganda National Climate Change Policy is based on the following priority concerns: adaptation, mitigation, and research and observation. Like the EAC regional policy, this national policy emphasizes climate change adaptation as the top priority for Uganda, while mitigation efforts are embraced by the policy as secondary. One of the policy priorities is to promote research and development, transfer and diffusion of technology through the use of appropriate information sharing, incentive schemes and support mechanisms, as relevant to the various sectors concerned.

Given the policy priorities, information from this study will adequately contribute to policy implementation and review particularly on technology transfer and adoption. This study clearly provides knowledge on the effect of various management practices on production risks to inform decisions and implementation of climate smart agriculture practices by farmers, and support Uganda's climate change decision makers. Generation of knowledge on farmer practices and factors affecting farmers' decisions to adopt certain practices builds knowledge of what works in what context and why, and how best the government can foster adoption of adaptation practices. Understanding farmer behaviors and technology adoption is also critical in informing the role of farmers in technology development. This affects how farmers' decisions for adoption are made.

An analytical framework used in this study can also be adopted by other stakeholders to undertake technology analyses in other geographical locations to provide a comprehensive listing of technology effectiveness. This study is therefore well grounded into the national, regional and international climate change frameworks and will make contributions in ensuring adaptation by farming communities.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter presents the research design in section 3.2 and empirical models for the study and variables in sections 3.3 and 3.4 respectively. The chapter further presents the study area and target population, sampling procedure and sample size in sections 3.5 and 3.6 respectively. Research instruments, data collection techniques and pilot study are presented in sections 3.7, 3.8 and 3.9 respectively. Further the section looks at logistical and ethical considerations which are presented in section 3.10. Finally, data analysis and interpretation is covered in section 3.11, and shows the procedures for data analysis and estimation of the study variables.

3.2 Research Design

The research used a cross sectional study design. The study was done in phases; the first phase involved collection of preliminary information on the study area such as biophysical characteristics of the region, agro-ecologies and farming systems. This was followed by a pilot study to pretest the data collection instruments. The final phase involved collection of information on the variables relevant for this study. Both qualitative and quantitative data as well as primary and secondary data were collected.

3.3 Empirical Models

The dependent variables analyzed in this study are; adoption of crop and land management practices, and crop production. The econometric models used depended on the nature of the dependent variables, as described in sections 3.3.1 and 3.3.2.

3.3.1 Adoption of Crop and Land Management Practices

A farmer *i* can choose either to use or not to use particular management practices (crop or land management). This leads to a binary outcome, whether to adopt or not. Choice -either or not to use certain management practices depends on both economic and non-economic factors (X). In econometrics, outcomes which are binary are analyzed using Binary Choice Models (BCM) (Greene 1993). These include Linear Probability Models or nonlinear models (Probit or Logit models). Logit and Probit models are quite comparable; however the logistic has slightly flatter tails. Thus the choice between the two is one of convenience and ready availability of computer programs.

When decision process by farmers to adopt management practices requires more than one step, models with two-step regressions are employed to correct for the selection bias generated during the decision making processes (Heckman, 1976). The probit model for sample selection assumes that there exists an underlying relationship between the selection and outcome models given by equations 3.1 and 3.2:

$$Y_1 = b'X + U_1 \qquad (3.1)$$

$$Y_2 = g'Z + U_2 \qquad (3.2)$$

Where, X is a k-vector of regressors, Z is an m-vector of repressors; the error terms U_1 and U_2 are jointly normally distributed, independently of X and Z with zero expectations. The independent variable Y_1 is only observed if $Y_2 > 0$. Thus the actual dependent variable is presented in equation 3.3 as:

$$Y = Y_1 \text{ if } Y_2 > 0,\ Y \text{ is a missing value if } Y_2 \leq 0 \qquad (3.3)$$

The latent variable Y_2 itself is not observable, only its sign. $Y_2 > 0$, if Y is observable, and $Y_2 \leq 0$ if not. If the sample selection problem is ignored and Y regressed on X using the observed Y's only, then the Ordinary Least Squares (OLS) estimator of b will be biased, as depicted by equation 3.4:

$$E[Y1|Y2 > 0, X,Z] = b'X + rsf(g'Z)/F(g'Z) \qquad (3.4)$$

Where F is the cumulative distribution function of the standard normal distribution, f is the corresponding density, s^2 is the variance of U_1, and r is the correlation between U_1 and U_2. When $r \neq 0$, standard probit techniques yield biased results. Thus, the Heckman probit model provides consistent, asymptotically efficient estimates for all parameters in such models (StataCorp, 2003).

Heckman probit model has been used in previous studies related to adoption of production technologies and management practices. For instance, William and Stan (2003) employed the Heckman's two- step procedure to analyze the factors affecting the awareness and adoption of new agricultural technologies in the United States of America. Similarly, Yirga (2007) and Kaliba et al. (2000) employed the Heckman's selection model to analyze the two-step processes of agricultural technology adoption and the intensity of agricultural input use. Other studies using the same approach are; Kurukulasuriya and Mendelsohn (2006b) in the developing a choice model for irrigation; Deressa et al. (2008) and Maddison (2006) in assessing the perception of, and adaptation to climate change in the Nile Basin of Ethiopia, and Africa respectively.

The Heckman probit model uses a univariate technique for discrete choice dependent variables and models adoption as a function of the common set of explanatory variables. The shortfall of this approach is that it is prone to biases caused by ignoring common factors that might be unobserved and unmeasured and affect the different management practices. Some farmers may use more than one management practice on their farms, thus this approach fails to take into account the relationships between adoptions of different measures. Farmers might consider some combinations of management practices as complementary and others as competing (Nhemachena and Hassan, 2007).

Analytical approaches that are commonly used in adoption decision studies involving multiple choices are the multinomial logit (MNL) and multinomial probit (MNP) models. The shortfall of MNL approach is that interpretation of the influence of the explanatory variables on choices of each of the separate adaptation measures is very difficult. In such situations estimation of multinomial probit (MNP) is more appropriate and both Bayesian and non-Bayesian simulation methods can be used to estimate parameters of large MNP and mixed logit models (Golob and Regan, 2002).

Following Lin et al. (2005), the multivariate probit econometric approach is characterized by a set of *n* binary dependent variables *Yi*, is expressed as in equation 3.5:

$$Y_i = 1 \text{ if } X'\beta_i + \varepsilon_i > 0,$$

$$Y_i = 0 \; X'\beta_i + \varepsilon_i \leq 0, \; i = 1,2,\ldots, n \qquad (3.5)$$

where X is a vector of explanatory variables, $\beta_1, \beta_2,\ldots,\beta_n$ are conformable parameter vectors, and random error terms $\varepsilon_1, \varepsilon_2,\ldots,\varepsilon_n$ are distributed as multivariate normal distribution with zero means, unitary variance and an $n\times n$ contemporaneous correlation matrix $R = [\rho_{ij}]$, with density $\emptyset(\varepsilon_1, \varepsilon_2, \ldots \varepsilon_n; R)$.

Multivariate models have been employed in climate change studies pertaining to the conceptual similarities in agricultural technology adoption and climate change. For example, Nhemachena and Hassan (2007) employed the multivariate probit model to analyse factors influencing the choice of climate change adaptation options in Southern Africa. Other studies that analyze such joint endogenous decisions include use of multinomial logit model for crop selection (Kurukulasuriya and Mendelsohn, 2006a), livestock choice (Seo and Mendelsohn, 2006), and adaptation strategies (Hassan and Nhemachena, 2008).

This study hypothesized that farmers' decision to adopt new management practices (crop and land), in the face of climate variability, is a two-step process. The first step involves farmers perceiving climate variability, and the second step making a decision to adopt particular practices in response to the perceived climate variations. This leads to sample selectivity problem since only those who perceive climate variability will adjust their farm management practices, whereas there is need to infer about the adaptation made by the agricultural population in general. In order to correct for selection bias, this study used the Heckman's two- step probit model to analyze factors influencing farmers' decisions to adopt crop and land management practices in response to climate variability. The study estimated a dichotomous choice model for management practices adoption, T_{AD}, where $T_{AD} = 1$ if farmers reported to have adopted one or more management practices in response to climate variability, and $T_{AD} = 0$ otherwise.

Further, multivariate probit model was used to simultaneously model the influence of a set of explanatory variables on each of the different management practices employed by farmers. This was in consideration that farmers employed more than one measure on their farms in response to climate variability.

3.3.2 Crop Production

In order to estimate effects of management practices on crop production, this study employed the Just and Pope stochastic production frontier framework (1979). Just and Pope Framework focuses on production risks measured by the variance of output, and suggest the use of production function specifications satisfying some desirable properties. The Just and Pope parametric approach allows yield enhancing inputs to have either a negative or a positive effect on the variance of yield by relating the variance of output to explanatory variables in a multiplicative heteroskedastic regression model (Kato et al., 2009).

The stochastic production function is represented as in equation 3.6:

$$y = f(X, \beta) + \mu = f(X, \beta) + h(X, \alpha)^{0.5} + \varepsilon \qquad (3.6)$$

Here, y is the output or yield, X is a vector of explanatory variables, $f(.)$ denotes the deterministic component (mean function) of yield and relates X to average yield with β representing the set of estimated coefficients, μ is the heteroskedastic disturbance term with a zero mean, $h(.)$ is the stochastic component (variance function) of yield and relates X to the standard deviation of yield with α representing the corresponding set of estimated coefficients, and ε is a random error term with a mean of zero and variance of σ^2. Thus this specification shows mean yield and yield variance as two separate components being explained by change in input variables i.e. rainfall and other derived variables (Chen et al., 2004; Just and Pope 1979).

Rainfall variables were included in the model to capture effects of rainfall variability on the mean and variance of crop production. Rainfall in the corresponding crop growing season was used to capture the effect of changes in rainfall, so the model included the mean of the monthly precipitation over August - November 2010 growing season and the subjective rainfall index. Also, standard deviation in monthly precipitation over the same season was included to capture the effect of variance in rainfall on the mean and variance of crop production in the way similar to Cabas et al. (2010), and Barnwal and Kotani (2010).

The analysis also controlled for a number of explanatory variables that were hypothesized to be correlated with the observed plot-level crop outputs. These include; plot-level covariates (use of chemical fertilizers, land size), and household-level covariates (sex, age, household size and education of household head). Furthermore, district fixed effects were included to control for unobserved soil conditions as well as weather specific effects of the different agro-ecological zones.

The Just and Pope framework has been widely used in previous studies (for example, Barnwal and Kotani, 2010; Kato et al., 2009; Koundouri et al., 2006; Smale et al., 1998; Di Falco and Perrings 2005). It is applied in this study to investigate the effects of various adaptation measures on crop production. This analysis provides information on the risk effects of these investments across three distinct agro-ecological zones in Eastern Uganda.

The dependent variable for the Just and Pope model was expressed as value of production (VOP) per hectare, which was considered a better representation than yield because some plots had intercropping with more than one crop, making estimation of single crop-production functions difficult. This approach of aggregating all crops on a plot into a single measure of value of crop production per hectare rather than using individual crop yields has been used in many previous plot-level-based micro-econometric studies in Ethiopia and sub-Saharan Africa (Benin et al., 2007; Jansen et al. 2006; Kato et al., 2009; Nkonya et al. 2008; Pender and Gebremedhin, 2006, 2007).

The value of production (VOP) where n crops are grown was calculated using the formula (van de Steeg et al., 2009) as shown in equation 3.7:

$$VOP = \sum_{i=1}^{n}(q_i \; x \; p_i) \qquad (3.7)$$

Where: *VOP* is aggregate value of production (UGX), Q_i is the quantity produced of crop i (kg) and P_i is the price of crop i (UGX/kg). The VOP was then divided by the plot area to standardise the value of production. Average market prices were used in the computation of VOP.

3.4 Predicted Impact of Selected Explanatory Variables

3.4.1 Adoption of Management Practices (Outcome Model)

The variables hypothesised as affecting farmers' decisions to adopt crop and land management practices (outcome model) include; the household's endowment of human capital (gender, age, education of household head, size of household), physical capital (land, livestock), and financial capital (household income, off farm income); institutional factors (extension on crop and livestock, use of credit, access to weather information and distance to input and output markets), and rainfall variables. The agro-ecological zone where the household is located is also added to control for the possibility that households in more favourable zones might be more likely to adopt some new technologies. The AEZs are represented by the three sample districts – Mbale, Pallisa and Sironko (ref. Table 3.1). In the following, the variables are described and the researcher's *a prior* expectation about their relationship to the dependent variables.

Gender of head of household: Male-headed households are often considered to be more likely to get information about new technologies and take risky businesses than do female-headed households (Asfaw and Admassie, 2004). Tenge and Hella (2004) argued that female- headed households may have negative effects on the adoption of soil and water conservation measures because they have limited access to information, land and other resources due to traditional social barriers. The result of Nhemachena and Hassan (2007) indicated a contrary result to the above argument by showing that female-headed households are more likely to take up climate change adaptation methods. This study follows the prior argument and hypothesizes that male-headed households are more likely to take up adaptation methods as they have more access to resources and information.

Age of head of household: The age of household head is incorporated as it is believed that with age, farmers accumulate more knowledge and personal capital and, thus, show a greater likelihood of investing in innovations (Uaiene et al., 2009). However, it may also be that younger household heads are more flexible and hence likely to adopt new technologies, while older ones are less efficient to carry out demanding farm operations resulting in low technology adoption. The expected sign of the coefficient on age is indeterminate.

Farming experience: Farming experience was taken as the number of years a farmer has been involved in farming as the primary source of livelihood. As one becomes more experienced in farming, it's highly likely that he/she will adopt new and improved technologies, based on the experience with previous technologies. Foster and Rosenzweig (1995) found that initially farmers may not adopt a new technology because of imperfect knowledge about management of the new technology; however, adoption eventually occurs due to own experience and neighbours' experience. Similarly, Conley and Udry (2000), looking at pineapple cultivation in Ghana, found that a farmer increases (decreases) his fertilizer use when a neighbour experienced higher than expected profits using more (less) fertilizer than he did, indicating the importance of social learning.

Education: More educated farmers are typically assumed to be better able to process information and search for appropriate technologies to alleviate their production constraints (Norris and Bati, 1987). High level of education enhances the understanding of instructions given and should also improve the farmers' level of participation in agricultural activities. Evidence from various sources indicates that there is a positive relationship between the education level of the household head and the adoption of improved technologies (Igoden et al., 1990; Okuthe et al., 2007; Uaiene et al., 2009) and adaptation to climate variability and change (Maddison, 2006). Therefore, farmers with higher levels of education are more likely to adopt production risk reducing technologies and adapt to climate variability and change.

Household size: The influence of household size on use of adaptation methods can be seen from two angles. The first assumption is that households with many family members may be forced to divert part of the labour force to off-farm activities in an attempt to earn income in order to ease the consumption pressure imposed by a large family size (Yirga, 2007). The other assumption is that large family size is normally associated with a higher labour endowment, which would enable a household to accomplish various agricultural tasks. For instance Croppenstedt et al. (2003) argue that households with a larger pool of labour should be more likely to adopt agricultural technology and use it more intensively because they have fewer labour shortages at peak times. Here it is expected that households with large family are more likely to adopt agricultural technologies for reducing climate related production risks.

Household income: Household income can be used as a proxy to working capital because it determines the available capital for the investment in the adoption of technologies and it is a means through which the effect of poverty can be assessed. Household income has a bearing on the socio-economic status of farmers. Farmers from higher economic status have access to resources and institutions controlling resources necessary for the effective adoption of technology (Franzel, 1999).

Non-farm income, Farm size and livestock ownership: These are considered to represent wealth. It is regularly hypothesized that the adoption of agricultural technologies requires sufficient financial well- being (Knowler and Bradshaw, 2007). On this line of argument, other studies, which investigate the impact of income on adoption, revealed a positive correlation (Franzel, 1999). Higher income farmers may be less risk averse, have more access to information, have a lower discount rate and longer term planning horizon (CIMMYT, 1993). Farmers with bigger land holding size are assumed to have the ability to purchase improved technologies and the capacity to bear risks if the technology fails. This has been confirmed in the case of fertilizer application in northern Tanzania (Nkonya et al., 1998), and Kenya (Hassan et al., 1998). Non-farm income, farm size and livestock ownership are hypothesized to increase adoption of adaptation technologies.

Extension: Extension on crop and livestock production and information on climate represent access to the information required to make decision on adaptation to climate variability. Various studies report a strong positive relationship between access to information and the adoption behaviours of farmers (Yirga, 2007). Maddison (2006), and Nhemachena and Hassan (2007) showed that access to information through extension increase the chance of adapting to climate variability and change. Thus, this study also hypothesizes that access to extension services and weather information increases chance of adopting adaptation technologies.

Credit: Availability of credit eases the cash constraints and allows farmers to use purchased inputs such as fertilizer, improved crop varieties and irrigation facilities. Researches on adoption of agricultural technologies indicate that there is a positive relationship between the level of adoption and the availability of credit (Yirga, 2007). Likewise, this study also hypothesizes that there is a positive relationship between availability of credit and adaptation.

Market access: Distance to market is assumed to play an important role in technology adoption. The hypothesis here is that, the further away a village or a household is from input and output markets, the smaller is the likelihood that they will adopt new technology. Proximity to market is an important determinant of adaptation, presumably because the market serves as a means of exchanging information with other farmers (Maddison, 2006). It is hypothesized that the lesser the distance to output and input markets, the more adaptation to climate change.

Rainfall variables: Detailed analysis of the relationships between climatic variables such as temperature and rainfall on adaptation requires a time series data of how farmers have behaved over time in response to changing climatic conditions (Maddison, 2006). As this type of data of farmers' response over time is not available, for this study, it is assumed that cross- sectional variations can proxy temporal variations. This study therefore relies on rainfall subjective index constructed from asking farmers a number of questions related to rainfall adequacy in the previous season. Long term rainfall indices (e.g. deviation from the 40-year running average, coefficient of variation) are also included to capture the effects of extreme events on the mean and variance of crop production. It is hypothesized that there is a positive relationship between adoption of production risk reducing technologies and an unfavourable rainfall pattern.

3.4.2 Perception of Rainfall Variability (Selection Model)

For the selection model, it was hypothesized that, gender, age, farming experience, and education of head of household; access to weather information, and access to extension services, influence the awareness of farmers of climate variability and change. The argument on the likely impact of education, age of household head on perception is more or less similar to the case with technology adoption; in that they make farmers to access to available and more information. Thus, the likely relationships follow the same argument as put in the outcome equation and thus are omitted here to reduce redundancy.

The case of information on climate change from either extension agents or any other organization is self-explanatory in that it is meant to create awareness. A set of dummy variables describing the local AEZs (represented by study districts) are included in anticipation of climate variability and change being more pronounced in some AEZs than in others.

3.4.3 Crop Production

The major explanatory variable is adoption of management practices, which is hypothesized to affect the mean and variance (risk) of crop production. Some technologies may be risk reducing, while others may be risk increasing under variable climatic conditions. Other explanatory variables included were; Rainfall variables (rainfall subjective index, mean seasonal rainfall and standard deviation of seasonal rainfall over the same period), plot-level covariates (use of chemical fertilizers, land size), and household-level covariates (sex, age, household size and education of household head).

Furthermore, district fixed effects were included to control for unobserved soil conditions as well as weather specific effects of the different agro-ecological zones.

The predicted impact of household characteristics on the mean and variance of crop production follows the same trend as described above for adoption of technologies, since their effect on production is through their direct effect on the farmers' ability to use technologies. Table 3.1 shows the summary statistics of the study variables.

Table 3.1: Summary Statistic for Study Variables

Variable	Description	Mean	SD
Dependent variables			
Technology adoption (T_{AD})	Dichotomous variable where $T_{AD} = 1$ if a farmer is using one of more technological options, and 0 otherwise.	0.71	0.46
Farmer perception of CV	Farmer has perceived climate change / variability (1=Yes, 0=No)	0.91	0.28
Crop production (expressed as VOP)	Value of crop production measured as output x price (UGX[1] '000' per hectare)	894	719
Independent variables			
Gender	Gender of household head (1=Male, 0=Female)	0.84	0.36
Chronological age	Age of the household head in years	44.93	14.89
Farming experience	Farming experience of the household head in years. Years of farming as the primary source of livelihood.	19.71	14.89
Education level	Level of education of the household head measured on a scale where 1=none, 2=Primary, 3=Secondary, 4=Tertiary	2.14	1.13

[1] Conversion rate used is 1USD = UGX2470 (The New Vision, June 11, 2012, Vol. 27 No.116)

Table 3.1: Continued

Variable	Description	Mean	SD
Household size	Number of household members	7.05	3.75
Off farm income	Farmer has off farm income source (1 = Yes, 0=No)	0.52	0.50
Livestock size	The number of cows, sheep and goats owned by the household (TLUs)[2]	0.90	0.06
Credit access	Farmer has access to credit formal or informal (1=Yes, 0=No)	0.44	0.50
Farm size	Total farm size in hectares	1.06	0.94
Fertilizer	Fertilizer applied (1=Yes, 0=No)	0.27	0.45
Extension access	Farmer has access to extension services (1=Yes, 0 = No)	0.39	0.49
Weather information access	Farmer has access to weather forecast information (1=Yes, 0=No)	0.70	0.46
Input market	Distance to input market in km	4.81	4.19
Output market	Distance to output market in km	3.84	5.59
Rainfall satisfaction index	Subjective index constructed from responses of a set of questions related to rainfall timeliness, amount and distribution	0.19	0.11
Local agro-ecology	Local agro-ecology represented by the study districts. District dummy 1 = 1 if Mbale, 0 otherwise; District dummy 2 = 1if Sironko, 0 otherwise		

Source: Field data, 2011

3.5 Study Area and Target Population

The study was carried out in Eastern Uganda. The region in general has about 6,301,677 people, which is 25.5% of the total population of Uganda (Uganda Bureau of Statistics [UBOS], 2002). The region has the highest mean

[2] TLU: Total Livestock Unit; **conversion factors**: cattle (0.50), sheep and goats (0.10), pigs (0.20), and poultry (0.01). Source: FAO (2005); Chilonda and Otte (2006)

population size per village with 304 households (Bashasha et al., 2008). More than 70% of the rural families in this region are involved in subsistence farming as the main source of livelihood. Major crops grown are bananas, coffee, maize, sweet potatoes and cassava, in the highlands and millet, sorghum and beans in the low lying areas of Pallisa.

The region comprises 32 districts[3] in three distinct agro-ecological zones (AEZ) - Lake Victoria Crescent and Mbale farm lands (L.Victoria Crescent), Southern and Eastern Lake Kyoga basin (SE L. Kyoga), and Mt. Elgon high farmlands (Mt. Elgon) (Wortmann and Eledu, 1999). The AEZs are largely determined by the amount of rainfall, which drives the agricultural potential and farming systems and range from sub-humid to semi-arid (Global Resources Information Database [GRID], 1987). They also capture variability in altitude, soil productivity, cropping systems, livestock systems, and land use intensity.

This study sampled one district per AEZ. That is Mbale, Pallisa, and Sironko from L. Victoria Crescent, SE L. Kyoga, and Mt. Elgon respectively. Figure 3.1 shows the general map of Uganda, study location and sample districts. Table 3.2 summarizes the characteristics of the sample districts, and their relevance to SSA agro-ecologies.

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[3] These are the districts reported by Ministry of Local Government as at August 2, 2010. Source: http://molg.go.ug/local-governments, accessed July 2, 2012.

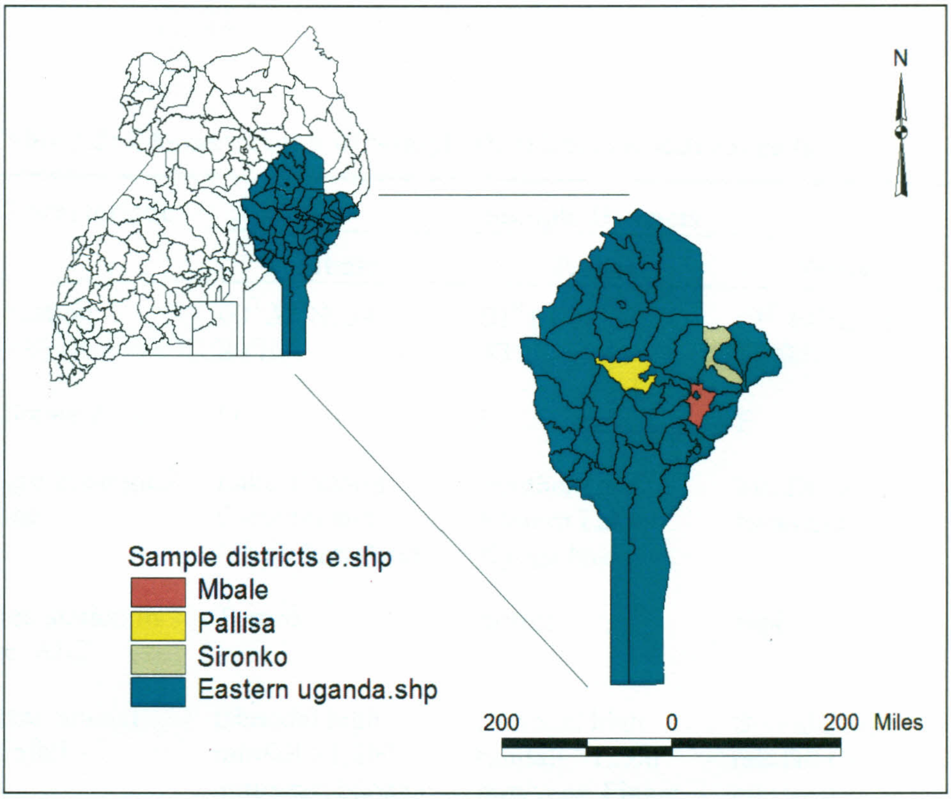

Figure 3.1: Map of Uganda showing the Study Location and Sample Districts

Source: Adopted and modified from www.ilri.org/GIS

Table 3.2: Characteristics of Sample Districts and Relevance to SSA

Characteristic	**Sample Districts**		
	Mbale	**Pallisa**	**Sironko**
Location	00^0 57'N, 34^0 20'E	01^0 01'N, 33^0 43'E	01^0 14'N, 34^0 15'E
Climate Zone	D	E	F
Agro-ecological zone	Lake Victoria Crescent and Mbale Farmlands	Southern and Eastern Lake Kyoga basin	Mt. Elgon High farmlands
Met. station in the AEZ	Tororo	Soroti	Sipi
Mean annual rainfall	Bimodal high rainfall >1,200 mm/year; banana, coffee farming system	Bimodal high rainfall >1,200 mm/year; Finger millet, banana, maize	Bimodal high rainfall (>1,200 mm/year); banana, Irish potato, and vegetables
Mean altitude (m.a.s.l)	1174	1075	1299 - 1524
Soils	Petric Plinthosols (Acric)	Gleysols (for Kumi area)	Vertisols
Population density	166.3/km^2 (431/sq mi)	252/km^2 (650/sq mi)	770/km^2 (2,000/sq mi)
SSA countries with similar biophysical characteristics	West-central (Democratic Republic of the Congo, Congo, etc.), and coastal region of western Africa	Countries along the desert margin (e.g., Burkina Faso, Northern and central Nigeria, Namibia, central Sudan)	Highlands of Cameroon, Ethiopia, Kenya, Malawi, Rwanda, and Tanzania (southern highlands)

Source: Adapted and modified from Wasige (2009)

Although all the AEZs of Uganda are grappling with the effects of climate change and variability, the Eastern region is most affected. This is attributable to the fact that the region is less socially and economically developed, and even among the generally poorer parts of Uganda as a whole. It is characterized by a combination of acute poverty, vulnerability to drought, floods and landslides, and natural resource degradation.

Recent floods in the Teso sub region and landslides in Bududa have led to crop loss and subsequent hunger and displacement of people (GOU, 2009). These climate challenges combined constrain crop production, increasing crop failure, and consequently exacerbating poverty. There is need therefore to develop options for adapting to climate variability and reducing its risk effects on agriculture, the key source of livelihoods for people in this region. Given the challenges in the region and the need to develop effective adaptation options, this study selected this region with a view that the findings would add value to both the local communities, local stakeholders and government as they work towards ensuring effective adaptation.

3.6 Sampling Procedure and Sample Size

Stratified random sampling technique was used, where AEZs formed the strata. Simple random sampling was used to select one district from each stratum. Mbale, Pallisa and Sironko districts were selected (refer to Table 3.2). A list of all sub-counties (S/C) and villages in each district was developed for purposes of sample selection. From each of the districts, three sub-counties were selected randomly and one village per sub-county giving a total of nine sample villages. At village level, a list of households (HHs) was obtained from the Local Council Chairperson, from which a random sample of respondents was drawn. A sample of 105 households per district was generated using coefficient of variation method. Using probability proportional to size, sample size per village was obtained, based on the village population vis avis the total sample required per district (Table 3.3).

Table 3.3: Study Districts, Sample Villages and Sample Size

District	# of S/C	Sampled S/C	Sampled villages	# of HH	Sample HH	# in FGD	KIIs *
Mbale	23	Bungokho	Mangho	136	39	12	7
		Mutoto	Bukumeka 1	86	25	12	
		Bumbobi	Nankombi	145	41	11	
		Total		367	105	35	7
Pallisa	18	Olok	Kadengerwa	186	32	12	8
		Apopong	Akum	197	34	12	
		Pallisa Rural	Komolo	227	39	12	
		Total		610	105	36	8
Sironko	19	Bumasifa	Jewa	105	39	12	8
		Buhugu	Buholiwa	99	36	10	
		Bumalimba	Kisenyi	80	30	11	
		Total		284	105	33	8

*Key informant interviews were conducted by district

In addition to household surveys, focus group discussions (FGDs) and key informant interviews (KIIs) were conducted, aimed at corroborating information from household interviews regarding selection and adoption of various technologies in the sample districts. From each of the nine sampled villages, one FGD was conducted. Focus groups reached 104 participants purposively selected from the sample villages based on the following criteria: education level, age and gender of respondent, primary activity, leadership responsibility, opinion leaders, village leaders, wealth category (including positive deviants), participation in village savings scheme, and distance to trading centre. Local Council Chairpersons played a key role in identification of the FGDs participants to ensure diversity and representation of all social-economic categories in the community.

A total of 23 key informants were also interviewed. They included; agricultural extension workers, district agricultural officers, agro-vet suppliers, chairpersons of village saving schemes, farmer group representatives, Local Council chairpersons, Research Officers, District Environment Officers, and Community Development Officers. These were purposively selected because of their perceived contribution to local adaptation to climate variability.

3.7 Research Instruments

A variety of research instruments were used to collect data from the respondents. Primary data was collected via two sets of questionnaires and FGDs (Appendix 3 a-c). The first questionnaire was administered to household heads, while the second was administered to key informants in the community and districts in general. Apart from the relevance of the instruments to the proposed data collection techniques, questionnaires and interview schedules were deemed best for collecting attitudinal and perceptual data from respondents. In total, nine FGDs were held, one in every village. The sizes of the focus groups varied between 10 and 12 members.

3.8 Data Types, Sources and Collection

Data were collected at two levels; household and district. Household data were entirely primary and were collected from households. In interviewing households, household heads or their spouses who were considered to be the main decision makers for the family regarding agricultural investment were targeted. Though selection of respondent households was random, minimum bias was employed to ensure gender representation, since gender was considered one of the independent variables for this study. At district level, key informant interviews were conducted. Primary data were obtained on various dependent and independent variables as described in section 3.4.

Crop production data were obtained by asking farmers to estimate area planted, crops planted per unit (including crops in an intercrop) and quantity harvested for the September – December 2010 growing season. Data on production technologies were obtained by taking an inventory of technologies used on cultivated plots during the base year, as opposed to crop specific. Moderator and intervening variables such as farmers' perceptions, use of purchased inputs, household socio-economic variables, access to information, credit, markets and extension services access were measured by directly asking farmers and marking on a measurement scale (Likert or subjective index scale), or binary scale for Yes and No responses.

Farmers' perceptions of climate variability were obtained by asking two sets of questions: first, if they had observed any change in rainfall pattern, and if so, how many years back they had noticed this change; and secondly, asking their perception of rainfall adequacy in the preceding agricultural season (August –November 2010, the base season for this study). The questions asked on rainfall adequacy included; whether rain came and stopped on time, whether there was enough rain at the beginning and during the growing season and whether it rained at harvest time (Table 3.4).

The responses for these questions were dichotomized in such a way that those who respond "on time" coded into one and others (early /late) into zero. The responses were analysed using Principal Component Analysis to obtain rainfall satisfaction index (RSI). The RSI was then included in various regression models as an explanatory variable.

Table 3.4: Rainfall Satisfaction Index Construction

	During the growing season preceding the last main harvest:*	Codes	Recorded into:	
1	Did the rainfall come on time?	1=on time; 2=too early; 3=too late	On time Others (2 and 3)	1 0
2	Was there enough rain on your fields at the beginning of the rainy season?	1=enough; 2=too little; 3=too much	Enough Others (2 and 3)	1 0
3	Was there enough rain on your fields during the growing season?	1=enough; 2=too little; 3=too much	Enough Others (2 and 3)	1 0
4	Did the rains stop on time on your fields?	1=on time; 2=too late; 3=too early	On time Others (2 and 3)	1 0
5	Did it rain near the harvest time?	1 = no; 2 = yes	No Others (2)	1 0
6	Number of rainfall days	1=No change; 2=Reduced; 3= Increased	No change Others (2 and 3)	1 0
7	Frequency of heavy rains	1=No change; 2=Reduced; 3=Increased	No change Others (2 and 3)	1 0
8	Frequency of dry spells	1=No change; 2=Reduced; 3=Increased	No change Others (2 and 3)	1 0
9	Duration of the growing season	1=No change; 2=Reduced; 3=Increased	No change Others (2 and 3)	1 0

* Reference was made to August - November 2010 rainy season

Historical rainfall data for the period 1971 to 2010 were collected by reviewing recorded data from the Meteorology Department of the Ministry of Water and Environment. Rainfall data were obtained from three meteorological stations[4]. That is Tororo, Soroti and Sipi was obtained, one from each of three studies agro-ecological zones (as shown in Table 3.1 above).

Farmers' perceptions of effectiveness of technologies they employ in reducing production risks were obtained using a five-point Likert scale. Farmers rated their technologies either as; very effective, effective, neither/nor, not effective, or very ineffective. This ranking may however be subjective as farmers may have considered other factors other than climate related in their judgement of the technologies. None the less, the perceptions of farmers are important in conditioning the technologies they adopt, therefore necessary if one is to make practical recommendations for technology adoption.

Other secondary data sources included; published literature, reports and statistical abstracts from National Agricultural Research Organization (NARO); Uganda Bureau of Statistics (UBOS); FAO Statistics; Ministry of Agriculture Animal Industry and Fisheries (MAAIF); and Global Resource Information Database. Appendix 2 summarizes the study variables, type of data collected and data sources.

3.9 Pilot study

The first draft of the research instruments was circulated to supervisors for purposes of ascertaining their construct validity and reliability. The suggestions given were then incorporated into the second draft, which was then

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[4] From each of the agro-ecological zones, there was one meteorological station from which data was collected to generalize for the AEZ. The location of the stations are different from the sampled districts. But for consistency in this report, only names of sampled districts will be used in all data presentations.

pre-tested on a sample of 20 households in Bubulo village in Mbale district that has similar characteristics to the study area. The number 20 was chosen for pre-test because according to Kathuri and Pals (1993) it is the smallest number that can yield meaningful results on data analysis in a survey research. The questionnaire was also checked for its reliability. The results of the pilot-test indicated a reliability coefficient of 0.7 for the whole instrument using the Cronbach's alpha coefficient. Based on the results of the pre-test, the questionnaire was then adjusted.

3.10 Logistical and Ethical Considerations

The research was undertaken in consultation with local leaders in the target districts and villages. Households' consent was sought before any data was recorded for the respective households. A dissemination meeting was held in the three sample districts, involving district officials, research and extension personnel, policy makers and farmers, to provide them with findings of the research as well as receive feedback on the key issues before writing the final thesis.

3.11 Data Analysis and Interpretation

After data collection, the questionnaires were cleaned for any errors made during data collection. Summarized and coded data were entered into EpiData and exported to Statistical Program for Social Scientists (SPSS), STATA and XLSTAT computer programmes for analysis. Content analysis was used in the analysis of qualitative data (Bryman, 2008). Qualitative analysis of information from community interviews and key informant interviews was continuous starting during data collection with identification of major themes and ending with an in-depth description of the results. Qualitative data were summarised according to key themes and illustrated by direct quotes, recounting particularly relevant experiences and views of smallholder farmers, essential for authenticity of findings.

Analysis of quantitative data involved both descriptive and econometric analyses, with the descriptive statistics involving multivariate analysis and paired *t*-tests for hypothesis testing. Analysis of variance was used to compare means of various variables by district to understand level of significance, as well as testing the variability of rainfall over time. Detailed analytical frameworks are indicated below presented by research question.

Research Question 1: What is the extent of variation of annual and seasonal rainfall in Eastern Uganda for the period 1971-2010?

Data for the three meteorological stations were analysed to characterise the variability and trends in the amount and distribution of rainfall. Data were first evaluated for discontinuities by inspection of each time series and then tested for homogeneity using the Student's t-test (von Storch and Zwiers, 1999) and found to be homogenous.

First moments of variation (minimum, maximum, mean, and standard deviation) were obtained using descriptive analysis. Graphical methods were used as a tool for visualization of temporal variation of annual and seasonal rainfall amounts over the study period – 1971 to 2010. Coefficient of Variation

(CV) and anomalies for rainfall were computed using spreadsheet based tools. Inter-annual variability in rainfall was evaluated by calculating the standardised anomalies for rainfall (SRA) using equation 3.8 (Oliver, 1980):

$$SRA = P_t - P_m / \sigma \qquad (3.8)$$

Where is P_t annual rainfall in year t, P_m is long-term mean annual rainfall over the period of observation and σ is standard deviation of rainfall.

Research Question 2: What factors influence farmers' decisions to adopt crop and land management practices for reducing production risks under rainfall variability in Eastern Uganda?

Heckman's sample selectivity probit model was used to analyze the two step process of technology adoption. The first stage involved analysis of perceptions of climate variability (selection model) and the second stage estimated adoption of new agricultural technologies for reducing production risk, conditional on the first stage of perceived change in climate (outcome model). The model outcome equation was defined as adoption of technologies and the model selection equation was defined as perception of climate variability by farmers. In addition, multivariate probit model was employed to assess the effect of various explanatory variables on adoption of individual management practices.

Research Question 3: What are the effects of farmer-preferred crop and land management practices on crop production risk under variable rainfall regimes?

Three stage Feasible Generalized Least Squares (FGLS) procedure was applied to estimate the parameters of equation (3.6) following Judge et al. (1982). In the first stage, y was regressed on $f(X, \beta)$ using ordinary least squares (OLS); in the second step, least square residuals were calculated as $\hat{\mu} = y - f(X, \beta)$, where $\hat{\mu}$ is a consistent estimate of μ, a heteroskedastic disturbance term with zero mean. In the third step, squared residuals were used as the dependent variable for the variance function estimation $h(X, \sigma)$ using OLS, where $h(.)$ is assumed to be in exponential form. In all three stages, district dummies were included to take fixed effects into account.

The estimated set of parameters β and α provide information about the effect of technology on mean and variability of crop production respectively. In other words, α is estimated with Log Yield variance regression in the second stage and it provides an estimate of effect of technology factors on the yield variability. On the other hand, β is estimated with Yield mean regression in the third stage and it gives an estimate of effect of technology on the variance yield. Here, the interpretation of positive coefficient implies that a higher yield variance is expected with an increase in the corresponding explanatory variable, keeping all other factors constant.

The Semi logarithmic functional form specification helped to improve normality of the dependent variable and residuals, thus reducing problems of nonlinearity, heteroskedasticity, and sensitivity to outliers (Kato et al., 2009).

The data were tested for multicollinearity using the variance inflation factors (VIF) and also by pair-wise correlations. Multicollinearity was not a serious problem: the VIFs were less than 3.0 and the pair-wise correlations were less than 0.5, indicating that the standard errors were not being affected by collinearity problems.

Research Question 4: What are the perceptions of farmers regarding the success of different crop and land management practices in reducing rainfall variability-induced production risks?

Descriptive analysis involving an examination of the frequency distribution for describing the responses on rating of each technology, using counts and percentages was done to analyse farmers' perceptions of technology effectiveness. The five-point Likert scale was used to rate farmers' perceived effectiveness of the technologies in reducing climate-induced production risks. The technologies were rated either as; very effective, effective, neither/nor, not effective, or very ineffective. This ranking is very subjective as farmers may have considered other factors other than climate related in their judgement of the technologies, as the effectiveness of a technology depends on a number of factors as described in results in chapter four. None the less, the perceptions of farmers are important in conditioning the technologies they adopt, therefore necessary if one is to make practical recommendations for technology adoption.

Other options for analysing perceptions such as factor analysis (FA), and principal components analysis (PCA) were not easily applicable because of the nature of the data collected for this research question. Farmers were asked to rank only the technologies they were using or had used before, not the entire range of technologies. So given that there were incomplete responses for the entire list of technologies, analytical tools such as FA and PCA were not possible. Content analysis was used to analyse qualitative data from community and key informant interviews.

CHAPTER FOUR

RESULTS

4.2 Descriptive Results

This section presents and discusses the distribution of the main variables in the study, both the dependent and independent. Study variables have been categorized and presented by the following categories: household socio-economic characteristics, land use pattern and ownership, livestock ownership, crop production, access to institutional support services, rainfall variables, and adoption of management practices. These are discussed in subsequent sub sections.

4.2.1 Respondent Characteristics

Data were obtained on respondent characteristics – age, gender and education level. At least 16% of the respondents were women (Table 4.1). There were proportionately more women respondents in Sironko as compared to Pallisa and Mbale.

In terms of age distribution of respondents, there were relatively more middle-aged respondents (41-55 years) across all the locations (Table 4.2). There was no statistically significant association between location and age distribution of respondents (ChiSq = 9.001, p = 0.342). Age and gender distribution of respondents showed a majority of female respondents above 55 years, while male respondents were majorly between 41 and 55 years (Table

4.3). Test of association showed significant association between gender and age difference of respondents (ChiSq = 18.469, $p = 0.018$).

Table 4.1: Proportion of Study Respondents by Sex

District	Number of respondents			% female
	Male	Female	Total	
Mbale	93	11	104	11
Pallisa	91	12	103	12
Sironko	79	26	105	25
Total	263	49	312	16
Pearson chi2(4) = 10.8589		P value = 0.028		

Table 4.2: Average age of respondents by location

District	Age of respondent in years				Total
	18-30	31-40	41-55	Above 55	respondents
Mbale	26	25	33	20	104
Pallisa	22	24	34	23	103
Sironko	14	25	35	31	105
Total	62	74	102	74	312
Pearson chi2(8) = 9.001			P value = 0.342		

Table 4.3: Average age of respondents by sex

Gender of	Age of respondent in years				Total
respondent	18-30	31-40	41-55	Above 55	respondents
Male	53	68	88	54	263
Female	9	6	14	20	49
Total	61	74	102	74	312
Pearson chi2(8)= 18.469			P value = 0.018		

The level of education in the surveyed communities was generally low, with the majority of respondents having primary level education (Table 4.4). At least 15% of the respondents had not received any formal education while 58% had undergone primary education only. Only 18% and 8% registered secondary and tertiary levels of education respectively, a significantly low representation. There was no statistically significant association between location and education level of respondents (ChiSq = 13.942, $p = 0.083$).

Table 4.4: Education level of respondent by location

Education level	District				% of total
	Mbale	Pallisa	Sironko	Total	
None	10	15	23	48	15
Primary	59	61	60	180	58
Secondary	29	18	13	60	19
Tertiary	6	9	9	24	8
Total	104	103	105	312	100
Pearson chi2(8) = 13.942			P value = 0.083		

4.2.2 Household Economic Characteristics

Average annual household income in the sampled villages was approximately Uganda Shillings (UGX) 1 million. With an average family size of seven persons, this gives a per capita income of UGX 143,571 (approximately USD58). Crop and livestock farming contributed highest to family incomes accounting for 44% and 20% respectively (Figure 4.1). Other sources of incomes for the sampled households included business, formal employment, and casual labour. Much as farming was the major source of household income for the sampled households, at least 52% of respondents indicated to have off farm sources of income, mainly trading.

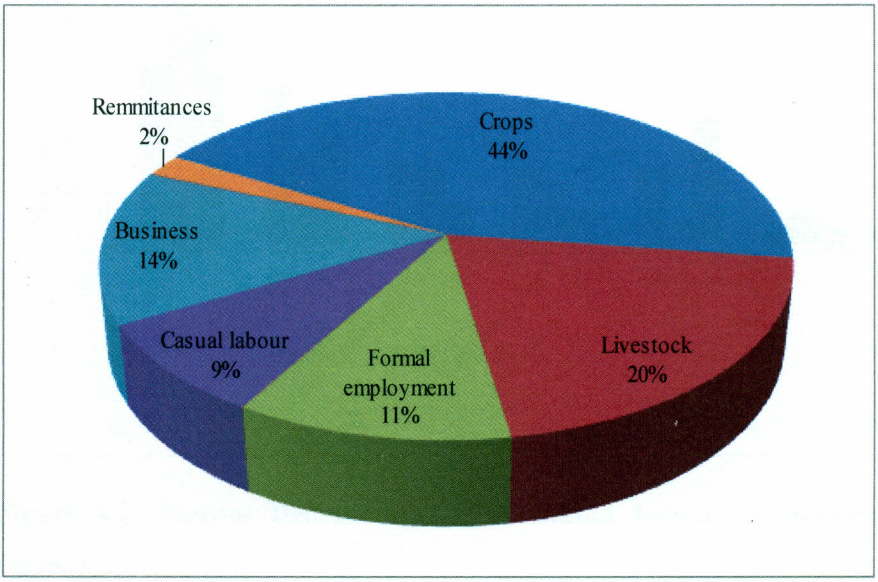


Figure 4.1: Distribution of Household Income by Source in the study Districts

Source: Field data, 2011

Household income was further disaggregated by district (Figure 4.2). Income from crops was the most important across all the districts contributing over 30% of total household income, on average. In Pallisa, crop income contributed up to 52% of all household incomes. Livestock income was most important in Mbale as compared to the other two districts, while business income was most important in Sironko. Income from remittances was proportionately higher in Pallisa as compared to Mbale and Sironko.

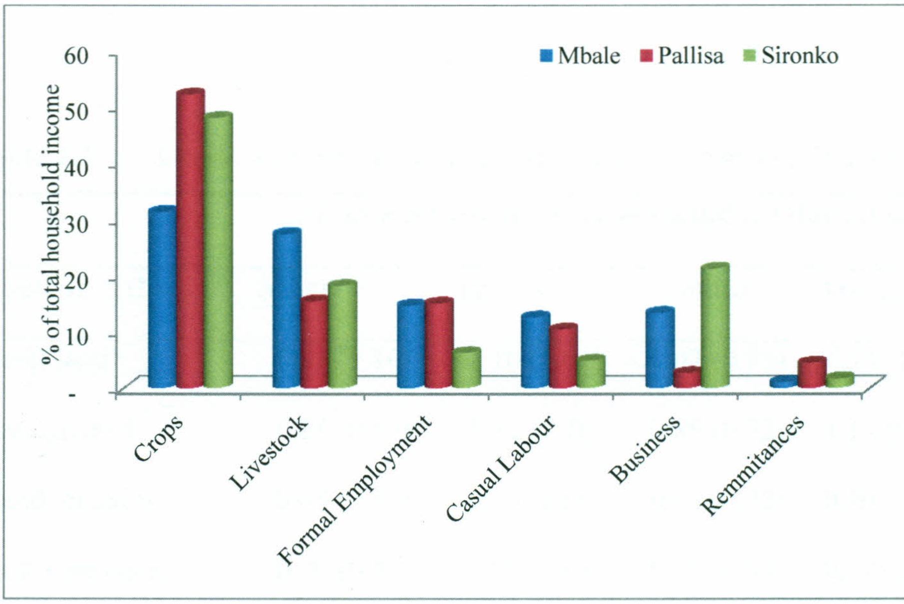


Figure 4.2: Percent Distribution of Household Income by Source and District

Source: Field data, 2011

4.2.3 Land Use Pattern and Ownership

Land ownership was classified into; owned, and rented in. For owned land, the average land size per household was 1.1 hectares with households in Pallisa having relatively more land than households in Mbale and Sironko (Table 4.5). About 20% of the farmers rented in land to expand their farming operations. Over 85% of the total land, is allocated to crop farming, and very small proportions (<5%) allocated to pasture, fallow or woodlots.

Table 4.5: Land Use Pattern in Sampled Villages in Eastern Uganda

	Mean land size in hectares (standard deviation)			
Land area (ha)	**Mbale**	**Pallisa**	**Sironko**	**Overall**
Total land*	0.89 (1.16)	2.10 (1.61)	1.02 (0.79)	1.33 (1.22)
Land owned	0.81 (0.59)	1.71 (1.16)	0.89 (0.72)	1.14 (0.95)
Land rented in	0.08 (0.17)	0.39 (1.06)	0.13 (0.28)	0.20 (0.65)
Cultivated land	0.70 (0.52)	1.50 (0.83)	0.71 (0.53)	0.97 (0.74)
Pasture land	0.07 (0.17)	0.09 (0.23)	0.04 (0.11)	0.07 (0.18)
Fallow land	0.03 (0.12)	0.12 (0.46)	0.07 (0.21)	0.07 (0.30)
Woodlot	0.01 (0.05)	0.00 (0.02)	0.07 (0.14)	0.03 (0.09)

*Total land = Land owned + Land rented in
Source: Field data, 2011

4.2.4 Livestock Ownership

Despite the fact that land allocation to livestock farming was limited, about 72% of the respondents indicated to own at least one type of livestock (Table 4.6). Livestock ownership expressed in total livestock units (TLU) was approximately 0.9 TLUs, with a standard deviation of 0.06. Local goats were the most popular, owned by 40% of households followed by local cattle and cross breed cattle. There were relatively more local goat and local cattle keepers in Pallisa as compared to other locations. Sironko on the other hand, has relatively more farmers engaged with cross breed cattle. These livestock are managed under open grazing on communal lands (particularly in Pallisa), while in more land restricted areas like Sironko and Mbale, cattle are managed under cut and carry system where they are fed mainly on crop and household residues. Also, Pallisa being mainly in the cattle corridor, with limited rainfall, farmers have moved more towards adoption of small ruminants and local cattle, which are considered to be more tolerant to hardy conditions.

Table 4.6: Livestock Ownership in the Sampled Villages in Eastern Uganda

Type of livestock	% who own livestock			
	Mbale	Pallisa	Sironko	Overall
Cross breed cattle	23	14	30	22
Local cattle	13	65	45	41
Improved goats	4	4	12	7
Local goats	31	60	30	40
Sheep	0	7	3	3
Improved pigs	0	2	1	1
Local pigs	5	19	10	12

Source: Field data, 2011

4.2.5 Crop Production

The major crops grown in the sampled villages included bananas, coffee, maize and beans in the highland areas, and millet, maize, sorghum, beans, ground nuts and green grams in the lower lying areas. Table 4.7 shows the average estimated value of crop production (VOP) from sampled households' plots per hectare. The VOP was highest in Sironko and lowest in Pallisa. The standard deviation was also high across the locations indicating that some households were earning almost twice per unit as compared to their counterparts.

Table 4.7: Value of Crop Production by District

District	VOP (UGX per hectare)	Std. Dev.
Mbale	630,834	802,968
Pallisa	449,203	476,200
Sironko	1,602,783	878,856
Average	894,273	719,341

Source: Field data, 2011

4.2.6 Access to Information and Institutional Support Services

The study established the level of farmer access to information and institutional support services. Farmers were asked if they or any member of their household had received information on weather forecast, new farming practices or technologies, and markets. In addition, farmers were asked if they had received extension or credit services. Responses were dichotomised and percentages of farmers receiving these services obtained (Table 4.8).

On average, 70% of respondents indicated to have received weather forecast information mainly through radio and farmer to farmer exchanges. There was a statistically significant difference between districts and access to weather forecast information (ChiSq = 89.633, $p = 0.000$). Noteworthy was the very low percentage response regarding access to information on agricultural risk management and improved production technologies for all the three study districts.

Table 4.8: Level of Access to Information and other Support Services

	Variable*	Proportion of respondents receiving information and services				Pearson chi2(2)	*p*-value
		Mbale	Pallisa	Sironko	Average		
1	Weather forecast	76	97	38	70	89.633	0.000
2	Production technologies	28	41	14	28	18.388	0.000
3	Agricultural risk management	09	01	04	05	6.717	0.035
4	Market information	69	65	51	62	45.378	0.000
5	Extension Services	35	51	32	39	9.301	0.010
6	Credit services	24	55	54	44	25.802	0.000

Source: Field data, 2011

In terms of access to credit, at least 44% of the respondents indicated that they have access to credit, majorly from village saving schemes. Credit was normally taken to meet immediate household requirements such as children's school fees, buy inputs (mainly seeds, fertilizer and pay for cropping labour). Only 39% of respondents reported to have accessed extension on crop and livestock farming. In Pallisa, there were relatively more farmers receiving extension as compared to the other two districts. Overall, there was statistically significant association between access to information and institutional services and study districts at $p \leq 0.05$.

4.2.7 Rainfall Variables

Descriptive analysis of observational rainfall data was done to obtain maximum, minimum and mean annual and seasonal rainfall as well as the standard deviation and coefficients of variation (CV) across the three sample districts (Table 4.6). Farmers in the study area recognise two rainy seasons – the 1st season stretching from March to June (MAMJ) and 2nd season from August to November (ASON), and these are the ones that were considered for computation of seasonal rainfall.

Mean annual rainfall in Eastern Uganda varied from 1368mm in Pallisa to 2058mm in Sironko. Mean seasonal rainfall was 522mm and 905mm in Mbale and Sironko, respectively. Sironko exhibits the highest mean rainfall both annually and seasonally, as compared to Mbale and Pallisa. Results of CV for annual and seasonal rainfall amount show CVs less than 30% for all locations, except season two for Sironko which shows a CV of 38%. The highest coefficients of variation were noted for Sironko area for both annual and seasonal rainfall. In addition, the variation was higher for season two as compared to season one for all locations.

In addition farmers' perceptions of rainfall variability were obtained by asking a series of questions related to rainfall adequacy in the previous growing season. Over 90% of the farmers interviewed had perceived change in rainfall pattern, dating as far back as 10 to 15 years. Rainfall subjective index (RSI) was created by PCA using the perception questions captured in the survey. The questions were checked for internal consistency using Cronbach's alpha test, and they exhibited high internal consistency of 0.85 ($p \leq 0.05$). Based on this statistic, all the questions were aggregated into and index.

Table 4.9: Rainfall Variables for Mbale, Pallisa and Sironko districts

Sample district	Rainfall	Annual (1971-2010)	Mar-Jun (MAMJ)	Aug-Nov. (ASON)
Mbale	Minimum (mm)	1018	445	283
	Maximum (mm)	2068	932	840
	Mean (mm)	1503	659	522
	Std. Dev.	226	123	137
	CV[5]	15.04	18.66	26.25
Pallisa	Minimum (mm)	895	306	271
	Maximum (mm)	1844	936	74
	Mean (mm)	1368	574	539
	Std. Dev.	231	14	115
	CV	16.89	2.44	21.34
Sironko	Minimum (mm)	1409	528	420
	Maximum (mm)	3001	1287	2546
	Mean (mm)	2058	812	905
	Std. Dev.	349	166	328
	CV	16.96	20.44	38.24

Source: Based on observational rainfall data from Meteorological department

Farmers' generally reported late on set of rain, poor distribution within the season, and sometimes early cessation. In particular, they noted that the first season had shifted from a start in early March to mid or late March and now ended in June rather than May. Meanwhile, they claimed the second

[5] Coefficient of variation

season had shifted from a start in August to September and now ended in November rather than December. Considerable differences between sample districts exist. In Pallisa, respondents highlighted drought in the first season as an increasing problem, and more frequent flash floods as a result of increased rainfall intensity. In Sironko and Mbale, increased rainfall intensity leading to increased ground water and water logging and landslides was reported.

4.2.8 Crop and Land Management Practices used by Farmers

An inventory of farmer preferred management practices was made based on responses obtained from the survey. For each of the management prtactices on farm, adoption was dichotomized, where a value of one was given if a farmer reported to use a particular technology in response to climate variability, and zero otherwise. Overall, 71% of the respondents had employed at least one management practice on farm. Farmers employed a number of crop and land management practices on their farm, either singly or in combination (Table 4.8). It should be noted that there were multiple responses on farmers using more than one management practice.

A majority of farmers generally changed sowing dates to coincide with onset of rain or planted as and when it rained. Another important crop management practice was intercropping, practiced by 72% of the respondents. Other crop management practices included; changing crop density, changing crop varieties, and changing crop association. On crop density, majority of farmers reported to have used more seed per unit area. This is linked to continuous planting, re-planting or gap filling. There were also cases of increased number of seeds per planting hill which also led to increased seed use per unit area.

Table 4.10: Proportion of Respondents using various Technologies by District

Management practices	Proportion of respondents using management technologies			Pearson chi2(2)	P- value
	Mbale	Pallisa	Sironko		
Crop management					
Changed sowing date	63	100	74	45.251	0.000
Crop density	35	75	34	50.194	0.000
Crop varieties	39	27	30	3.808	0.149
Crop rotation	6	94	29	176.472	0.000
Intercropping	55	82	83	27.082	0.000
Land management					
Soil bunds	48	48	19	24.283	0.000
Mulching	13	50	30	34.123	0.000
Grass strips	15	43	36	19.786	0.000
Compost manure	36	55	50	8.379	0.015
Cover crops	11	76	58	95.382	0.000
Inorganic fertilizer	7	8	67	126.816	0.000

Source: Field data, 2011

Farmers also reported change of crop varieties to early maturing varieties particularly maize, beans and ground nuts. There were cases of farmers in Sironko introducing non-traditional crops such as paddy rice and coco yam to cope with increased soil water and logging. In Pallisa, there were cases of farmers moving back to using local varieties of finger millet and sorghum, which they perceived to be more hardy and tolerant to prolonged dry spells as opposed to improved varieties.

Cover crops, compost manure and crop rotation were the most common land management practices employed by farmers in the sampled villages in that order. Other land management practices used by farmers included; soil bunds, terraces, mulching, water ways, grass strips, use of inorganic fertilizer and agro-forestry. Overall, by district, the three most common management practices were as follows: Mbale, altering sowing dates, intercropping and soil bunds; Pallisa, altering sowing dates, crop rotation and intercropping; and Sironko, altering sowing dates, intercropping and cover crops. Test of whether the observed differences in adoption of crop and land management practices per district were significantly different from zero indicates statistically significant differences in adoption of management practices in the three sample districts at $p \leq 0.05$. The strongest differences were observed for crop rotation, inorganic fertiliser and cover crops with ChiSq > 95 and p = 0.000.

Much as farmers generally indicated that they had changed their farming practices in response to climate variability, to better understand why farmers made these changes, the study also included response variables measuring reported reasons for change. In particular, the study primarily examined whether farmers made on farm changes due to any other reason, and not only changes that were specifically in response to weather and climate patterns. The data reflect only reported changes, and not whether a change was adaptive, a concept implying that a change confers some benefit to the farmer that made that change (Table 4.11).

Table 4.11: Farmers' Reasons for Adopting Various Crop and Land Management Practices in the Study Districts

Change drivers	Percent of respondents			
	Mbale	Pallisa	Sironko	Average
No change	60	0	25	28
Change*	40	100	75	72
Reasons for change**				
Poor rainfall pattern	43	33	27	33
To increase crop yield	29	17	18	20
Limited land	19	2	11	8
To spread risk	2	30	6	17
Reduce soil erosion	2	5	24	11
Reduce flooding / water logging	0	8	14	8
Limited labour	5	2	0	2
Low cost	0	3	0	1

*No change is the total number of farmers who reported making no crop or land management related change.
**Reasons for change are proportionately computed from only those who indicated to have changed their farming practices.

Farmers' reasons for using various crop and land management practices ranged from weather, to land and cost related reasons. Overall, climate related reasons (rainfall pattern, increase yield, reduce risk, reduce erosion and reduce flooding/water logging) were the commonly mentioned across the study districts. Limited land was a big factor in Mbale and Sironko rating 19% and 11% respectively.

4.3 Extent of Annual and Seasonal Rainfall Trends and Variability

Trend analysis using graphical visualization of annual rainfall for the period 1971 to 2010 showed that there is an increasing trend of total annual rainfall for Mbale and Sironko and a decreasing trend for Pallisa (Figure 4.3).

Seasonal rainfall for MAMJ and ASON indicated higher rainfall amounts for MAMJ than ASON in Mable and Pallisa as compared to the situation in Sironko (Figure 4.4). Similarly, in Pallisa, MAMJ rainfall is higher for the duration of study as compared to ASON. On the other hand, in Sironko, ASON rainfall was generally higher than MAMJ for the study period. Notable were the large peaks in ASON rainfall in 2007, and the general observed increases in rainfall in Sironko and Mable districts for the period 2005 to 2010.

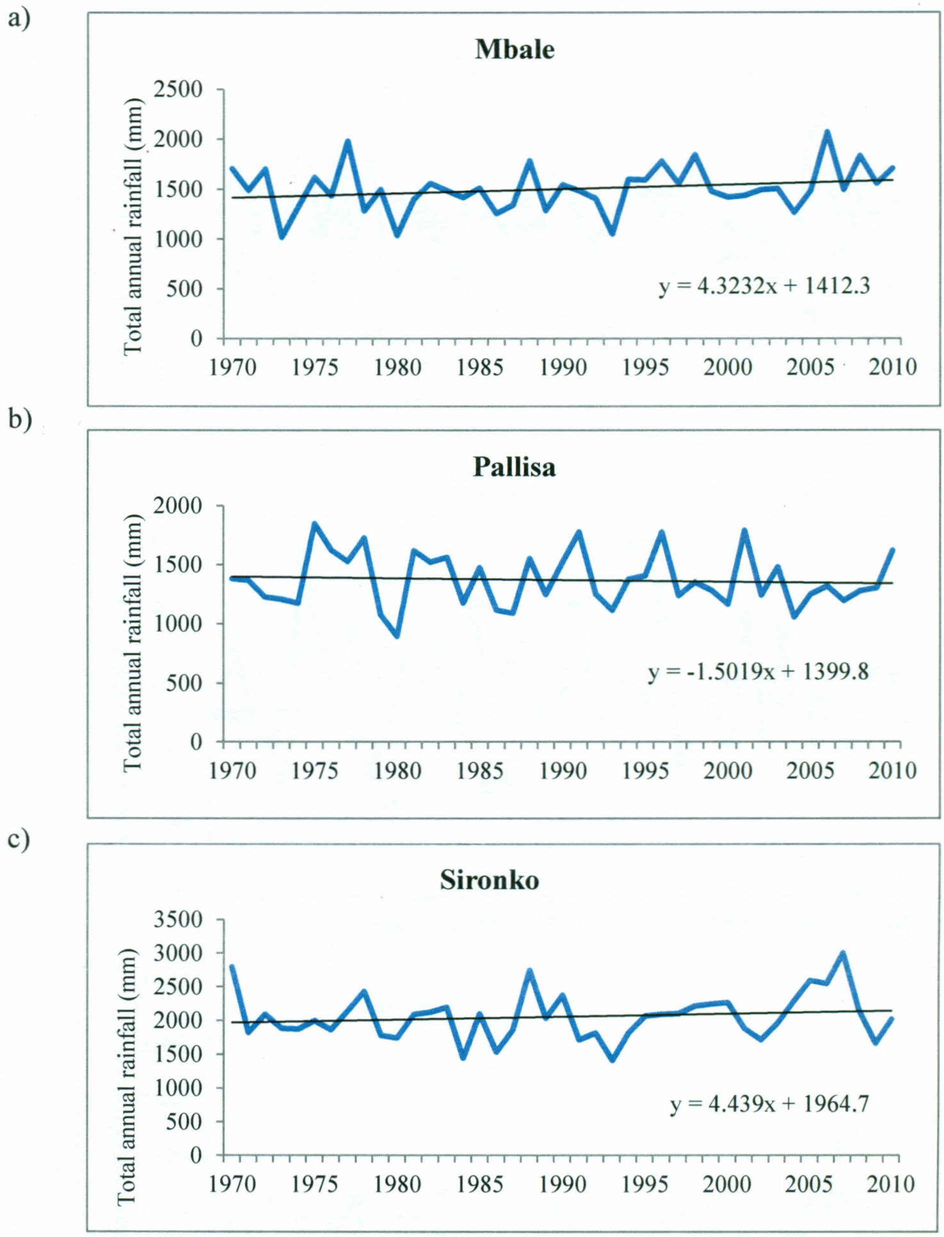


Figure 4.3: Trend of Annual Rainfall for (a) Mbale, (b) Pallisa and (c) Sironko

Source: Field data, 2011

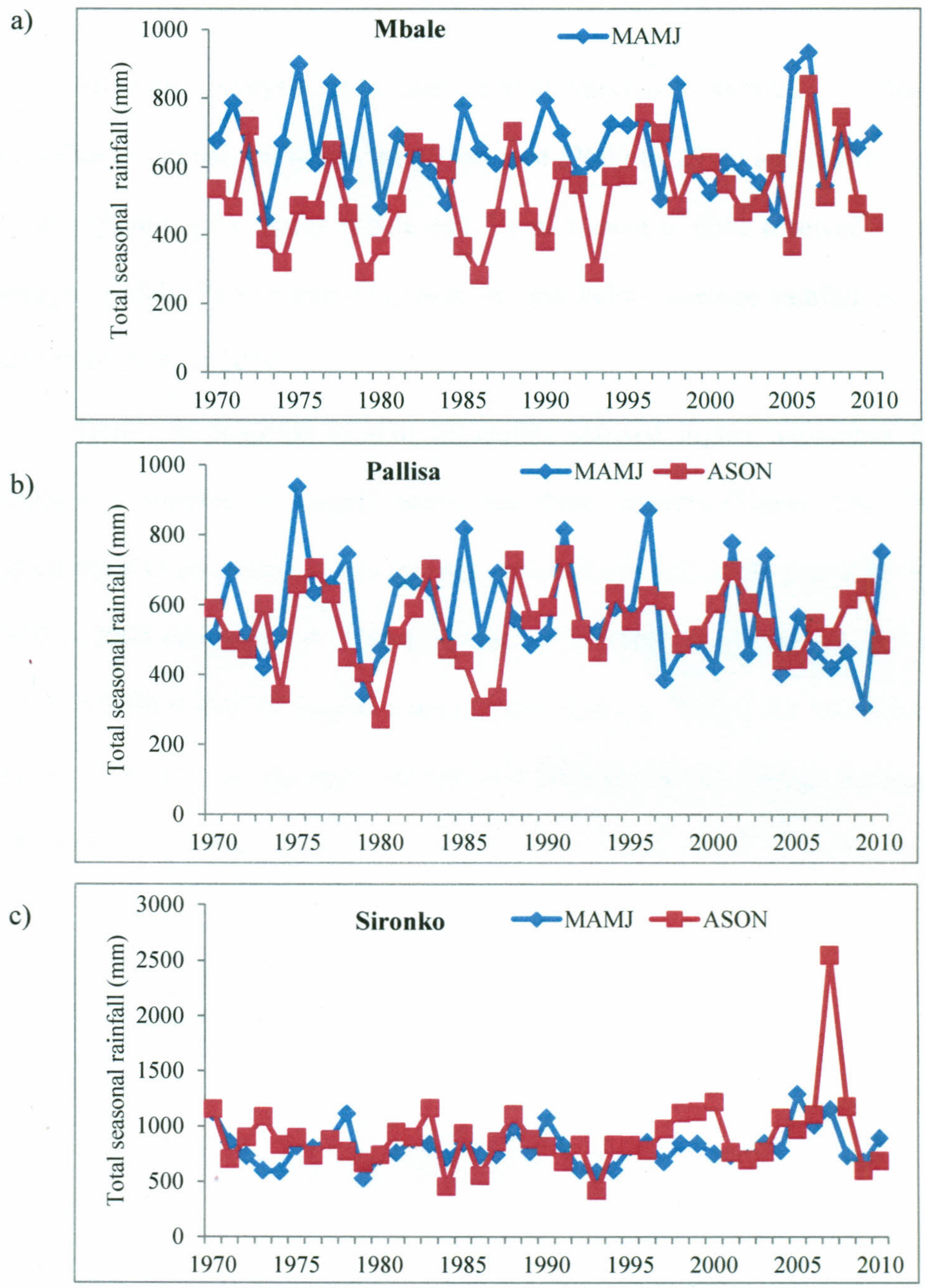


Figure 4.4: Trend of Seasonal Rainfall for (a) Mbale, (b) Pallisa and (c) Sironko

Source: Field data, 2011

Similarly, analysis of annual rainfall variability showed significant anomalies in annual rainfall in the recent past (2000 to 2010) across the three districts (Figure 4.5). While Mbale and Sironko seem to have received above average rainfall, Pallisa received more or less below average rainfall in the years from 2000 to 2010.

Trends in seasonal rainfall anomalies showed higher anomalies for ASON as compared to MAMJ across the three districts (Figure 4.6). The highest positive anomalies were recorded in Sironko (+4.6) in the year 2007 for ASON. 2006 recorded the highest anomalies for both ASON and MAMJ in Mbale. ASON exhibited higher negative anomalies in Pallisa for the period 1980 to 1990, and subsequently rainfall in Pallisa fell below average for most of the years after 1996.

a)

b)

c)

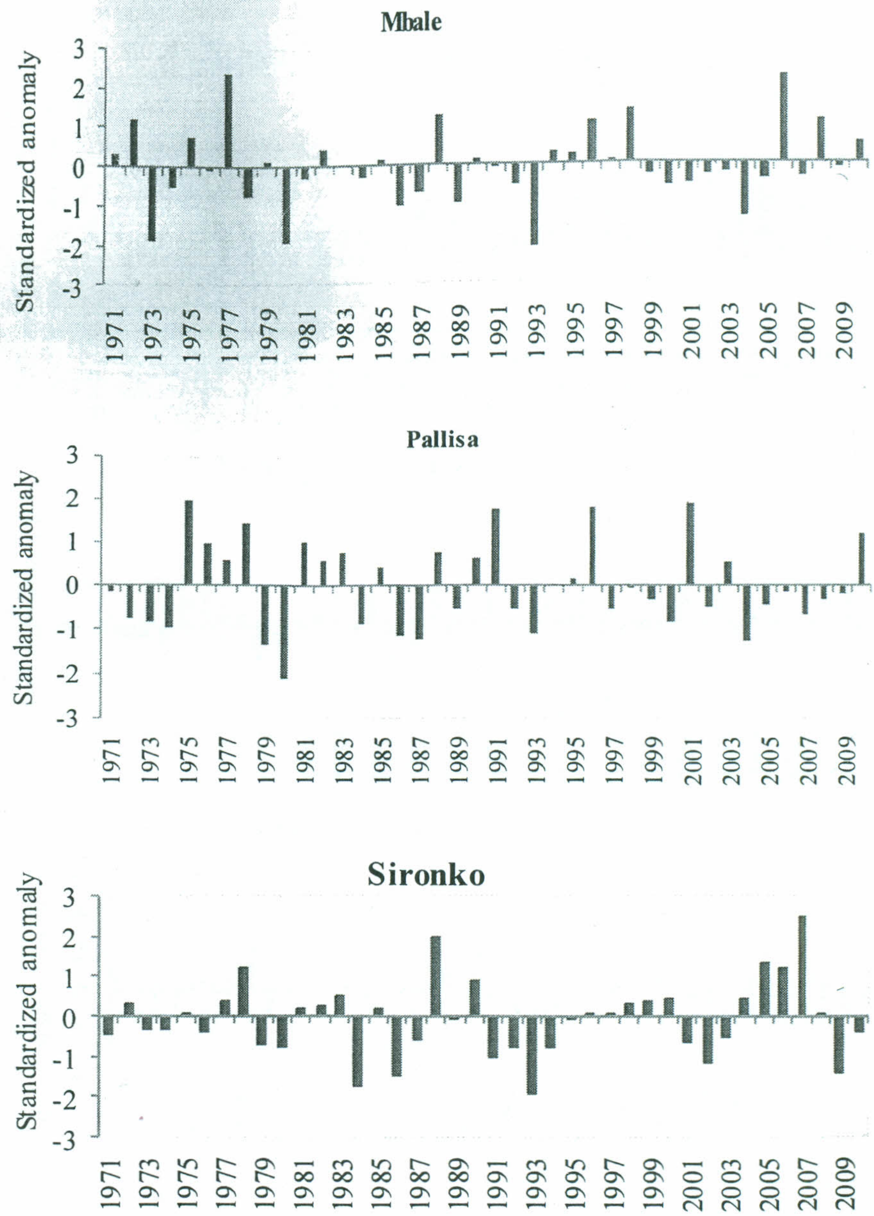
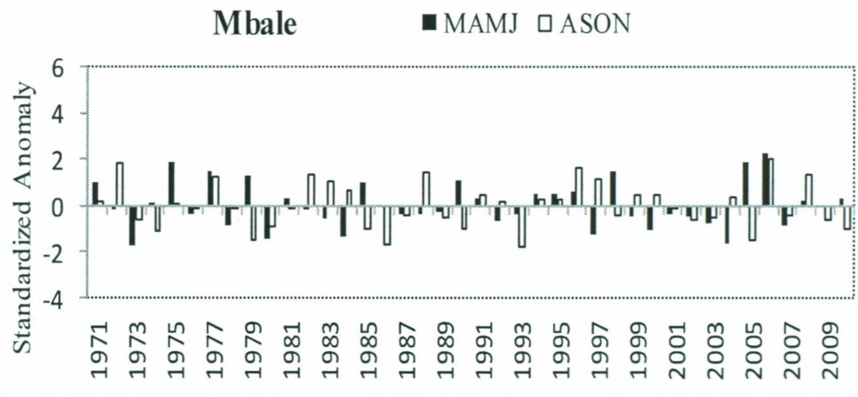
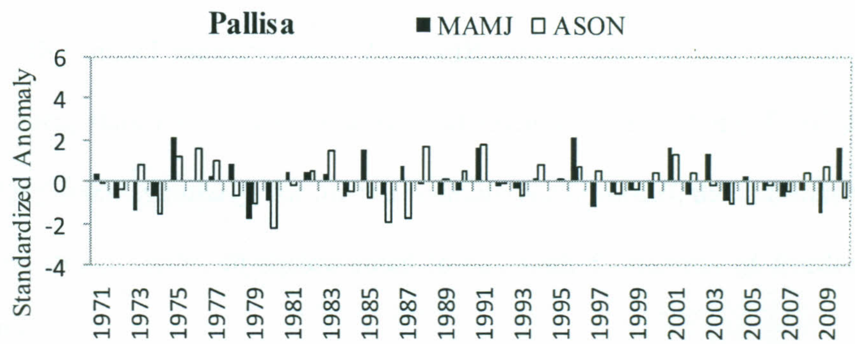


Figure 4.5: Trends in Annual Rainfall Anomalies Relative to the 1971-2010 Mean Rainfall for (a) Mbale, (b) Pallisa and (c) Sironko

a)



b)



c)

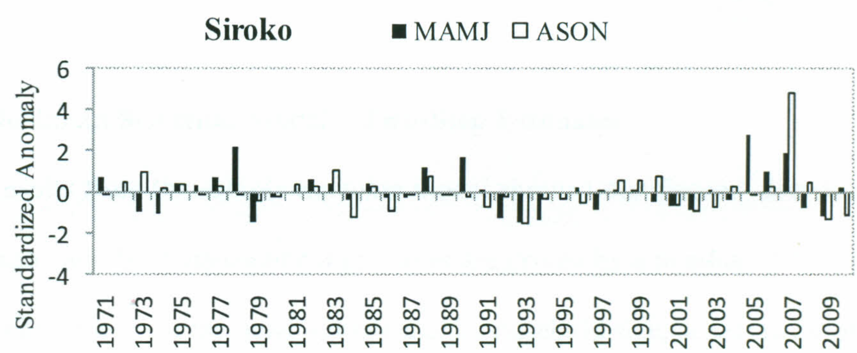


Figure 4.6: Trend in Seasonal Rainfall Anomalies Relative to the 1971-2010 Mean Rainfall for (a) Mbale, (b) Pallisa and (c) Sironko

Source: Field data, 2011

4.4 Factors Influencing Farmers' Decisions to Adopt Management Practices

Factors influencing farmers' decisions to adopt crop and land management practices were analyzed using the Heckman's sample selectivity probit and multivariate probit models. The models were first tested for fitness given the predicted variables using the Wald test. For the Heckman model, the chi-squared value generated by the Wald test was 179.82 with 16 degrees of freedom. The model indicated that the coefficients were not simultaneously equal to zero, thus the model variables statistically improved the fit of the model at $p \leq 0.05$. Similarly, for the multivariate probit model, the coefficients were equal to zero with chi-square equal to 423 with 55 degrees of freedom, and $p \leq 0.05$.

4.4.1 Heckman Selection Model – Two-Step Estimates

Results from the sample outcome model showed that farmer' decisions to adopt crop and land management practices are driven by a number of factors (Table 4.12). Gender of the head of household, household size, access to output markets, and perception of rainfall variability and residence of farmer in Pallisa compared to Mbale and Sironko significantly increased the probability of the farmer adopting management practices.

Table 4.12: Heckman's Sample Selection Model of Whether a Farmer Fails to Respond to Climate Variability

Variables	Outcome Model		Selection Model	
	Coefficient	Std. Err.	Coefficient	Std. Err.
Gender (M=1, F=0)	0.105*	0.063	0.266	0.301
Age (Years)	-0.001	0.002	0.002	0.012
Experience (Years)	-0.001	0.002	0.014	0.010
Education (None=1, Primary=2, Secondary=3, Tertiary=4)	0.009	0.018	0.046	0.099
Household size (#)	0.025***	0.006		
Off farm income (Yes=1, No=0)	-0.005*	0.049	0.118	0.257
Livestock (TLU)	0.023	0.021		
Credit (Yes=1, No=0)	0.057	0.046		
Extension (Yes=1, No=0)	0.065	0.048	-0.302	0.267
Weather information (Yes=1, No=0)			0.999***	0.269
Output market (km)	0.012**	0.006		
Input market (km)	-0.029***	0.008		
Farm size (acres)	-0.010	0.026		
Rainfall satisfaction index	0.348**	0.143		
D1= Mbale (cf. Pallisa)	-0.359***	0.767	-0.683	0.471
D2= Sironko (cf. Pallisa)	-0.148*	0.085	-0.936**	0.466
_cons	0.657***	0.122	0.930	0.639
Total obs	291			
Censored	26		265	
Rho	0.572		179.82	
Prob > chi2	0.0000			

Statistical significant at the 0.01 (***), 0.05 (**), 0.1 (*) level of probability

Source: Field data, 2011

On the other hand, access to off-farm income, input markets, and location in Mbale and Sironko compared to Pallisa negatively affected adoption of management practices. Institutional variables such as extension on crop and livestock, and access to credit were positively correlated with adoption of management practices, but were not significant in explaining the observed practice adoption at farm level.

Results of the selection model indicate that only access to weather information explains the perceived change in climate. Unlike the *a priori* expectations, local agro-ecology negatively affected perception of climate variability, with location in Sironko compared to Pallisa negatively related to farmer perception on climate variability.

From the marginal impact analysis of the various factors (Table 4.13), there are marked differences in the ability of farmers from different agro-ecologies to respond to climate variability. The probability of responding to climate variability by farmers in Mbale and Sironko was smaller by about 15% and 6% respectively as compared to Pallisa.

Male headed households had higher probability of adapting to rainfall variability which is revealed by the fact that a unit change from being headed by a female to male increases the probability of adapting to rainfall variability by 12%. Increasing household size, by one unit increased the probability of a farmer adopting adaptation practices by 23%. Likewise, the shorter the distance to the market where inputs are sold increases the probability of the farmer adopting production practices. A farmer who has perceived changes in rainfall has 9% chance of adopting new production practices than one who has not.

Table 4.13: Marginal Impacts of Adaptation to Climate Variability

Variable	δy/δx†	Std. Err.	Z value	P>|z|
Gender (Male=1, Female=0)	0.121*	0.074	1.64	0.101
Age (Years)	-0.085	0.132	-0.64	0.521
Experience (Years)	-0.038	0.058	-0.66	0.510
Education (None=1, Primary=2, Secondary=3, Tertiary=4)	0.026	0.053	0.49	0.625
Household size (#)	0.236***	0.056	4.19	0.000
Off farm income (Yes=1, No=0)	0.028	0.026	1.07	0.284
Livestock (TLU)	-0.004	0.035	-0.12	0.906
Credit (Yes=1, No=0)	0.035	0.028	1.24	0.213
Extension (Yes=1, No=0)	0.035	0.026	1.38	0.167
Output market (km)	0.064**	0.030	2.14	0.032
Input market (km)	-0.189***	0.053	-3.54	0.000
Farm size (acres)	-0.014	0.038	-0.37	0.712
Rainfall satisfaction index	0.090***	0.036	2.45	0.014
Dummy Mbale (cf Pallisa)	-0.152***	0.035	-4.31	0.000
Dummy Sironko (cf Pallisa)	-0.068*	0.041	-1.67	0.095

† y = Linear prediction (predict) = 0.740

Statistical significant at the 0.01 (***), 0.05 (**), 0.1 (*) level of probability

Source: Field data, 2011

4.4.2 Multivariate Probit Model Estimates

Multivariate probit model was used to simultaneously model the influence of a set of explanatory variables on each of the different crop and land management practices employed by farmers (Table 4.14). Changing sowing dates was significantly influenced by gender, age and education of household head, household size, access to weather information, and input markets. The same set of explanatory variables significantly affected adoption of crop rotation and crop density. Changing crop varieties was significantly affected by farmers' farming experience, access to credit, input markets, and location in Mbale and Sironko as compared to Pallisa.

Adoption of land management practices was also affected by a number of variables. Generally, farmers' experience, household size, access to credit, livestock ownership, access to weather information and farm size positively affected adoption of land management practices, though the level of significance varied. Adoption of soil bunds was significantly and positively affected by farming experience, household size, and availability of off farm income, access to credit, input markets and farm size.

On the other hand, some of the explanatory variables studied negatively affected adoption of crop and land management practices. Output markets, rainfall satisfaction index, and location in Sironko as compared to Pallisa generally had negative effects on adoption of management practices. While access to extension negatively affected adoption of crop management practices, it had a positive effect on adoption of land management practices, in general.

Table 4.14: Effect of Explanatory Variables on Adoption of Crop and Land Management Practices

Explanatory variables	Crop Management Practices				Land Management Practices						
	Sowing date	Crop Density	Crop varieties	Crop rotation	Soil bunds	Mulching	Grass strips	Compost manure	Cover crops	Intercropping	Inorganic Fertiliser
Gender (Male=1, Female=0)	0.228***	0.104*	0.016	0.137***	0.017	0.121**	(0.055)	(0.074)	0.033	0.184***	0.013
Age (Years)	0.006***	0.006**	0.001	0.003	(0.001)	0.000	0.001	0.004*	0.004**	0.001	(0.003)
Experience (Years)	(0.000)	0.002	0.004***	0.002	0.004*	0.005***	0.004	0.002	0.001	0.002	(0.002)
Education (None=1, Pri.=2, Sec.=3, Tert.4)	0.066***	0.074**	0.011	0.067***	(0.028)	(0.021)	0.029	(0.029)	0.043*	0.052*	(0.048)**
Household size (#)	0.018**	(0.004)	0.008	0.025***	0.022**	0.008	0.011	0.019*	0.024***	0.003	0.001
Off farm income (Yes=1, No=0)	0.044	0.047	0.022	0.061	0.177***	0.035	(0.049)	(0.012)	0.057	0.004	0.045
Livestock (TLU)	0.000	0.009	0.040	0.030	(0.029)	0.006	0.011	0.068**	0.039*	0.018	0.041**
Credit (Yes=1, No=0)	0.029	(0.054)	0.147***	0.005	0.154***	0.103*	0.215***	0.063	0.106**	0.049	0.049
Extension (Yes=1, No=0)	(0.039)	(0.119)**	(0.089)*	(0.021)	0.019	0.109**	0.072	0.143**	0.105**	0.023	0.076

Statistical significant at the 0.01 (***), 0.05 (**), 0.1 (*) level of probability

Source: Field data, 2011

Table 4.14 continued

Explanatory variables	Crop Management Practices				Land Management Practices						
	Sowing date	Crop Density	Crop varieties	Crop rotation	Soil bunds	Mulching	Grass strips	Compost manure	Cover crops	Intercropping	Inorganic Fertiliser
Weather information (Yes=1, No=0)	0.177***	0.244***	(0.006)	0.151***	0.047	0.046	0.101	0.104*	0.240***	0.202***	0.093
Output market (km)	(0.023)***	(0.019)***	(0.028)***	(0.025)***	0.004	(0.020)***	(0.007)	(0.021)***	(0.023)***	0.002	0.013***
Input market (km)	0.036***	0.016	0.029***	0.015*	0.026***	0.002	0.002	(0.011)	(0.025)***	0.000	0.000
Farm size (acres)	0.013	(0.038)	0.009	0.027	0.082***	0.028	(0.003)	0.066*	0.004	0.032	0.064***
Rainfall satisfaction index	(0.204)*	(0.044)	(0.383)	0.431	(0.150)	0.120	0.270*	0.323**	0.058	0.004***	(0.217)**
Dummy Mbale	0.020	(0.242)***	0.141*	(0.306)***	(0.179)**	(0.061)	0.090	0.225***	0.129*	0.221***	0.672***
Dummy Sironko	(0.343)***	(0.398)***	0.192**	(0.760)***	0.051	(0.206)**	(0.155)*	0.099	(0.287)***	(0.178)**	0.109*

Statistical significant at the 0.01 (***), 0.05 (**), 0.1 (*) level of probability

Source: Field data, 2011

4.5 Effects of Management Practices on the Mean and Variance of Crop Production

Results of the Just and Pope Production function (Table 4.15) showed that changed crop varieties, soil bunds, and inorganic fertilizer showed positive and significant impacts on the mean of crop output. Soil bunds showed the largest production elasticity among the management practices employed by farmers. The rest of the management practices showed either positive or negative impacts on mean of production but with no statistical significance.

Most of the management practices studied above showed significant effects on the variance of crop production. Changing sowing dates, changing crop varieties, soil bunds, compost manure, cover crops, crop rotation and intercropping all had significant negative coefficients on yield variability, thus are considered risk reducing. On the other hand, changing crop density and mulching had significant positive coefficients, implying that they are risk increasing.

Examination of effects of other non-technological variables on the mean and variance of crop production indicated that rainfall subjective index and rainfall standard deviation significantly and positively affected the mean yield, and negatively affected yield variability. Household social economic characteristics such as age of household head, education level, household size, gender of household head and farm size did not show any significant impacts on mean yield. Only farm size showed significant risk reducing effects on crop variability.

The effect of agro-ecology on mean and variance of yield was such that location in Mbale compared to Pallisa decreased the mean yield by about 25%, while location in Sironko compared to Pallisa as well increased the mean yield by 37%. Yield variability followed the opposite trend with location in Mbale having positive effects and location in Sironko negative effects, both compared to location in Pallisa. That means that location in Mbale was more risk increasing, and location in Sironko risk reducing in comparison to Pallisa.

Table 4.15: Effects of Management Practices on Mean and Variance of Crop Production

Management Practices	Log VOP for Mean		Log VOP for Variance	
	Coef.	Std. Err.	Coef.	Std. Err.
Management Practices				
Changed sowing date	0.110	0.246	-0.481*	0.753
Changed crop density	-0.093	0.128	0.340*	0.582
Changed crop varieties	0.456**	0.207	-0.951**	0.633
Crop rotation	0.209	0.301	-0.573*	0.921
Soil bunds	0.971***	0.197	-2.865***	0.607
Mulching	-0.149	0.232	0.765*	0.704
Grass strips	-0.222	0.224	0.107	0.690
Compost manure	0.217	0.192	-0.824*	0.591
Cover crops	0.257	0.242	-1.444*	0.744
Intercropping	0.259	0.211	-0.462*	0.642
Inorganic fertilizer	0.164*	0.152	-0.697*	0.808
Rainfall variables				
Rainfall subjective index	0.507**	0.584	-1.252	1.797
Mean seasonal rainfall	-0.516	0.003	0.000*	0.009
Std. Dev. rainfall	2.412*	1.518	-0.008*	0.017

Table 4.15 continued

Log VOP	Log VOP for Mean		Log VOP for Variance	
	Coef.	Std. Err.	Coef.	Std. Err.
Household characteristics				
Age of HH head (years)	-0.002	0.006	0.004	0.019
Education of HH head	-0.121	0.091	0.581	0.353
HH size (#)	0.009	0.091	0.006	0.079
Gender of HH head (1= Male)	0.099	0.294	-0.398	0.885
Farm size (acres)	0.071	0.101	-0.296*	0.308
District (cf. Pallisa)				
D1= Mbale	-2.561*	0.401	0.234	1.205
D2 = Sironko	3.713**	1.620	-0.856	4.871
Intercept	4.573	1.826	6.833*	5.490
R^2	0.250		0.211	
Adjusted R^2	0.189		0.151	
F	4.14		3.491	
Pr > F	0.000		< 0.0001	

VOP = Value of Production

Statistical significant at the 0.01 (***), 0.05 (**), 0.1 (*) level of probability

Source: Field data, 2011

Results further indicated varying effects of the various management practices on the mean and variance of crop production by district (Table 4.16). In Mbale, changed crop varieties and soil bunds showed significant positive effects on the mean of crop yield. In Pallisa, the management practices that showed positive impact on mean yield were, soil bunds, compost manure, and cover crops, while in Sironko, crop varieties, soil bunds, compost manure and intercropping showed significant positive impacts on yield. Of the yield enhancing technologies, only soil bunds, compost manure, intercropping and inorganic fertiliser showed significant risk reducing effects on crop yield.

Table 4.16: Effects of Management Practices on Mean and Variance of Crop Production by District

Management Practices	Mbale Log VOP		Pallisa Log VOP		Sironko Log VOP	
	Mean	Variance	Mean	Variance	Mean	Variance
Technologies						
Changed sowing date	0.305	-0.554	-1.671	3.866	-0.261*	0.534
Changed crop density	-0.037	-0.845	-0.125	1.339	-0.429***	0.732**
Changed crop varieties	0.995**	-0.192	-0.126	0.833	0.328*	-0.264
Soil bunds	1.508***	-4.812***	0.337*	-0.619*	0.395**	-0.191*
Mulching	-0.377	1.404	0.035	0.341	0.019	0.038
Grass strips	-0.424	2.556	-0.106	0.320	-0.400**	0.348
Compost manure	0.146	-0.697	0.817**	-3.225**	0.267*	-0.321
Cover crops	0.681	-0.407	0.695*	-1.243	0.111	-0.557
Crop rotation	0.539	-2.144	0.759	0.204	0.043	0.072
Intercropping	0.432	-1.068	-0.463	0.377	0.571***	-1.300***
Inorganic fertilizer	0.736	-1.508	-0.475	0.535	0.531***	-0.614*
Rainfall variables						
Rainfall subjective index	1.260	0.623	1.731	-5.786	0.417	-0.693
Mean seasonal rainfall	0.343	-2.574	-0.022	0.147	-0.001	0.003
SD rainfall	-0.002	-0.020	0.004	-0.016	-0.825	1.568

Table 4.16: Continued

Log VOP	Mbale		Pallisa		Sironko	
	Mean	Variance	Mean	Variance	Mean	Variance
Household variables						
Age of HH head	-0.010	0.019	0.005	-0.006	0.004	-0.011
Education of HH head	-0.713**	0.495	-0.059	0.203	-0.014	0.168
HH size	-0.018	0.059	0.009	-0.034	-0.045*	0.131**
Gender of HH head (= Male)	0.619	-2.678	-1.323	-1.343	-0.097	-0.309
Land variables						
Farm size	0.101	0.325	0.108	-0.531*	0.010	0.046
Intercept	-174.428	1351.872	15.113	-74.123	276.29	-515.2
Observations	104		102		104	
R^2	0.290	0.272	0.272	0.280	0.414	0.244
Adjusted R^2	0.119	0.097	0.092	0.102	0.273	0.061
F value	1.698	1.552	1.510	1.571	2.936	1.337
Pr > F	0.050	0.086	0.101	0.081	0.000	0.180

VOP = Value of Production

Statistical significant at the 0.01 (***), 0.05 (**), 0.1 (*) level of probability

Source: Field data, 2011

4.6 Effectiveness Scale of Farmer-Preferred Management Practices

Using the subjective effectiveness scale, farmers rated the various crop and land management practices they employed according to their judgement of their effectiveness in reducing risk of crop failure associated with rainfall variability. Subjective effectiveness analysis was done per management practice and by location (Table 4.17). On average, over 45% of the farmers agreed that their management practices were either very effective or effective in reducing risks associated with rainfall variability. This average however varied by management practice and location.

In Mbale, compost manure was rated as the most effective by the users. At least 73% rated it as either effective or very effective. Other technologies rated as effective in Mbale included, altering sowing date, changing crop density, changing crop varieties, mulching, and cover crops. However, intercropping, crop rotation, grass strips and soil bunds were rated as either not effective or farmers were not certain about their effectiveness in reducing production risks.

In Pallisa, farmers rated changing crop varieties (82%), changing sowing date (74%), compost manure (68%) and mulching (64%) as either effective or very effective in reducing production risks. Changing crop density on the other hand, though practiced by a majority of farmers in Pallisa as compared to Mbale and Sironko, about 62% of farmers in Pallisa rated it either as ineffective or they could not establish its effectiveness in reducing production risks. Other practices considered to be less effective in Pallisa were, mulching, grass strips, cover crops, and intercropping. In Sironko, most of the management practices were rated as effective or very effective by over 65% of the respondents (on average). Management practices considered least effective were, changing sowing date and changing crop density.

There were also a high proportion of farmers that were not able to assess the effectiveness of the management practices they employ on their farms in reducing production risks, especially in Mbale and Pallisa. A majority of farmers in Mbale using crop rotation, grass strips and soil bunds were not sure of their effectiveness in reducing production risks. It is no wonder that these management practices were employed by a very small proportion of farmers. On the contrary, in Pallisa, the management practices where farmers were not sure of their effectiveness were practiced by a majority of farmers. For example, intercropping, crop rotation, cover crops and grass strips.

Table 4.17: Subjective Effectiveness Scale of Farmer-Preferred Crop and Land Management Practices

Location	Scale*	Sowing date		Crop density		Crop varieties		Soil bunds		Mulching	
		Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Mbale	5	26	40	17	47	16	39	11	22	7	54
	4	15	23	7	19	12	29	10	20	1	8
	3	19	29	7	19	10	24	26	52	3	23
	2	-	-	2	6	3	7	1	2	-	-
	1	5	8	3	8	-	-	2	4	2	15
	Total	65	100	36	100	41	100	50	100	13	100
Pallisa	5	58	57	7	9	18	64	5	10	4	8
	4	17	17	22	29	5	18	20	41	6	12
	3	26	25	18	23	4	14	24	49	41	80
	2	-	-	2	3	-	-	-	-	-	-
	1	1	1	28	36	1	4	-	-	-	-
	Total	102	100	77	100	28	100	49	100	51	100
Sironko	5	36	47	11	31	29	94	13	65	26	84
	4	-	-	-	-	-	-	2	10	-	-
	3	-	-	-	-	-	-	5	25	5	16
	2	-	-	-	-	-	-	-	-	-	-
	1	41	53	24	69	2	6	-	-	-	-
	Total	77	100	35	100	31	100	20	100	31	100
Average	5	120	49	35	24	63	63	29	24	37	39
	4	32	13	29	20	17	17	32	27	7	7
	3	45	18	25	17	14	14	55	46	49	52
	2	-	-	4	3	3	3	1	1	-	-
	1	47	19	55	37	3	3	2	2	2	2
	Total	244	100	148	100	100	100	119	100	95	100

*Scale is given as: 5 = Very effective; 4 = Effective; 3 = Not sure; 2 = Somehow effective; 1 = Not effective

Source: Field data, 2011

Table 4.17: Continued

Location	Scale*	Grass strips		Compost manure		Cover crops		Crop rotation		Intercropping	
		Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Mbale	5	1	6	19	51	4	36	1	17	13	23
	4	4	25	8	22	2	18	1	17	13	23
	3	10	63	6	16	-	-	4	67	29	51
	2	1	6	1	3	3	27	-	-	1	2
	1	-	-	3	8	2	18	-	-	1	2
	Total	16	100	37	100	11	100	6	100	57	100
Pallisa	5	4	9	24	43	1	1	15	16	21	25
	4	5	11	14	25	12	15	13	14	19	23
	3	35	80	17	30	63	81	66	69	38	45
	2	-	-	-	-	1	1	-	-	5	6
	1	-	-	1	2	1	1	2	2	1	1
	Total	44	100	56	100	78	100	96	100	84	100
Sironko	5	26	70	34	65	39	65	20	67	39	45
	4	-	-	5	10	1	2	-	-	17	20
	3	10	27	11	21	19	32	9	30	28	33
	2	-	-	-	-	1	2	-	-	1	1
	1	1	3	2	4	-	-	1	3	1	1
	Total	37	100	52	100	60	100	30	100	86	100
Average	5	31	32	77	53	44	30	36	27	73	32
	4	9	9	27	19	15	10	14	11	49	22
	3	55	57	34	23	82	55	79	60	95	42
	2	1	1	1	1	5	3	-	-	7	3
	1	1	1	6	4	3	2	3	2	3	1
	Total	97	100	145	100	149	100	132	100	227	100

*Scale is given as: 5 = Very effective; 4 = Effective; 3 = Not sure; 2 = Somehow effective; 1 = Not effective

Source: Field data, 2011

CHAPTER FIVE

DISCUSSION

5.1 Introduction

This chapter discusses the findings revealed in chapter four. Through it, evidence supporting the findings and reasons for occurrence of the findings are provided. The discussion also provides an opportunity for comparing the findings of this study with those of other scholars to establish a perspective for the study. The in-depth discussion of the study findings also forms a basis for drawing conclusions about the study and making recommendations to policy makers and policy implementers.

The chapter is organized in six sections. Section 5.2 discusses the descriptive results. Section 5.3 discusses results of annual and seasonal rainfall trends and variability. In sections 5.4 and 5.5, results of management practices employed by farmers and the factors influencing farmers' decisions to adopt the various practices are discussed. Sections 5.6 and 5.7 discuss effects of the various farmer-preferred management practices on the mean and variance of crop production; and the subjective effectiveness scale of technologies in reducing production risks respectively.

5.2 Descriptive Statistics

Agriculture in Eastern Uganda is characterized by mixed crop and livestock farming, and these also contribute the largest proportions to household incomes. There were differences in land use patterns by district, with relatively more local cattle and goats reared in Pallisa as compared to Mbale and Sironko. This could be linked to the fact that households in Pallisa had relatively more land, and also the existence of communal grazing lands in Pallisa as compared to the other two districts. Further, Pallisa falls in the cattle corridor of Uganda, characterised by relatively low crop production potential. In Sironko on the other hand, farmers reared cross bred cattle under restricted feeding. This may be attributed to limited land available in the highland areas.

The VOP averaged at UGX 894,273 per hectare (approximately USD363), highest in Sironko and lowest in Pallisa. However, given the small land holdings in the study location, this translates into small incomes for farming households as indicated by per capita income. The difference in VOP may be directly linked to the crops grown as well as commercialisation of crops. For example in Sironko, the major crop grown was maize of which 90% is traded to markets in Kenya. In Pallisa, most of the crops grown were majorly food crops that may have low value and low commercialisation for example finger millet, sorghum and green grams. In Sironko and Mbale, there was also mixed coffee and banana farming system. Coffee being high value crop could explain the higher incomes from crop production. Banana is also demanded within the region and nationally thus fetching higher farm incomes for households engaged in its production. Similarly, the difference in VOP may be linked to differences in crop and land management practices used, agricultural potential of the area and rainfall amounts and distribution which affect expected yield.

Pender and Gebremedhin (2006) in their study on land management, crop production, and household incomes in the highlands of Tigray in Northern Ethiopia noted that land investments and land management practices, have statistically significant influences on the value of crop production. In the same study Pender and Gebremedhin observed that "many of the same factors that affect the value of crop production also affect per capita income" (p.127).

In terms of access to information and institutional support services, a greater proportion of households in Pallisa indicated that they have access to information and other services, as compared to Mbale and Sironko. Significant differences were also noted across the three districts in terms of access to information. This difference may be attributed to ease of accessing these locations by extension agents. Pallisa is generally easily accessible with good road network as compared to Sironko and parts of Mbale that are generally hilly and hard to reach.

5.3 Extent of Annual and Seasonal Rainfall Trends and Variability

Study results showed that mean annual rainfall in Eastern Uganda varies from 1368 mm in Pallisa to 2058 mm in Sironko. In comparison, the average long-term annual rainfall for Uganda is 1318 mm, which is considered adequate to support agricultural activities (Osbahr et al., 2011). This implies that Eastern Uganda receives adequate rainfall to support agriculture. However, study results indicated significant variation in its distribution both on the annual and seasonal scales. This also varied by district, with Sironko having relatively higher rainfall amounts and more variability in seasons than Pallisa and Mbale. Seasonal trends generally indicated decreasing and increasing rainfall for MAMJ and ASON respectively.

These results are in line with those of earlier studies in Uganda and government analysis reports which indicated increasing trends in inter-annual rainfall, and decreasing trends in March-April-May (MAM) rainfall (GOU, 2007; Goulden, 2008; Hepworth and Goulden, 2008; Osbahr et al., 2011). Although McSweeney et al. (2008) reported decrease in annual rainfall, they agreed that the MAM rainfall is decreasing. FEWSNET (2012) indicated that 2000–2009 rainfall was on average, about 8 percent lower than rainfall between 1920 and 1969.

The high coefficients of variation in ASON rainfall indicate greater variability in the season, especially in Sironko. According to Araya and Stroosnijder (2011), a CV > 30% is an indicator of large rainfall variability. This anomaly could be attributed to very high rainfall amounts received during 2007, linked to El Nino rains that characterised the OND season in Uganda (GOU, 2009). Links between El Nino and climate variability have also been suggested by other studies (e.g. Anyah and Semazzi, 2007). Shisanya et al. (2011) also reported above normal rainfall during OND season than preceding MAM rainfall in ASALs of Kenya during El Nino years.

In terms of variability, seasonal rainfall in Eastern Uganda varies a lot around the mean, with occasions of subsequent below average rainfall. The variations are more pronounced for ASON than MAMJ seasons, and in the years from 2006 to 2010. Mutai et al. (1998), and Phillips and McIntyre (2000) also observed that OND variability is stronger than MAM.

Farmers' perceptions of climate variability were in line with these findings, noting variability in the duration, timing and distribution within seasons, including in winds and heavy rains at the start of the seasons. This is a common finding from other studies on perceptions of resource users of climate change such as in the Sahel (Mertz et al., 2009), Nile basin of Ethiopia (Deressa et al., 2008), semi-arid central Tanzania (Slegers, 2008); Asia (Marin, 2010) and Uganda (Magrath, 2010), where farmers perceived increased variability of rainfall and shifts in the growing seasons.

Seasonal distribution of rainfall affects the decisions made by farming households on what type of crops to grow and land management practices to adopt (Komutunga and Musiitwa, 2001). In addition, excessive rains both in intensity and duration lead to water logging conditions that negatively affect crops and pasture (GOU, 2007; Komutunga and Musiitwa, 2001). For example drought in 2008 caused an average reduction in yield of 50% of simsim, sorghum, groundnuts, cassava and maize in Uganda (Ocowunb, 2009). Heavy rainfall experienced between 2006 and 2010 is responsible for massive floods in the low land areas and numerous landslides in the mountainous regions in Eastern Uganda (GOU, 2009), affecting crop production and people's livelihoods.

In related studies in East Africa, Recha et al. (2012) reported that persistence of below normal rainfall is a great risk to people's livelihood in Tharaka district in Kenya, where majority of people have been left vulnerable to hunger and famine. Similar observations have been reported by various scholars studying, for example intra-seasonal factors, such as the timing of the onset of first rains affecting crop-planting regimes (Tennant and Hewitson, 2002), the distribution and length of period of rain during the growing season (Mortimore and Adams, 2001), and the effectiveness of the rains in each precipitation event (Usman and Reason, 2004), are the real criteria that affect the effectiveness and success of farming. IPCC (2007) reported that changes in rain-fall amount and patterns also affect soil erosion rates and soil moisture, both of which are important for crop yields.

From the farmers' perspective, this uncertainty in addition to increasing food insecurity due to crop failure generally increases the cost of production as sometimes farmers have to re-plough and replant destroyed crop fields. As noted by Olupot John (37 years) from Kadengerwa village, Pallisa district in a focus group discussion during this study:

> *"We've stopped even adopting seasonal planting, because it's useless. Now we just try all the time. We used to plant in March, and that would be it. Now we plant and plant again. We waste a lot of seeds that way, and our time and energy. Sometimes we've hired labour and end up losing all that money for preparing land".*

5.4 Farmers' Response Mechanisms to Rainfall Variability

In response to both perceived and actual rainfall variability, farmers in Eastern Uganda employed a number of crop and land management practices aimed at reducing production risks associated with the varying rainfall patterns. Crop management practices are those practices aimed at ensuring proper timing of farming operations or proper mix of crops in the field to reduce the risk of crop failure (Mubiru, 2010). Land management practices on the other hand are those practices aimed at improving the productivity of the land and include practices for fertility management and soil and water conservation (Akponikpe et al., 2010).

Rainfall variability response strategies reported by farmers in Eastern Uganda are comparable with measures identified by climate change research community in Uganda and Africa as a whole as detailed by various authors for example Bradshaw et al., 2004; Kurukulasuriya and Mendelsohn, 2006a; Maddison, 2006; Mubiru, 2010; Mubiru and Magunda, 2010; Nhemachena and Hassan, 2007; and Nzuma et al., 2010.

Altering sowing dates was intended to ensure that sowing/planting coincide with onset of rain. The decisions by farmers whether to plant or not were generally dependent on their prediction of start of rains. Similar practice has been observed in Tanzania (Liwenga et al., 2007; Mary and Majule, 2009), where farmers planted before rain onset (dry land) on uncultivated land, immediately after rain, or a few days after the first rains. This technique ensures risk distribution by ensuring that any rain is utilized to the maximum by the crop planted in the dry field.

Given challenges with acquiring seed, it is expected that farmers would ensure appropriate seeding to avoid any wastages. On the contrary, farmers reported to have increased the number of seeds planted per hill, which translates into increased seed density. When asked the rationale for increasing seeds per planting hill, Akol Pricilla (68), one of the participants in a focus group discussion conducted during this study in Komolo village, Pallisa district had this to say:

> *"When we plant more seeds in each planting hole, chances of seed survival are increased. The seeds that are in the middle, not in direct contact with soil retain the moisture while the ones in contact with the soil are burnt away when it gets very hot. Therefore, we still have some seeds germinating even when there has been a dry spell immediately after planting. If we are lucky and the rain is normal, then we thin out the extra plants."*

Farmers also indicated to have changed crop varieties, moving to crops they thought would perform better under the prevailing climatic conditions. Kurukulasuriya and Mendelsohn (2006a), note that farmers adapt their crop choices to suit the local conditions that they face. For example, farmers in dry regions choose millet and sorghum whereas farmers in wet regions choose maize-beans, cowpea-sorghum, and maize – groundnut combinations or mixes. However, farmers often select a crop combination that will survive the harsh conditions, such as maize-beans, cowpea-sorghum, and millet-groundnut.

Intercropping was also used to ensure optimum utilization of the available plots of land and spread the risk of crop failure. Farmers are assured of at least getting some output from one of the crops in an intercrop. Dixon et al. (2001) showed that mixed cropping systems reduce risk, reduce crop losses from pests and diseases and make more efficient use of farm labour. Further, Dixon et al. noted that at the level of the individual farm unit, farmers typically cultivate 10 or more crops in diverse mixtures that vary across soil type, topographical position and distance from the household compound.

Utilization of land management practices on the other hand greatly varied across the sample districts. Cover crops, crop rotation and soil bunds (trenches), are majorly practiced in Pallisa, for moisture retention and fertility improvement. Being a low lying area with frequent dry spells, and episodes of flash floods, soil bunds are used to collect and retain water in the fields (or contain excess water which would normally cause flooding). Given the land use practices in Pallisa, cover crops and intercrops of cereals and legumes provide better options for ensuring moisture retention, and fertility improvement.

Compost manure, cover crops and grass strips were mainly practiced in Sironko. Increased use of compost manure could be linked to the practice of zero grazing (or stall feeding) mainly practiced in Sironko. Being a high ground area, the use of cover crops and grass strips were intended to reduce run off from the steep slopes and stabilize the soils. Interestingly, in Sironko, over 66% of the households use inorganic fertilizers. This partially explains the high value of production in Sironko as opposed to Mbale and Pallisa, though there is need to understand the comparative net benefits and factors driving inorganic fertilizer use in Sironko. This study has not looked at this aspect as it's outside the scope.

However, given the challenges to inorganic fertilizer adoption in African farming systems, agricultural technologies that rely to a greater extent, on renewable local or farm resources could form key interventions for fertility management (Kassie et al., 2009). Organic farming practices, such as compost manure, cover crops and mulching, are among such technologies. The water retention characteristics of these technologies make them especially appealing in water deficient farming areas (Twarog, 2006). In addition to reducing natural risks, they enable poor farmers to avoid the financial risk of buying chemical fertilizer on credit and—given that compost and conservation tillage are available when needed—overcome the prevailing problem of late delivery of chemical fertilizer.

Case studies by the International Federation of Organic Agriculture Movements [IFOAM], (2009) in Ethiopia, Burkina Faso, Kenya and Egypt, demonstrate the adaptation potential of organic agricultural practices in these very different contexts. The case studies demonstrate that organic agriculture fulfils most of the requirements identified for successful adaptation strategies.

Farmers use terraces and soil bunds as strategies to minimize soil erosion to encourage better root penetration and enhance moisture conservation. The findings are in line with a study by Mahoo et al. (2007) which indicated that, farmers adopted tillage methods, agronomic practices and crop diversification approaches to maximize yield from available water. In this case, tillage tends to improve infiltration rates of water and thus reducing surface runoff associated with short but heavy rains which are usually common in study areas.

Application of crop and land management practices across study districts indicated statistically significant differences ($P \leq 0.05$). This confirmed findings by previous studies which reported that technology adoption is location specific (for example Kassie et al., 2009). Farmers' reasons for adopting various crop and land management practices included; changed rainfall patterns, availability of land and labour and the cost associated with the management practice. These also varied by location, and possibly explain the differences in management practices applied across the study districts.

5.5 Factors Influencing Farmers' Decisions to Adopt Management Practices

Farmers' decisions to adopt crop and land management practices were positively influenced by gender of the head of household, household size, access to output markets and farmers' perceptions of rainfall adequacy. The probability of adopting management practices increases by at least 12% for male headed households as compared to their female counterparts. This result is in line with the argument that male-headed households are often considered to be more likely to get information about new technologies and take risky businesses than female-headed households (Asfaw and Admassie, 2004).

This study also observed that most of the technologies employed by farmers generally require labour input. It can also be inferred that gender effect on technology adoption is generally due to the differences in labour endowment between men and women. Pender and Gebremedhin (2006) indicated that female-headed households used significantly less labour, because of labour constraints. As such, they are less likely to apply compost manure and less likely to use contour ploughing, which are generally labour intensive.

However, it should also be noted that among the reasons farmers gave for adopting various production changes, labour was less significant (approximately 2% of respondents), implying that farmers could still adopt labour demanding practices if they consider that the practices will address production risks.

Age of the head of household, farming experience, distance to input market and farm size were negatively related to adoption of management practices in general. However, the influence of these factors on adoption of specific management practices varied. For example age of household head positively influenced the decisions on sowing date, crop density and use of cover crops, and negatively influenced soil bunds and inorganic fertiliser use. Kassie et al. (2009) found a negative and significant impact of age on the likelihood of adopting conservation tillage in Ethiopia, and attributed it to the fact that younger farmers are more likely to try innovations as compared to older people. Other studies conducted in Uganda also confirmed a negative relationship between age and adoption of technologies (for example, Mugisha et al. 2004, 2012; Walusimbi, 2002).

Contrary to the *a priori* expectation that the more experienced a farmer is the more he/she would be willing to face risks associated with a new farming method, this study revealed that the length of farming experience among the respondents was not a very important determinant of adoption of management practices in general. Based on Saha et al. (1994) findings, this can be attributed to the fact that farmers who have been long in the business are usually older, less educated and are more resistant to change than new entrants. Mugisha et al. (2012) reported contrary results where they indicated that farmer's experience positively and significantly influenced the rate of technology adoption. Mugisha et al. further reported that for an extra year of experience, there is likelihood for the rate of adoption to increase by 0.9%. Experienced farmers have better technical knowledge and are likely to adopt new agricultural technologies.

Similarly, results on extension advice are contrary to the *a priori* expectation of this study. While access to extension has been linked to adoption of improved technologies by various studies (for example Atta-Krah and Francis, 1987; Maddison, 2006) and adaptation to climate change (Nhemachena and Hassan, 2007), this study showed contrary results in terms of general adoption of management practices. However, in terms of specific management practices, access to extension positively influenced adoption of mulching, compost manure and cover crops.

Bearing in mind the critical role extension plays in agricultural development, the government of Uganda has prioritized it in its planning, and strategy papers such as the Poverty Reduction Strategy Paper and the National Development Plan (GOU, 2010). The government also established the National Agricultural Advisory Services (NAADS), as an innovative public-private extension service delivery, aimed at increasing market oriented agricultural production in the country.

Previous studies on extension in Uganda have indicated less favourable results on the impact of extension on agricultural productivity (Benin et al., 2007). More generally, lack of funds and equipment to facilitate the work of extension agents is a common complaint at the local government level (Sserunkuuma et al., 2001). In the study on extension systems in Sub Saharan Africa, Kristin (2008) found similar problems in extension systems, citing a combination of a lack of relevant technology, failure by research and extension to understand and involve clientele in problem definition and solving, lack of incentives for extension agents, and weak linkages between extension, research, and farmers.

Given the low extension access rate in Eastern Uganda (30% of households), coupled with limited information on new technologies, and information on risk management, it's highly likely that extension may not influence adoption of new management practices in the wake of rainfall variability, especially those that relate to crop management. According to Benin et al. (2007), extension *per se* does not improve technology adoption, and productivity, but complement progress in other areas such as development of market and financial systems. It is therefore important to tailor extension messages to the existing farmer challenges other than general extension messages.

The probable reason for the negative relationship between adoption of management practices and farm size could be due to the fact that adoption of practices is plot specific. This means that it is not the size of the farm, but the specific characteristics of the farm that dictates the need for a specific production practice. This finding is in line with Deressa et al. (2008) who found that farm size was negatively related to adaptation to climate change. Benin et al. (2007) also affirmed that reduction in farm size was a major determinant for adoption of improved crop production practices, and improved soil fertility management.

Modelling the influence of various explanatory variables on each of the crop and land management practices identified in the study districts gave almost similar results as the outcome model, based on Heckman probit. Different explanatory variables affected adoption of specific management practices differently. This could be attributed to the nature of the practice, ease of access of the technology/innovation, and the reasons for which a farmer would be interested in that practice.

5.6 Effects of Farmer-Preferred Management Practices on the Mean and Variance of Crop Production

Most of the farmer-preferred management practices showed significant, positive mean impacts on yields, but they had different risk-reducing effects on yield. The different effects on yield variability could be attributed to technology characteristics and their intention in farming systems. Changing crop varieties ensures that farming households introduce crops that are best suited to the current climatic and other biophysical conditions peculiar to the site. This strategy was however limited by resources for purchasing improved seed, hence the few farers using it. It was mainly used in Mbale and Sironko, with better access to markets and less constraining pedoclimatic conditions than Pallisa. In a similar way, Kurukulasuriya and Mendelsohn (2006) demonstrated that crop selection is an important adaptation strategy to climate variability.

Innovations in soil and water conservation such as soil bunds, compost manure and cover crops address the risk of soil moisture deficits associated with shifting precipitation patterns besides controlling soil degradation, which would otherwise render the crops prone to unfavourable climatic conditions. Soil bunds were effective in increasing yields and reducing risk in all agro-ecologies because they minimise runoff thus increasing infiltration of water in to the soil. In this way, the soil bunds facilitate recharge of soil water storage capacity for the benefit of the crops against drought stress, besides controlling soil degradation through erosion. This is in line with the observation that soil bunds were particularly effective in Mbale, which has rugged terrain prone to soil erosion.

The observation that soil bunds had positive significant mean impacts on the value of crop production is consistent with previous studies in Ethiopia that made similar observations (Bekele, 2005; Gebremedhin et al. 1999; Kassie et al. 2008; Kato et al., 2009). Other studies on the role of technology in agricultural productivity corroborate this finding. For example, Ramakrishna et al. (2005) demonstrated that use of improved production technologies in India (particularly high-yielding pigeon pea variety and appropriate seed rate) gave higher yields and recorded a mean grain yield of 1.61tones per hectare, which was 204% higher than that obtained with the farmers' practice yields of 0.53tons per hectare.

Byiringiro and Reardon (1996) using farm-level data in Rwanda found that farms with greater investment in soil conservation had much greater land productivity than did farms without such investment. In Lesotho, Kaliba and

Rabele (2004) found a statistically significant, positive association between wheat yield and short- and long term soil conservation measures. Several other studies (e.g., Byiringiro and Reardon, 1996; Kassie et al., 2008; Shively, 1999) found that soil and water conservation technologies contributed positively to land productivity.

Compost manure was particularly effective in Pallisa. This is because the area receives less rainfall yet it has light-textured soils with poor soil moisture storage capacity and low cation exchange capacity for holding nutrients against leaching loss. Application of manure may have improved the available soil water storage capacity through increase in soil organic matter, which may have also contributed towards increased base cation nutrient retention against leaching loss due to increase in cation exchange capacity of the soil. Cover crops can also achieve the same effects since their biomass ultimately ends up contributing to soil organic matter, hence their yield-increasing and yield stability effects in Pallisa.

The effects of crop rotation and intercropping are mainly on the ability of these innovations to break the pest cycle, ensure crop diversification and thus reduce the risk of crop failure. For example, Di Falco *et al.* (2006) reported that variety richness increases farm productivity, and reduces yield variability. Dixon *et al.* (2001) showed that mixed cropping systems reduce crop losses due to pests and diseases and make more efficient use of farm labour.

Changed sowing date had risk-reducing effects though it did not show significant effects on mean yield. Changed sowing date ensures more effective use of precipitation available during the season such that yields are optimized. This is in agreement with Chiotti *et al*. (1997), de Loe *et al*. (1999) and Smit and Skinner (2002) who reported that changing the timing of farm operations has the potential to maximize farm productivity during the growing seasons and to avoid heat stresses and moisture deficits during times of increased climate perturbations. The observed risk-increasing effects of changing crop density are attributed to the fact that increasing crop density increased the input costs, yet the output may not significantly offset the additional cost.

The observed variability of technology effects by agro-ecological zone is attributed to the different biophysical characteristics and farming systems in these areas that define the farming potential. Gebremedhin *et al*. (1999), Bekele (2005), Kassie *et al*. (2008) and Kato *et al*. (2009) also indicated significant variations in the effect of technologies in low and high rainfall zones.

The effect of farmers' perception of rainfall on yield variability could be due to the fact that farmers' perception determines the timing of operations as well as the type of crops to grow. It is anticipated that if farmers' perception of rainfall adequacy is correct, then adjustment in their farming operations should give risk-reducing effects on the variance of crop yield. Similarly, farmers' perceptions of technology effectiveness have a strong bearing on the decisions of what adaptations to employ.

5.7 Subjective Effectiveness Scale of Farmer-Preferred Management Practices

The main finding from this section is that farmers recognise the importance of management practices in reducing production risks associated with rainfall variability. Overall, changed crop varieties and compost manure were considered effective management practices across the three study districts. This is in agreement with results obtained on effect of these production practices on variance of yield. Empirical evidences from other studies also confirmed effectiveness of such practices such as compost manure (e.g. Kassie et al., 2009; Wahba and Darwish, 2008) and crop selection (Kurukulasuriya and Mendelsohn, 2006a) in reducing production risks.

There were noted differences in farmers' perceptions of effectiveness of the various production technologies they use across the study districts. In Sironko, farmers generally rated land management practices more effective than crop management practices. The situation was different in Pallisa where crop management practices were rated more effective than land management practices. This could also be related to differences in bio-physical characteristics of the three locations and farming potential. For example, in Sironko, the high rainfall amounts and steep slopes make it vulnerable to water logging, erosion and mud slides. As such, land management practices such as soil bunds, mulching and cover crops are more relevant to farmers there. Pallisa on the other hand is generally flat with lower rainfall amounts. Thus interventions in crop and opposed to land management are more appreciated by farmers.

There were cases of farmers not being sure of the effectiveness of the management practices they use in reducing production risks. This has implications on adoption and retention of management practices. Farmers are obviously lacking information on how to effectively assess the performance of the various management practices against a set of objectives for which they are employed. It is also important to note that some of these practices have been implemented over time in response to decreasing crop productivity, and have not fully been assessed in response to changing rainfall regimes.

CHAPTER SIX

SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

In this chapter findings discussed in chapter five are summarized. The chapter also discusses the broader implications of the results. It is also used to provide recommendations for improvement of farming practices and for provision of guidance to future researchers in the field. In this way, the relationship between the research hypotheses is identified to form a basis for deriving a general conclusion through appropriately synthesizing ideas.

6.2 Summary of Findings

This study aimed to assess the determinants of crop and land management practices and their effects in reducing production risks associated with variable rainfall in Eastern Uganda. This involved establishment of the extent of variability of rainfall, understanding the farmer-preferred management practices in response to varying rainfall regimes and factors influencing their decisions of which management practices to adopt, and establishment of the effects of the various farmer-preferred management practices on the mean and variance of crop production. In addition, perceptions by farmers regarding the effectiveness of the technologies in reducing production risks were explored and compared across the study districts.

Three hundred and fifteen household surveys, nine community interviews involving 104 community members, and 23 key informant interviews were conducted, using structured and semi-structured questionnaires and interview schedules. Observational rainfall data for the study location were obtained from Meteorological department for the 40 year period from 1971 to 2010. Both descriptive and econometric methods were used to analyze and present the results from the study. Data were analyzed using SPSS, STATA and XLSTAT computer packages.

Analysis of annual rainfall data showed significant variation in the amount and distribution of annual and seasonal rainfall. Increasing trends have been noted for annual and ASON rainfall, and decreasing trends for MAMJ rainfall. The variation is more pronounced in ASON than MAMJ season and exhibits higher anomalies in the years after 2006. High land areas showed increasing rainfall amounts and higher variability as compared to low lying areas which showed decreasing rainfall and less variability within and between seasons.

Farmers' perceptions of rainfall variability were in line with observational rainfall data, where they indicated that rainfall amounts are generally increasing and the seasons changing. In particular, farmers acknowledged late rainfall onset, increased intensity within the season, mid-season droughts and early cessation. This has greatly affected crop and livestock production, where in extreme cases there was total crop failure either due to prolonged droughts or heavy erosive rainfall or floods washing away the crop.

In order to reduce climate risks to crop production, farmers employed a number of crop and land management practices, either singly or in combination. Crop management technologies include; changing planting dates, changing crop varieties and crop density. Land management practices include; soil bunds, grass strips, crop rotation, intercropping, compost manure use, cover crops and mulching. Farmer's perception of rainfall adequacy or its variation was significant in explaining farmers' decision to adopt production technologies. Other factors that positively and significantly affected farmer's decisions to adopt management practices were; gender of head of household, household size, and access to output markets. The key issue that relates to these variables and their effect on technology adoption is essentially labour endowment, considering that most of them are labour intensive. Male headed households and households with more people are generally well endowed and therefore have high chance of adopting production technologies.

Analysis of the effects of various management practices on the mean and variance of crop production showed differing effects by management practice and by district. A number of farmer-preferred management practices were found to be risk reducing, for example soil bunds, changed crop varieties, changed sowing dates, compost manure, cover crops, crop rotation, and intercropping. There were also a number of farmer-preferred management practices that showed risk increasing effects. In general, soil bunds showed risk reducing effects across sample districts, while the rest of the technologies were either risk increasing or risk reducing depending on the district.

Finally, farmers' had opposing perceptions of effectiveness of management practices depending on location. In particular practices appreciated in highland areas were different from those appreciated in low lying areas. There were also a large proportion of farmers that were not sure of the effectiveness of the practices they are using.

6.3 Implications of the Findings

Study findings have the following implications: First, within season rainfall variability is a constraint to agriculture production as it increases risk of crop failure. It is evident that second season (August to November) rains are increasing in magnitude and variability as compared to first season (March to June) rains which are generally reducing. The implication is that this changing scenario will affect cropping patterns in the study districts thus requiring introduction of crops or varieties best suited to the patterns. For example, in Sironko, introduction of water tolerant crops would be an option while in Pallisa, introduction of early maturing crops. This also has implication on the selection of crops to be grown per season.

Secondly, farmers' perceptions of rainfall adequacy, coupled with information on climate forecast were important explanatory factors for farmers' decisions to adopt certain management practices in response to rainfall variability. In addition, gender of head of household, household size, and access to output markets positively affected farmers' decision to adopt management practices. To reduce risks associated with farmers' decisions, availability of appropriate weather forecast information combined with farmers' perceptions is critical in informing targeting of adaptable management practices. Further, the effect of household socio-economic factors and access to markets on adoption of management practices underscores the need to incorporate them in the design and implementation of adaptation measures. Therefore, the success (or failure) of climate variability adaptation will to a large extent depend on how these factors (or information on them) are utilized or incorporated in design and implementation of adaptation programs.

Thirdly, the effect of crop and land management practices on production risk varies by location. While some technologies were risk reducing in one location, they were either risk increasing or had no effect at all in another location. This highlights the importance of developing and disseminating location specific adaptation technologies to reduce production risks, instead of blanket recommendations of similar adaptation measures across locations. For instance, in high-rainfall, highland areas (e.g. Sironko), placing appropriate land management measures such as soil bunds, mulching and cover crops, could help channel excess water from the fields and improves fertility. In low lying and low-rainfall areas (e.g. Pallisa), soil bunds and compost manure showed risk reducing effects on crop production, and may be appropriate in conserving the little rains received, and improving fertility respectively.

Lastly, farmers' perceptions of the effectiveness of various crop and land management practices in reducing production risks differed by practice and district. This has implications on adoption and retention of management practices by farmers. If farmers perceive a management practice to be noneffective, they will not retain it even if they had adopted it initially. In addition, the fact that a number of farmers were not sure of the effectiveness of their management practices in reducing production risk, and yet continued to apply them implies that farmers still adopt conservative measures sometimes at the expense of higher productivity and sustainable management. The challenge therefore is to ensure effective documentation and innovative approaches to share information regarding effectiveness of these practices, especially in the wake of uncertain rainfall regimes.

6.4 Conclusions

From the results, the following conclusions have been reached based on the research hypotheses:

1. There is significant variation in the pattern of annual and seasonal rainfall, in the study areas. This is attributed to increase in extremes of rainfall on the annual scale such as high intensity rainfall and droughts thus affecting the variability. On the seasonal scale, falls have either increased or decreased, depending on the location, with increases in high land areas and decreases in low lying areas. Seasons have also altered with late onset and early cessation leading to the perceived variation. Greater variation is observed for second season, than first season for all the locations.
2. Farmers' perceptions of rainfall variability affect their decisions to adopt production technologies. In addition, household socio-economic factors such as gender of head of household, household size, off farm income, and access to input and output markets significantly affect farmers' decisions to

adopt management practices in general. Effect of these explanatory variables on farmers' decisions to adopt specific management practices varied with some of the factors increasing or decreasing the probability of adoption of specific management practices.

3. Farmer-preferred crop and land management practices have different effects on production risk. While most of the management practices showed significant, positive mean impacts on yields, they did not all show a correspondingly similar risk reducing effect on yield variability. The varying effects on yield variability could be attributed to characteristics of the management practices and their intention in farming systems. Soil bunds showed significant risk reducing effects on crop production in all the locations.
4. Farmers' perceptions of the effectiveness of the management practices they employ varied by district. Some of the practices for example changed crop varieties and compost manure were appreciated across the three districts. Land management practices were more appreciated in highland areas while in low lying areas, crop management practices were appreciated. Farmers' perceptions were comparable to results obtained from the econometric analysis above indicating that compost manure and crop varieties are among the management practices that are risk reducing in the face of climate variability.

6.5 Recommendations

Based on study findings, the following are recommended:

1. In the design and delivery of climate risk reducing programs, production and dissemination of weather forecast information, including promotion of its utilization should form a critical component. If such information is not provided, farmers will continue to use their own perceptions to make decisions, some of which may be inaccurate and misleading.
2. Similarly, Government and other development initiatives promoting adaptation to climate variability should ensure support to farmers to build their socio-economic and knowledge base in order to enhance adoption of adaptable management practices. For example, building the capacity of extension workers to provide targeted extension messages, building social safety nets, trainings and awareness of climate variability.
3. Considering that productivity impact of adaptation practices is location specific (considering biophysical characteristics), Government and development agencies need to consider innovative dissemination strategies that take into account how management practices adaptable to change are used by farmers and with what impact. This may also include development of management packages tailored to locations and farming systems as opposed to blanket recommendations.
4. Finally, in the design and implementation of projects and policies on adaptation to rainfall variability, there is a need to focus not only on technical aspects but also social dimensions such as perceptions of

smallholder farmers. For example, integration of farmers' perceptions in evaluation of new management practices.

6.6 Further Research

This study assessed risk effects of technology on the value of crop production measured at plot level. However, it was found that technologies are mainly used in combination on farmers' plots. The implication is that the reported findings are attributed to the observed technologies on the farmers' fields. The study also aggregated production per hectare expressed as value of crop production because most of the plots were planted with more than one crop. However, to make a robust conclusion on the effectiveness of specific technologies on production risks this study suggests further research on the effect of technologies employed singly on a plot. Also, considering that different crops may require different management practices, this study further suggests research on the effect of various technologies on selected crops.

While majority of farmers indicated that they have received weather forecast information, this study did not establish the extent to which this information is being utilized by farmers to inform their technology adoption decisions. Secondly, the study did not establish the perception of farmers regarding the accuracy or usefulness of weather forecast information. Thus further research in this area is suggested, if weather information is to be appropriately developed, disseminated and used by farmers to reduce climate-induced production risks.

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Appendix 1: Key Studies Reviewed in Relation to this Study Problem and Knowledge and Methodological Gaps

Author	Study Objectives	Methods used	Findings	Research gap
Cabas et al. (2007)	Estimate effects of weather and climate variability on average yield and the variance of yield for corn, soybeans and winter wheat in Canada	Just and Pope stochastic production function approach. Estimated variables using feasible generalized least squares (FGLS) under heteroscedastic disturbances	Climate variables have a major effect on crop yield distribution. The major effect on average yield is the length of the growing season while variance of yield, is largely affected by the variance of temperature and precipitation.	Technology use was not explicit in the model.
Di Falco et al. (2006)	Estimate effects of wheat genetic diversity and land degradation on risk and agricultural productivity in less favored production environments in Ethiopia	Just and Pope stochastic production functions to test the effects of variables on the mean and variance of durum wheat yield. The analysis incorporated skewness of yield and downside risk aversion.	Variety richness increases farm productivity. Variety richness also reduces yield variability but only for high levels of genetic diversity.	Study analyzed risk exposure on degraded lands. Environment risks were considered, but not climate risks
Gardebroek et al. (2010)	Assess factors influencing production technology and risk in organic and conventional arable farming in Netherlands	Used panel data on organic and conventional farms for the period 190-99. Just and Pope Stochastic production function was used estimating elasticities of production and production risk	Organic farms face more output variation than conventional farms. Manure and fertilisers have a positive impact on production of organic farms but significantly increase production risk.	Study analyzed risk effects of various organic farming technologies on crop production. Climate variables were not explicitly included in the model.
Juma et al. (2009)	Analyze effects of production risk on farm technology adoption among small holder farmers using plot-level data from semi-arid areas of Kenya	Employed a two-stage approach to estimate a production function, and computed the mean and the production risk factors (both variance and skewness).	Yield variability and the risk of crop failures affect technology adoption decisions in low- income, rain-fed agriculture. But, the direction and magnitude of effects depend on the farm technology under consideration.	Production risk was considered as the dependent variable, affecting adoption of technology.

Author	Study Objectives	Methods used	Findings	Research gap
Iglesias and Quiroga (2007)	Provided a methodology for measuring agricultural risk to climate among geographic regions, integrating both empirical and probabilistic information, and the effect of different risk scenarios on potential yields of wheat in Spain	Multiple linear regression models with climatic data as explanatory variables. Monte Carlo models used to analyse in detail the probabilistic properties of the agricultural yields. Risk factor index applied in order to compare the risk of attaining low yields owing to climate among 5 sites.	Observed yield patterns contain substantial information on the relative importance of climate and management variables for yield variability	Major limitations of the results arise from the simplicity of the variables considered in the empirical models, the aggregation of some data variables, and the quality of data.
Kassie et al. (2008)	Assessing the effect of risk exposure, including the downside risk of chemical fertilizer and soil and water conservation adoption in Ethiopia.	Used modified probit random effects and pooled truncated regression models, where the right hand-side of each regression equation included the mean value of the plot-varying explanatory variables	Risk plays a significant role in technology adoption. The higher the expected return, the greater the probability that farmers would decide to adopt conservation technology, as they expected to be able to afford the adoption of new soil conservation measures.	The model did not consider selection bias in adoption decision. Rainfall variables not included in the model
Kassie et al. (2009)	Assessed factors influencing farmers' decisions to adopt sustainable agricultural production practices, with a particular focus on the adoption of compost and conservation tillage in Ethiopia	Used Stochastic Dominance Analysis (SDA) to assess how the use of organic farming technology impacts on crop productivity. The study compared adopters and non-adopters of organic farming focusing on four major crops	Results indicate clear superiority with the use of compost, compared to chemical fertilizers, when it comes to crop yields.	Climate variables not included in the analysis, therefore results do not provide risk effects of organic farming under variable climate.
Kato et al. (2009)	Impact of different soil and water conservation technologies on the variance of crop production in different regions and rainfall zones in Ethiopia	Using a household- and plot-level data set, applied the Just and Pope framework using a Cobb Douglas Production function to investigate the impact of various technologies on average and variance of crop yields.	Soil and water conservation technologies have significant impacts on reducing production risk. But, these investments perform differently in different rainfall areas, thus underscoring the importance of geographical targeting when promoting technologies.	While this study provides the general picture of technology risk effects in various rainfall zones, the variability of rainfall is not considered

Author	Study Objectives	Methods used	Findings	Research gap
Koundouri et al 2006	Assessed impact of production risk on irrigation technology adoption in Greece.	Analysis used moments of profit from cross-sectional data collected from 265 farm households	Climate variation significantly affects both mean and variance of crop yield	The unobserved heterogeneity that may influence technology adoption and production decisions and risk management strategies was not controlled for.
Kelbore Z. G. (2012)	Investigated impacts of climate change on mean and variance of crop yields in Ethiopia over a period of 28 years	Employed stochastic production function and estimated the effects of seasonal rainfall on crop yields and variances. Also included prediction models including CGCM2, PCM, and HadCM3.	Effects of the seasonal rainfalls differ across crops and regions. Prediction models indicate a U shape relationship between crop production technology and crop yields, except for maize.	The model assumes that all the included variables are stationery, and hence deterministic.
Kurukulasuriya and Mendelsohn (2006a)	Study estimated the climate sensitivity of specific crop choices made by farmers in Africa. That is, whether the choice of crops is affected by climate	Data were analyzed using MNL regression model, regressing crop choice on climate, soils and other factors. The climate variable measures used were annual temperature and precipitation.	Crop choice was very sensitive to climate. As temperatures get warmer, farmers shift towards more heat tolerant crops. Depending upon whether precipitation increases or decreases, farmers will also shift towards drought tolerant or water loving crops, respectively.	
Kurukulasuriya and Mendelsohn (2006b)	How climate affects the decision to employ irrigation, and how climate affects the net revenues of dry land and irrigated land in Africa	Ricardian 'selection' model, using a modified Heckman model was employed. The model examined dry land and irrigated land separately treating the choice of irrigation as endogenous.	Choice of irrigation is sensitive to both temperature and precipitation. Irrigated farms, are more resilient to temperature change, and are likely to realize slight gains in productivity. However, any reduction in precipitation will be especially deleterious to dry land farmers	Study considered the mean of production under technology adoption. No consideration of technology effects on the variance of crop yield (risk)

Author	Study Objectives	Methods used	Findings	Research gap
Pender and Gebremedhin (2006)	Impacts of community-level factors (population density, investments in irrigation and roads), household and plot-level on land management and the implications for agricultural productivity and land degradation in Ethiopia.	Multiple models of Crop production, Input use and land management, and Per capita income were developed and analyzed using multinomial regression.	Some land management practices were found to substantially increase crop production, including construction of stone terraces, reduced burning, and reduced tillage.	Variance of rainfall not included as an explanatory variable for the observed production risk under various technologies.
Poudel and Kotani (2013)	Investigated impact of climatic variation on agricultural yield and its variability by utilizing the data of rice, wheat and climate variables in the central region of Nepal	Used stochastic production function approach by controlling a novel set of season-wise climatic and geographical variables	An increase in the variance of both temperature and rainfall showed adverse effects on crop production in general. On the other hand, a change in the mean levels of the temperature and rainfall induced heterogeneous impacts, which could be considered beneficial, harmful or negligible, depending on the altitudes and the kinds of crops	
Sileshi et al., 2010	Assessed the probability distribution of yield risks associated with inorganic fertilizer, legume trees and green manure/cover crops in maize cropping systems in Africa	The effects of management and soil type on yield and yield gap were analysed using a linear mixed model, where either management or soil type was entered as the fixed effect and their interactions with study as the random effect	Yield gaps and yield risks are closely associated with the sensitivity and resilience of soils, climate and management (researcher vs. farmer). Inorganic fertilizer gives higher yields than the organic inputs, but organic inputs provide additional ecosystem services that cannot be provided by inorganic fertilizer.	Climate variables not explicitly used to explain the observed risks

Appendix 2: Study Variables, Data Collection and Measurement Procedures

Research qn.	Variables	Data collected	Collection methods	Calculation / units	Concerns / issues
RQ1: What is the extent of variation of annual and seasonal rainfall in Eastern Uganda for the period 1971-2010?	Rainfall variables	Monthly rainfall for the period 1971 to 2010 for three stations – Tororo, Soroti and Sipi	Review of met. records	Descriptive analysis to obtain annual & seasonal averages & totals (mm), SD, and CV. Use of single equation Regressions & ANOVA to assess trends, and variability of seasonal and annual rainfall.	While the sample districts were Mbale, Pallisa and Sironko, there were no Meteorological stations in these districts. The nearest stations in the same agro-ecological zones were Tororo, Soroti and Sipi representing the three sample districts respectively.
RQ 2: What factors determine farmers' choice of production technologies?	Technology adoption	List of technologies on farm; Land area where technology is used, crops grown	Farmer survey, observation, estimation of land area.	Inventory of best bet technologies. Adoption was dichotomized, where 1 was allocated for those using a particular technology, and 0 otherwise.	Partial application of technologies on some plots e.g. application of fertilizer in rates that are below the recommended rates Multiple technologies used on one plot e.g. soil bunds, mulching, compost manure
	Household social economic variables	Gender, age, sex, education, years of farming experience	Farmer survey	Descriptive analysis to determine means and SD of all variables	Farming experience was taken as the number of years the household head has done farming as the primary source of livelihoods, other than the entire farming life of the household head.
RQ 2: What factors determine farmers' choice of production technologies?	Access to institutional support services	Access to credit, extension and information, distance to markets (input and output)	Farmer survey	Descriptive analysis to determine means and SD of all variables	Access to institutional services may be biased by farmer expectations from the researcher. Levelling expectations was key to ensure non-biased data
	Farmer perceptions of rainfall	Perception of rainfall variability	Farmer survey	Rainfall satisfaction index based on a set of questions on rainfall adequacy.	Farmer perceptions may be subjective based on their expectations from the researcher. Levelling expectations was key to ensure non-biased data.

Research qn.	Variables	Data collected	Collection methods	Calculation / units	Concerns / issues
	Choice of technology	Technology adoption, household socio-economic variables and rainfall variables	Computation of interaction between the variables	Heckman's sample selectivity model.	There was no separate analysis of adopters and non-adopters. The choice of Heckman's model was to correct for this selection bias, where only those who perceive change in rainfall will adopt adaptation technologies.
RQ 3: What are the risk effects of the various farmer-preferred technologies on crop production?	Value of crop production per hectare	Harvested output Area planted (ha) Crops planted Price of products	Farmer survey, estimation of land area, market prices	(Output x price) /Area planted, measured in shillings per hectare	To cater for price seasonality, constant market prices were used. Crops harvested in piece meal were not easy to quantify e.g. cassava. Researcher used farmer estimates.
	Purchased inputs	Purchased inputs used, cost of inputs, area applied	Farmer survey	(quantity of input x price) / area	Inputs mainly applied on small plots of vegetables and yet the study focused on three major plots on farm.
	Technology risk effects	Technology adoption, household socio-economic variables, rainfall variables, value of production	Computation of interaction between the variables	Just and Pope production functions. The approach allows technologies to be either risk increasing or risk reducing	
RQ 4: What are the perceptions of farmers regarding the effectiveness of various technologies they employ for reducing climate-induced production risks?	Technologies employed on farm, farmer perceptions of technology effectiveness	Perception of technology effectiveness	Farmer survey	Rating scale of 1 to 5, where 5 is very effective and 1 not effective	Farmer perceptions may be subjective based on their expectations from the person conducting the research. Levelling expectations was key to ensure non-biased data.

APPENDIX 3: Data Collection Tools

A) Focus Group Discussion Guide

Name of interviewer.. Date of interview.......................................

District.. Village...

Total number of people participating in the interview.......... Male............... Female...................

A.	Land ownership	Response	Variable value	Remarks
a)	What is the average land holding for the majority of households in this village?		1 = 1 acre and below 2 = 2to 4 acres 3 = 5 to 7 acres 4 = 8 to 10 acres 5 = Above 10 acres	
b)	How do the majority of households acquire land?		1 = inherit 2 = purchase 3 = borrow 4 = rent	
B.	**Economic activities**			
a)	What is the major economic activity of the majority of households in this village?		1 = Crop farming, 2 = Livestock farming, 3 = Mixed crop and livestock 4 = Trading/business, 5 = Formal employment	
b)	If crop production, what are the major crops grown (name at least 4 major crops)		Crop 1 = Crop 2 = Crop 3 = Crop 4 =	
c)	For each of the crops, how do you rate production during the September-December 2010 season compared to previous years?	Crop 1= Crop 2= Crop 3= Crop 4=	1= decreased significantly 2= decreased 3= no change 4= increased 5= increased significantly	
d)	If decreased in any of the crops, what do you	Rank reasons using the scale below		

	attribute the change to?	*1=strongly disagree,*	*2=disagree*	*3 = un decided*	*4= agree*	*5=strongly agree*	
	i) Low soil fertility						
	ii) Pests and diseases						
	iii) Lack of improved varieties/breeds						
	iv) Poor access to inputs						
	v) Too little rain						
	vi) Too much rain						
	vii) Small land holding						
	viii) Lack of labor						
	ix) Others (specify)						
C.	**Climate variability and farmer perceptions**						
a)	What is the general perception of farmers regarding climate variability during the September to December 2010 season	*Probe answers to the attributes below*					
	i. Did the rainfall come on time?		1 = on time; 2 = too early; 3 = too late				
	ii. Was there enough rain at the beginning of the rainy season?		1 = enough; 2 = too little; 3 = too much				
	iii. Was there enough rain during the growing season?		1 = enough; 2 = too little; 3 = too much				
	iv. Did the rains stop on time?		1 = on time; 2 = too late; 3 = too early				
	v. Did it rain near the harvest time?		1 = no; 2 = yes				
	vi. Number of rainfall days?		1 = No change; 2 = Reduced; 3 = Increased				
	vii. Frequency of heavy rains?		1= No change; 2= Reduced; 3 = Increased				
	viii. Frequency of dry spells?		1= No change; 2= Reduced; 3 = Increased				
	ix. Duration of the growing season?		1= No change; 2= Reduced; 3 = Increased				
D.	**Farmer prefered adaptation strategies**						
a)	Considering the variability in the climate, (based on responses from 'C' above) what are the major actions farmers are employing to improve or sustain crop production?	b) How do farmers perceive the effectiveness of these practices in reducing the risk of crop failure? Ask '***is the practice effective or not?***'					
		1=strongly disagree,	*2 = disagree*	*3 = un decided*	*4 = agree*	*5=strongly agree*	
	1 =						
	2 =						
	3 =						
	4 =						

	5 =						

E.	**Crop management practices**							
a)	Do farmers in this community use any of these crop management practices intended to reduce the risk of crop failure? Probe the crop management practices suggested below	1=yes 2=no	b) If yes, what change?	c) How do farmers perceive the effectiveness of the management practice in reducing risk of crop failure? Ask only for those practices where farmers have indicated yes. Use same rating as in 'D' above				
				1	**2**	**3**	**4**	**5**
	i. Changing sowing date		1= Moved back, 2= Moved forward					
	ii. Changing crop density (amount of seed planted per plot or per hole)		1= Reduced, 2= Increased					
	iii. Changing crop varieties (change of different varieties of the same crop)		Which varieties before? ……………………………. And which varieties presently? …………………………….					
	iv. Changing crop association (change in types of crops in an intercrop)		Which crops before? …………………………. And which crops presently? …………………………….					
	v. Crop diversification (introduction of new crops not originally grown in the area due to changes in rainfall and water availability)		If changed which new crops have been adopted? …………………………. …………………………….					

F.	**Land and fertility management technologies**							
a)	Are you using any of these technologies? Is it a new or old practice? New practice if adopted at least 1 year ago. How do you perceive its effectiveness in terms of addressing the problems for which you adopted?	1=yes 2=no	Farmer perception of effectiveness in reducing production risk under climate variability					
			1=strongly disagree	*2 = disagree*	*3 = un decided*	*4 = agree*	*5=strongly agree*	
	i. Soil bunds							
	ii. Terraces							
	iii. Field water harvesting dams							
	iv. HH water harvesting tanks							
	v. Small plot irrigation (≤1/4 acre)							
	vi. Large plot irrigation (>1/4 acre)							

	vii. Mulching							
	viii. Water ways							
	ix. Stone bunds							
	x. Grass strips							
	xi. Compost/animal manure							
	xii. Cover crops							
	xiii. Crop rotation							
	xiv. Intercropping							
	xv. Agro-forestry							
	xvi. Chemical fertilizer							

G	**Access to extension services and agricultural information**			
a)	Do members of this village have access to agricultural extension services – crop and livestock production training?		1=yes 2=no	
b)	If yes, who provides the services?		1= Fellow farmers, 2= Government extension officer 3= NGO staff 4 = Farmer group (cooperative) 5= Other (specify)	
c)	Other than agricultural extension, do members in this village have access to agricultural related information?	1=yes 2=no	If yess, who provides the information? 1= fellow farmers, 2= government extension worker, 3=NGO staff, 5=Farmer group, 6=Radio/TV, 7= Other (specify)	
	i. Market information			
	ii. Agricultural output prices			
	iii. Weather forecast			
	iv. New agricultural technologies			
H.	**Access to credit**			
a)	Do members in this village have acces to agricultural credit?		1=yes 2=no	
b)	If yes, what are the major sources of agricultural credit?		1= Relatives and friends 2= Farmer savings groups / SACCO / VSLA 4= Government credit schemes 5= NGO/Church/Mosque 6= Bank or micro-finance institution	

B) Key Informant Interview Guide

Name of interviewer........................... Date of interview..................................
Name and function / title of respondent:..

Research question	Information required	Findings
1. Institutional support to agricultural production under climate variability	i. Which would you judge are the three most important economic priorities for local government in the district? (E.g. primary schools, health facilities, farmer extension services etc.) ii. What is the local government and authorities in the district doing to support increased agricultural production of small holder farmers in the district? iii. How would you judge the services rendered by extension workers in terms of reaching the majority farmers?	
2. Perception of climate variability and adaptation options	i. What do you judge have been the greatest impacts of climate variability in the district in the past 10 years? ii. What mechanisms have farmers put in place to reduce the impacts of climate variability on crop and animal production? iii. Do you think there has been a major shift in cropping patterns? If yes, which new crops have been introduced to cope with climate variability? iv. What do you judge has been the role of extension workers, research organizations, private sector and CSOs in supporting farmers' adaptation or coping to climate variability?	
3. Access to agricultural information	i. What do you judge has been the role of government, CSOs and private sector in providing information related to agricultural production, marketing, weather etc	
4. Credit availability	i. Is credit at current available in this community? ii. Who provides credit in this community at the moment? iii. Is credit available for crop production for farmers?	

C) Household Survey Questionnaire

Questionnaire Identifying Information

Name of the Supervisor		Date checked	
		Date entered	
Name of the Enumerator		Date of interview	

1. GENERAL HH INFORMATION

A. Respondent and general household information

a. Provide the following information about the respondent

Name of Respondent			
Telephone No.			
District		Sub-county	
Parish		Village	

b. Provide the following detail about the household head

Gender 1 = Male	Marital Status	Age (years)	Primary activity	Farming experience (years)	Education level

c. Is the household head the respondent? **1=Yes**☐, **2=No**☐

d. Is the household head the **farm owner**? **1=Yes**☐, **2=No**☐

e. If not, who is the **farm owner**? ___ ___________________________

f. **Number of Household members** (including HH head) living permanently on the compound

Age Categories	Males	Female	Total	No. actually working on the farm at least once a week
<13 years				
14-24 years				
25– 50 years				
> 50years				
No. of children attending school				

Marital status: *1=Married living with spouse, 2=Married but spouse away, 4=Widow/widower, 5=Single, 6=other, specify………*

Primary Activity of HH Head: *1=farming, 2=salaried employment, 3=business, 4=off farm laborer*

Education level: *1=none (illiterate), 2=Primary, 3=Secondary, 4=Tertiary*

2. LAND OWNERSHIP

B. Land holding

Ownership	Total land (acres)	Cultivated land (acres)	Pasture land (acres)	Fallow land (acres)	Wood lot (acres)
Owned					
Rented in					
Rented out					

a. What is the rental value per year per acres? ....

b. What is the purchase price per acres? ....

3. LIVESTOCK OWNERSHIP AND CROP PRODUCTION DURING 2010

C. Livestock ownership

Livestock livestock products	Do you own any of these (Y/N)	Source of livestock *(see codes)*	Number of animals on the farm in 2010	Livestock feeding (*see codes*)
Crossbred cattle				
Local cattle				
Improved goats				
Local goats				
Local sheep				
Improved pigs				
Local pigs				

Source: *1=Government program, 2=NGO, 3=Bought from market; 4=given by friends/relatives, 5=Bred on farm*

Livestock feeding: *1=feed mainly grass, 2=feed mix of grass and browse, 3=feed mainly browse*

D. Crop production. *Consider the last season of 2010, and start with major plots.*

Plot No	Area (acres)	Crops grown	Quantity harvested ***(kg)***	Quantity sold last season ***(kg)***	Average selling price ***per kg***
1					
2					
3					

E. Production constraints

a) Have you noticed any change in production of both crops and livestock in the recent past?
   1) Yes ☐ 2) No ☐

b) If yes, what type of change? 1=Increased ☐ 2=Decreased ☐, 3=Totally failed ☐

c) What are the reasons for the perceived change? *Rank (1 = highest priority, 5 = lowest priority)*

Crop production	**Rank**	**Livestock production**	**Rank**
Low soil fertility		Low quality pasture	
Pests and diseases		Pests and diseases	
Lack of improved varieties		Lack of improved breeds	
Poor access to inputs		Poor access to inputs	
Too little rain		Too little rain	
Too much rain		Too much rain	
Small land holding		Lack of grazing land	
Lack of labor		Lack of labor	
Others……………		Others………………..	

4. CLIMATE VARIABILITY, FARMER PERCEPTIONS AND ADAPTATION MEASURES

F. Rainfall satisfaction index

a) How many rainy seasons in your area?: 1) One ☐ 2) Two ☐

b) Rainy seasons:

1. 1st season: Begin:……………Max rains:………..…End……………..
2. 2nd season: Begin:……………Max rains:………..…End……………..

c) Have you noticed any change in rainfall pattern? 1) Yes ☐ 2) No ☐

d) If Yes, How many years back?:…………………………………

e) Perception of variability

During the growing season preceding the last main harvest:	**Codes**	**Response**
Did the rainfall come on time?	1 = on time; 2 = too early; 3 = too late	
Was there enough rain on your fields at the beginning of the rainy season?	1 = enough; 2 = too little; 3 = too much	
Was there enough rain on your fields during the growing season?	1 = enough; 2 = too little; 3 = too much	
Did the rains stop on time on your fields?	1 = on time; 2 = too late; 3 = too early	
Did it rain near the harvest time?	1 = no; 2 = yes	
Number of rainfall days	1 = No change; 2 = Reduced; 3 = Increased	
Frequency of heavy rains	1= No change; 2= Reduced; 3 = Increased	
Frequency of dry spells	1= No change; 2= Reduced; 3 = Increased	
Duration of the growing season	1= No change; 2= Reduced; 3 = Increased	

G. Adaptation strategies

a) What are the actions you have taken to improve /sustain your crop production in your farm in relationship with climate variability? How do you perceive the effectiveness of the measures employed in reducing production risk?

	Action/measures taken to sustain crop production	Reason for selecting the measure (*codes*)	Perception of effectiveness (rank on a scale of 1-5; where 1= not effective, and 5 = very effective)
1			
2			
3			
4			
5			
6			
7			
8			

Reasons: *1=low cost, 2=no additional labour, 3=increase crop yield, 4=reduce risk of crop failure, 5=water availability during dry season, 6=reduce floods, 7=reduce soil loss, 8=reduce risk of landslides, 9=input is available locally, 10=other (specify)*

b) **Crop management practices**. Have you practiced any of these? How do you perceive the effectiveness of the measures employed in reducing production risk?

	Activity	Change	Reason for change	Effectiveness (rank on a scale of 1-5; where 1= not effective, and 5 = very effective)
1	**Sowing date** (1=Moved back, 2=No change, 3=Moved forward)			
2	**Crop density** (1=Reduced, 2=No change, 3=Increased)			
3	**Crop Varieties** (1=Changed, 2=No change) If changed, which varieties before? .... And which varieties presently?			
4	**Crop association** (1=Changed 2=No change) If changed, which varieties before? .... And which varieties presently?			

c) **Land management technologies.** Are you using any of these technologies? Is it a new or old practice? How do you perceive its effectiveness in terms of addressing the problems for which you adopted?

Type of Technology	Are you using this technology? (Y/N)	Is it a new practice? (Y/N)	If Yes, reason for adoption of practice (*See codes below)*	Effectiveness (rank 1-5; where 1= not effective, and 5 = very effective)
Soil and water management				
Soil bunds				
Terraces				
Water harvesting dams				
Water harvesting tanks				
Small plot irrigation (≤1/4 ha)				
Large plot irrigation (>1/4 ha)				
Mulching				
Water ways				
Stone bunds				
Grass strips				
Soil fertility management				
Compost/animal manure				
Cover crops				

Crop rotation				
Intercropping				
Agro-forestry				
Chemical fertilizer				
Rhizobia inoculation				

If yes why: *1=increase crop yield, 2=water retention in the field, 3=reduce floods, 4=reduce soil erosion, 5=reduce risk of landslides, 6=other (specify)*

5. ACCESS TO FORMAL AND INFORMAL INSTITUTIONAL SUPPORT

H. Access to extension services

a) Did you or any member in your household receive agricultural information / advice during the last 12 months? 1) **Yes** ☐ **2) No** ☐

b) What kinds of assistance or information were requested or given?

Agricultural advice	Received service / advice (Yes/No)	Source of information or advice *(codes)*
Crop management practices		
Soil and water management		
Soil fertility management		
Pest & disease mgt		
Livestock management practices		
Insemination services		
Agricultural risk management		
Climate variability adaptation options		
Improved agricultural technologies		

***Source of information**: 1= Farmer to farmer, 2= Extension officer 3= Farmer group (cooperative), 4=National radio/TV, 5= Community radio, 6= News papers, 7=Phone sms, 8=Church/Mosque, 9= Market place posters/posted bulletin 10= Agricultural traders, 11=Other (Specify)*

I. Access to market and agricultural information

a) What is the average distance to nearest agricultural input market?......................................

b) What is the average distance to nearest agricultural output market?................................... ***(indicate '0' if more than 50% of farm produce is sold at farm gate)***

c) Do you have access to market and agricultural information? If yes, from whom or from which organization do you primarily obtain market information?

Type of information	Do you receive (Yes/No)	Source of information *(codes)*	How you use information
Market information			
Commodity prices in different markets			
Supply in different markets			
Weather forecast information			
Start of rainy season			
Extreme weather conditions			

Sowing dates			
What crops to grow			

***Source of information**: 1= Farmer to farmer, 2= Extension officer 3= Farmer group (cooperative), 4=National radio/TV 5= Community radio, 6= News papers, 7=Phone sms, 8=Church/Mosque, 9= Market place posters/posted bulletin 10= Agricultural traders, 11=Other (Specify)*

J. Access to credit services.

a) Do you have access to any of the following sources of credit?

Source	Have you ever borrowed (Yes/No)	Amount borrowed	Purpose (*see codes*)	Interest rate
Relative and friends				
Informal savings and credit group				
Money lender				
Government credit schemes				
NGO/Church/Mosque				
Bank or micro-finance institution				
Others..................				

***Purpose for borrowing:** 1=Purchase of food 2=Purchase of household assets 3=Payment of fees 4=Cover medical costs 5=Agricultural production 6=Cover educational costs, 7=other (specify)*

7. HOUSEHOLD INCOME

What is the estimated HH income for the last year (2010)? Consider all sources by HH members as long as income obtained is used to cater for HH requirements. Rank income sources in terms of contributing to Total HH income (*1=Not important, 2=Moderate importance, 3=High Importance, 4=Very High Importance)*

Income source	Estimated amount (USh) in 2010	Rank
Sale of crops		
Sale of livestock and livestock products		
Sale of other products (firewood/trees etc)		
Regular (formal) employment		
Casual employment		
Running own business		
Remittances from family members		

Appendix 4: List of publications emanating from this study

Kansiime, K.M., Shisanya, C.A. and Wambugu, S.K. (2014). Effectiveness of technological options for minimizing agricultural production risks under variable climatic conditions in eastern Uganda. Submitted to *Africa Crop Science Journal*.

Kansiime, K.M, Wambugu, S.K. and Shisanya, C.A. (2014). Determinants of Farmers' Decisions to Adopt Adaptation Technologies in Eastern Uganda. *Journal of Economic and Sustainable Development,* 5(3): 189-199.

Kansiime, K.M, Wambugu, S.K. and Shisanya, C.A. (2013). Perceived and Actual Rainfall Trends and Variability in Eastern Uganda: Implications for Community Preparedness and Response. *Journal of Natural Sciences Research*, 3 (8): 179-194.

Kansiime, K. M. (2012). Community-Based Adaptation for Improved Rural Livelihoods: a Case in Eastern Uganda. *Climate and Development*, DOI:10.1080/17565529.2012.730035 http://dx.doi.org/10.1080/17565529.2012.730035.