AN ECONOMIC ASSESSMENT OF FARMER ADAPTATION TO CLIMATE CHANGE USING INNOVATIONS IN SWEET POTATO TECHNOLOGIES IN UGANDA

BY
JOHN ILUKOR
BSC QUANTITATIVE ECONOMICS

A THESIS SUBMITTED TO THE SCHOOL OF POST GRADUATE STUDIES IN PARTIAL FULFILLMENT OF THE AWARD OF THE DEGREE OF MASTERS OF SCIENCE IN AGRICULTURE AND APPLIED ECONOMICS OF MAKERERE UNIVERSITY

DECEMBER 2010

DECLARATION

To the best of my knowledge, I declare that the contents of this thesis are original unless if stated otherwise and the thesis has never been submitted anywhere for any award

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JOHN ILUKOR **DATE**

This thesis has been submitted with permission and satisfaction from university supervisors

FIRST SURPERVISOR

…………………………………. **…………………**

DR FRED BAGAMBA **DATE**

SECOND SURPERVISOR

…………………………………… **………………**

PROF.BERNARD BASHAASHA **DATE**

DEDICATION

I dedicate this work to my uncles Anselm Ariko and James Oniaun, my mother Imalingat Jane, and my late father Patrick Kwanga.

ACKNOWLEDGEMENT

I wish to convey my sincere thanks and gratitude to my supervisors, Dr. Fred Bagamba and Assoc. Prof B. Bashaasha for not only giving me the guidance and direction but also for the support I received from them during my study. I also want to thank them for considering me in CIP Makerere University Climate Change project which sponsored my master's study.

I also wish to convey my sincere gratitude to TOA team and project leader Dr Claessens Lieven for the support, training they offered me in understanding the application of minimum data Trade-off methodology. Specific gratitude goes to Professor John Antle and Jetse stoorvegel for their relentless support during the running of the model.

Special thank go to Makerere University Business School Administration for allowing me to study. Specifically I want to thank the Principal Professor Wasswa Balunywa, Dr Michael Kakooza, and Dr Isaac Nkote Nabeta for granting me permission to study. I also want to use this opportunity to thank Assoc. Prof. Johnny Mugisha for defending my decision to study at faculty of Agriculture and for the great inspiration and motivation he offered to finish my studies on time.

My heart- felt thanks go to my classmates, Emmanuel Muhoozi, Arthur Shipekesa the Zulu, Alphonse Murasa and others from agricultural economics class for the support, the fun and encouragement they offered to me during my master's studies.

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ABSTRACT

Sweet potato technologies, like drought resistant varieties and virus cleaned planting material have shown resilience of agricultural systems to climate change related effects. However, adoption of these technologies is very low in Uganda. This study was designed to assess the adoption potential (economic feasibility) of these technologies by rural farm household under climate change conditions. Data were collected from study areas in Kabale and Soroti districts using household survey, focused group discussion and secondary sources. The Tradeoff Analysis, Minimum Data Model Approach (TOA-MD) was employed to estimate the adoption potential of alternative practices under climate change. Results from focused group discussion reveal that farmers have developed different adaptation strategies to climate change such as swamp reclamation, migration to other areas, mixed cropping among others. Access to these technologies was limited and government provision of planting material usually ends up with a few privileged farmers. Results from the model also show that, adoption potential under climate change is high and varies depending on agro-ecological zones, wealth status and opportunity costs of adopting the technology. However, providing free planting material is not feasible and if undertaken, it does not benefit the poor but the rich. We conclude that, adoption of these technologies is economically feasible and recommend that, climate change adaptation policy should target the poor, institutional framework and systems should be strengthen to improve on accountability in the implementation of climate change adaptation strategies of public nature. Measures are also needed to raise returns and reduce the opportunity costs of climate change adaptation strategies. Further research is needed to explore joint adoption of crop technologies that have show resilience to climate related effects.

CHAPTER ONE

1.0 Introduction

This Chapter presents background to a statement of the problem, research questions, objectives, hypotheses and justification of the study.

1.1 Background

Climate is often used to mean "average weather" and represents the state of climate system over a given time period. Climate change can therefore be defined as a long-term change in the patterns of average weather of a specific region or the world as a whole. Climate change reflects abnormal variations in the Earth's climate, such as in the ice caps and Ozone layer over long durations ranging from decades to millions of years. In recent usage, especially in the context of environmental policy, climate change refers to changes in modern climate often referred to as global warming. Global warming is mainly as result of past emissions of greenhouse gases and has resulted in floods and droughts. Occurrence of floods and droughts will inevitably lead to increased food prices and food insecurity in Africa over the next 30 years regardless of global mitigation efforts. Some studies have suggested that, crop yields may fall by 10 to 20% by the year 2050 because of warming and drying (Jones and Thornton, 2003; Thornton et al., 2006).

Climate change threatens to intensify development challenges already confronting the African continent, including food and water insecurity, widening and deepening poverty, HIV/AIDS, and ineffective governance (Intergovernmental Panel on Climate Change (IPCC), 2001a, ch. 10; IPCC, 2007b, ch. 9; International Development Research Centre, 2007; Slingo et al., 2005). In Uganda, the country has experienced frequent and severe droughts especially in the north, western and north eastern parts of the country. These areas were seriously affected in 2001, leading to food insecurity and social conflict as people searched for pasture and water for animals across local borders. According to OXFAM report 2008, Uganda is feeling the impacts of climate change despite the low contribution to global warming. Climate change has affected Uganda's agriculture in two ways. First, there has been more erratic, unreliable rainfall during first rainy season in March to June, and this has been followed by drought resulting in the reduction of crop yields. Second, the rainfall especially, in the second rains, is reported to be intense and destructive resulting into floods, landslides and soil erosion (OXFAM, 2008). These erratic climatic conditions have also led to increased pest and diseases out break for humans, animals and plants, declining soil fertility, food insecurity, reduced income and increased poverty.

African countries and their peoples need to devise adaptive strategies to abet the effects of climate change. Adaptation is considered especially relevant for Africa, where societies are already struggling to meet the challenges posed by existing climate variability (Yamin, Rahman and Huq, 2005; Adger et al., 2003; Watson and Ackerman, 2000; Thomas and Twyman, 2005), and are therefore expected to be the most adversely affected by climate change (Schipper, 2007; McCarthy et al., 2001). Until recently, however, adaptation has not been the focus of science and policy (Schipper, 2007; Klein, 2003). The recent Fourth IPCC Assessment Report emphasizes that "adaptation will be necessary to address impacts of climate change (IPCC, 2007a). Increasingly, adaptation has been embraced not only by the people affected by climate change, but also by development agencies like Department for International Development UK (DFID) and United Nations Development Programme

(UNDP) (DFID, 2005; UNDP, 2004; Mathur, Burton and van Aalst, 2004; Simms et al., 2004; AfDB et al., 2003). Orindi and Eriksen, (2005) suggest that adaptation to climate change should not only focus on entirely new activities but also on strengthening existing livelihood strategies and incorporation of development initiatives that may create and diversify opportunities for earning a living. An in-depth study of existing climatic adjustment strategies and the socio-economic and environmental trends that constrain or facilitate local livelihood security is considered necessary to adequately identify the measures that need to be prioritized for adaptation in Uganda. Such comprehensive adaptations measures will be aimed at increasing resilience and reducing vulnerability of farmers to climate change.

Recent research has shown that small, poor farmers are likely to be vulnerable to environmental degradation and climate variability because they are near critical thresholds for ecological and economic sustainability (Antle, Stoorvogel and Valdivia, 2006). Results from the Trade-off Analysis research project in the Machakos region of Kenya have shown that small farm households are near critical brink with respect to soil nutrients, soil organic matter and livestock (TOA Project, 2007). Likewise, research in Western Kenya by International livestock Research Institute shows that households can be pushed from sustainable to unsustainable trajectories by shocks such as weather or disease (Kristjanson et al., 2004). In Uganda, households have been forced to swamp reclamation, tree cutting, brick and charcoal burning partly as a result of climate change associated pressures. These vulnerabilities may be exacerbated by cultural norms which must be taken into account in formulating adaptation strategies. Also, vulnerability may depend on natural resource, human and social, physical and financial capital.

Though farmers have succeeded in continuously adapting to varying conditions, this frequent occurrence of extreme weather events are threatening to increase pest and disease spread in crops for example fungal infections occur during the period of high moisture. Earlier onset of warm temperatures could result in earlier threat from late blight for potatoes (Petzoldt and Seaman, 2008; Forbes and Simon, 2007) and sweet potato virus disease (SPVD) (Tairo *et al.*, 2004). The increase in incidence or infection of sweet potato virus diseases in south western Uganda could be a result of the rise in temperatures since the SPCSV, SPFMV and SPMSV virus tend to survive at 26^0 C-28^0 C (Claudia et al 2007). The Sweet potato virus disease can cause 65% to 72% reduction in yields from different cultivars (Gutiérrez *et al*, 2003. Results from NARO sweet potato programme indicate that the yield decline resulting from sweet potato virus ranges from 56 to 100%.

However, innovations in potato and sweet potato production technologists have improved resilience of agricultural systems and can reduce vulnerability of poor farm households to climate change related effects. These innovations include varieties that are disease resistant, tolerant to drought, heat and nutrient depletion, and of high nutrient value. The sweet potato varieties that have shown resilience to conditions resulting from variations in climate are NASPOT 1 (Gibson, 2005), New Kawongo, Dimbuka-Bukulula, NK259L, NK103M (Mwanga, 2007)**.** Cleaning of the planting material of the Sweet Potato Virus Disease (SPVD) also increase yields by over 56 percent in Uganda (Mukasa, et al 2006). Promotion of these varieties is very important in increasing resilience of the agricultural system to ensure that extremes are buffered irrespective of the direction of climate change.

1.2 Sweet Potato Production and Climate Change

Sweet potato is increasingly becoming an important crop for both home consumption and commercial purpose. Sweet potato plays a crucial role in the country's production systems offering potential benefits to poor farm households and urban consumers. It is particularly ideal for land scarce and poor farm house holds because it is an important food security crop reducing hunger when other crops fail (Ebregt et al, 2005, Smit, 1997, Bashaasha, et al, 1995). According to the Ministry of Agriculture, Animal Industry and Fisheries data, production in 2007 was estimated to be 2.8 million metric tons. Uganda is the second biggest producer in the world and takes the first position in Africa. On average, production has been growing at a rate of approximately 5% from 1998- 2002 and 6.8% from 2002-2007. This, according to Ministry, is attributed to increase in land allocated to sweet potato production. Studies by National agricultural research organization show that land allocated to resilient crops like Potatoes and sweet potatoes, cassava and sorghum is increasing while land allocated to vulnerable crops like bananas, coffee, millet with the exception of maize is reducing. However the yields per hectare of sweet potato have fluctuated with the lowest yields being 3 tones per hectare which is attributed to drought, declining soil fertility, pest and diseases, and poor quality of potato vines (PRAPACE, 2003, Ebregt et al, 2005, Smit, 1997, Bashaasha, et al 2001, 1995). According to studies by David & Stella (2006) pest and diseases are the main principle constraint to the farmers followed by drought. Bashaasha (2001) point out that, Ugandan farmers have identified drought as the most important abiotic constraint in sweet potato production. In addition, the heavy rains especially in the second season have become the constraint in form of floods destroying gardens and hindering harvesting. The *info-resources* focus suggests that, the problems facing sweet potato and potato production currently are mainly a result of change in climate yet it receives relatively less attention from breeders (info resources, 2008).

1.3 Problem Statement

Rural communities in Uganda dependent on small-scale, semi-subsistence agriculture have experienced a decline in agricultural production and productivity as a result of variations in climate. For the case of sweet potatoes, researchers are responding to this problem by developing resistant varieties (Mwanga and Sengooba, 1996) and cleaning sweet potato planting materials against SPVD (Gibson, 2005). These innovations in sweet potato production technologies have a potential to increase resilience of agricultural systems and reduce vulnerability of poor farm households to climate change. However, adoption of these technologies remains very low at about 30% (PMA, 2009) and this is mainly attributed to limited household capital endowment and access to rural services (Kato et al, 2009). Moreover, these technologies are being developed without considerations of farmer's economic potential to adopt these technologies. This study was designed to assess how sweet potato farmers are responding to climate variation and their capacity to adopt the new sweet potato technologies. Understanding farmer adaptation strategies to climate change, and assessing the benefits and the cost of these adaptation strategies was necessary in determining what farmers adopt, where, why and what incentives are required to achieve a target adoption rate.

1.4 The Objective of the Study

The purpose of this study was to assess the economic feasibility of climate change adaptation strategies among resource poor farmers in Uganda with the focus on sweet potato technologies.

The Specific Objectives of the Study

(i) To establish the adaptation strategies to climate change among the rural sweet potato farmers.

(ii) To evaluate the economic feasibility of adopting improved sweet potato varieties thought to build resilience to climate change.

(iii) To determine whether adoption potential varies by agro-ecological zone.

(iv) To determine whether adoption potential varies by based wealth status.

(v) To analyze the adoption implications of supplying free planting material of the technologies to farmers

1.5 Research Hypotheses

(i) Adoption of improved sweet potato technologies is economically feasible.

(ii) Adoption of improved sweet potato technologies does not vary with given agro-ecological zone.

(iii) Provision of free sweet potato planting material has no effect on adoption of these technologies.

(iv) The poor are less likely to adopt climate change adaptation strategies.

1.6 Justification of the Study

Climate change threatens Uganda's agricultural production through higher and more variable temperatures, changes in precipitation patterns, and increased occurrences of extreme events such as droughts and floods. It has dramatically affected agriculture as water sources become more variable. Droughts and floods will continue to stress agricultural systems, and some food-producing areas will be flooded and food production will fall (Nelson, 2009). Research that improves understanding and predictions of the interactions between climate change and agricultural technologies is needed. Climate change assessment tools that are more geographically precise are more useful for agricultural policy, and scenario assessment should be applied. These tools should clearly be able to integrate biophysical and socioeconomic scenarios in order to generate right policies to avert the effects of climate change and improve on adaptation. This is important because even with the best efforts to mitigate greenhouse gases (GHGs), it is inevitable that poor farmers will be affected (Nelson 2009). Also, Cost-effective ways to help poor farmers adapt to climate change are needed because of uncertainty about the magnitude of possible changes, their geographic distribution, and the long lead times needed to implement and enhance adaptation efforts or capacity. Participatory and interdisciplinary approach to assess how farmers are responding to climate variability and farmer's capacity to adopt the new adaptation strategies are essential in estimating the benefits and the cost of adaptation. This is useful in determining what farmers adopt, where, why and what incentives are required to achieve a target adoption rate.

CHAPTER TWO

THEORECTICAL FRAMEWORK AND LITERATURE REVIEW

2.0 Introduction

This chapter reviews the most important and recent work on climate change adaptation and factors affecting adoption of agricultural technologies. It provides context for the problem, and explores related works and ongoing debates in the field of climate change adaptation and effects of climate change on agriculture in general and on sweet potato production in particular.

2.1 Climate Change, Vulnerability and Adaptation

The change in climate may be due to natural variability or as a result of human induced increases of the greenhouse gases in the atmosphere. This is reflected by variations in weather variables like temperatures, precipitation and wind. Variations in these variables have far reaching effects on agricultural production. Adaptation to climate change refers to responses to actual or expected climate change. According to the IPCC report (2007), such responses include changes in process, practices, or structures either voluntarily or planned to minimize potential damages or take advantage of opportunities associated with climate change. The intergovernmental panel on climate change (IPCC, 2007) has pointed out that human activities are altering the climate system and that the global mean temperature is projected to increase in the range of 1.4 to 5.8 degrees centigrade. Results from climate change study in Ethiopia shows that farmers' perceptions of climate change are in line with the climatic data records. Nevertheless, only approximately half of the farmers had adjusted their farming practices to account for the impacts of climate change (Deressa & Hassan, 2009). Another study by Hassan (2008) revealed that mono-cropping is most vulnerable agricultural practice to climate change in Africa. Warming, especially in during the dry season, poses threats and to overcome these threats farmers need to engage in irrigation, multiple cropping and integrate of livestock to their farming system (Hassan, 2008). To improve household adaptation capabilities to climate change, key factors that need to considered are household size, farming experience, wealth, and access to credit, access to water, tenure rights, off-farm activities, and access to extension are the main factors that enhance adaptive capacity (Hassan, 2008; Deressa & Hassan, 2009). Therefore policy makers should develop strategies and policies aimed at improving these factors. The policy tools for promoting adaptation to climate change should include providing farm support (including tools and equipment), and supporting the poorest of the poor with food aid, subsidization of improved technologies and other forms of social assistance. Government aid, extension services, and information on climate change have been suggested to facilitate adaptation to climate change among the poorest farmers while wealthier farmers are more likely to adapt given access to land, credit and information about climate change(Bryan, Deressa, Gbetibouo, & Ringler, 2009).

2.1.1 Vulnerability and Adaptation of Uganda's Agriculture to Climate Variability

Uganda's agricultural sector, which is the backbone of Uganda's economy contributes 42% of the Gross Domestic Products, over 90% to exporting earnings and employs 80% of the labour force, is highly vulnerable to variations in climate (National Adaptation Program on Adaptation (NAPA), 2007; Oxfam 2008). Uganda's vulnerability can be clearly seen based on macro level indicators such as weak institutional capacity, limited skills and equipment for disaster management, heavy dependence on rain fed agriculture, limited financial resources and increasing population. In Uganda areas that are vulnerable have a population growth rate of about 5% on average, compared to the national average of 3.6% (Uganda National Adaptation Program on Adaptation, 2007). Vulnerability is also dependent on type of crop, and crop sensitivity to variations in climate varies with agro ecological zone (Orindi and Eriksen, 2005). Major studies on climate by the World Bank group, GTZ, and DFID clearly show that variations in climate will influence agricultural production by affecting the major factors influencing agricultural productivity like soil fertility, pest and diseases, temperature and rainfall and technology. Uncertainties in the onset and cessation of rainfall seasons which is high in the north eastern, eastern and northern Uganda affect agricultural production. This will always lead to high food prices, hunger and lower household revenue where the most vulnerable group being the rural poor households. Faced with such challenges households usually adopt various to strategies.

The effective adaptation strategies imply reducing present and future vulnerability to climate and include coping strategies or changes in practices and processes in light of the perceived climate change through innovation. These innovations include varieties that are pest and disease resistant, tolerant to drought and heat and nutrient depletion. Building resilience into the system ensures that extremes of the climate impacts are cushioned irrespective of the direction of climate change. Understanding how to approach vulnerability reduction or prioritization of adaptation support is critical. According to Uganda National Adaptation Programmes of Action, 2007, Ugandan communities have adopted different coping strategies to climate change effects which are categorized as A and B. Category A generally has positive environmental impacts and they include; exploitation of aquatic resources (fishing and consumption of aquatic plants) especially in areas of Soroti and Lira, food preservation technologies using herbal plants, sun drying, and ashes to store food. Herbal medicine is being resorted to for treating arising diseases. When agriculture production fails, farmers turn to alternative livelihood systems such as charcoal burning, and brick making. This is particularly the case in Soroti, Kumi and Rakai. Category B generally has negative impact on environment. Coping strategies include; encroachment on natural forests, wetlands and range land. In Soroti and Kabale land renting and degradation especially on arable land is increasing and arable land per household is decreasing at a rate of 2.5% per year. Encroachment on wetlands especially is preferred solution by those who own and are near wetlands or water bodies. Farmers have adopted mixed cropping and diversification of crops as a guard against the risk of harvest failure due to climatic change (Orindi & Eriksen, 2005). They also suggest the use of irrigation to provide crops with water from rivers and water bodies as it allows growing of vegetables during the dry season and drought period. Other strategies adapted by government and NGOs in Uganda to minimize climate related effects are distribution of improved crop technologies (Rugumayo, 2011)

2.2 Weather Variation and Sweet potato Production

The rainfall pattern in Uganda is bi-modal characterized by long rains in the first season from March to July and shorter rains in the second season from August to October. Most of the major crops like millet, cassava, maize, and groundnuts are grown in the first season (Bakema et al, 1994, Bashaasha and Scott, 2001, Ebregt et al, 2005). The major food crops grown depend on the agric-ecological zone and a decade ago sweet potato used to be planted only in second season because of risk of the millipedes destroying early plants thus limiting productivity in first planting season (Smit, 1997, Abidin, 2004, and Ebregt et al, 2004a, b,). Today farmer's plant sweet potatoes in first season as well (PRAPACE, 2003). Studies by Odongo and Schmit (1997) clearly suggests that, only one cropping season is possible and with its prolonged dry season, planting 2-3 months after the start of the rains seemed optimal for yields and control of weevil attack. Early planting (March/April) suffered from weevil attack on vines and high losses would be recorded during the harvesting because there is no adequate sunshine to dry potatoes unlike in second season. Lack of potato vines in first rain season is one main challenge that prohibited the growing of sweet potatoes in first season. The first season was used as a season of raising potato vines (Ebregt et al 2005 and Odongo and Schmit, 1997).

Unpredictability of the rainy season, water stress, changes in rainfall distribution and intensity is likely to put pressure on potato and sweet potato production. In some regions diseases and pests pressure are likely to increase due to climate change (CIP, 2001). Also the increase in temperatures puts additional pressure on potato and sweet potato production by threatening to limit the process of breeding new varieties. About 16-22% of these potato and sweet potato wild relatives are facing extinction by the year 2055 (Info Resource Focus, 2008). This is a precarious situation, since wild relatives are important gene pools for breeding new varieties. In addition, drought has made the raising of sweet potato vines very difficult such that resource poor households have to purchase the vines. However most of the farmers cannot afford to buy enough vines that meet subsistence production requirement let alone for commercial purpose. There is need to identify and support sustainable adaptation mechanisms to help poor farmers access the vines.

2.3 Adoption of Agricultural Production Technologies

There have been a number of studies that have been conducted on adoption of agricultural technologies. Yoko and Sserunkuuma (2007) in their study of adoption of new high yielding rice variety (NERICA) in Uganda found out that asset endowment does not limit farmer's adoption of new rice variety because government was promoting rice production through provision of free seed. Farmers who were in groups were more likely to adopt a new rice variety. Poor extension services, lack of training on post-harvest handling, and poor management practices for rice cultivation pose a threat to yield maximization. Studies by Neil and Lee (2001) found that land tenure, expansion of cattle industry and modernization of infrastructure limited the viability of maize-mucuna production systems by increasing its opportunity costs. These results imply that adoption of particular technology is influenced by returns from other uses of land. Extensive cattle production which is regarded as an adaptation strategy to climate change (Nelson, 2009) and the desire for structures and structural improvements for settlement increases the opportunity cost of adopting a given production technology depending on agro ecological zone. Yoko and Sserunkuuma's study highlights that agronomic biophysical and management factors are also important in influencing adoption of a particular production system. Vulnerability to pest and diseases and extreme climate do not favor adoption of agricultural production technologies.

Some studies examined the implications of alternative return assumptions on firm's technological adoption decisions (Isik et al, 2001). Although alternative return assumptions may not have significant impact on aggregate adoption, the firm-level adoption decisions would be significantly affected. This is because heterogeneous firms may respond to uncertainties differently due to varying productivity of new technologies.

Other studies have established that the choice of technology by farmers usually is based on considerations of the availability of alternatives. The use of scarce resources, such as land, labour and others inputs depends on the availability alternative activities. If all resources were unlimited and all options were available, the problem of choosing between alternatives would not exist. However, most resources are limited and this forces a farmer to make choices and choices entail sacrifices, namely the sacrifice of the alternative not chosen (opportunity cost). The concept of opportunity cost can be found in the works of many early economists (e.g. H.Knight (1921, 1928); Lionel Robbins (1930, 1932, and 1934) and Coarse (1938, 1946). A careful, analysis of these works indicates that the concept of cost embodied in them is conceptually distinct from the neoclassical paradigm. Coarse quite explicitly binds cost to choice, and he rejects any attempt to classify costs into categories of fixed and variable. The most significant contribution is that, any rewarding opportunity that is within the realm of possibility but which is rejected becomes a cost of undertaking the preferred alternative. In the strict neoclassical model, costs are distinguished from foregone profits because they are not tied directly to choice. Costs are objectively measurable outlays, and, provide the basis for a predictive hypothesis about the behavior of an individual's (firms) basing on prices and yields or returns. Opportunity costs on the other hand are approximated by the value of alternate product. The opportunity cost concept can be used to assess trade-offs that a farmer is faced with in adopting a given technology by considering the difference in returns between the observed practices and alternative practices.

According to Mattson *et al* (2000), another important factor in adoption of agriculture production technologies, is land. Land is an important resource and input in agricultural production. The visual effect of land use can also be of value in social terms. People might appreciate and give value to the rural landscape (Mattson *et al* 1999) and land value can also depend on nature of land, depending on whether it is hilly or not. Different uses of land are associated with different benefits but also with costs. In a decision-making situation, the cost of employing a given asset depends on the opportunity cost principles established by estimating the highest-valued opportunity that must be foregone. The opportunity cost is measured as a difference between returns of alternative uses. A decision-making process involves a comparison between the cost and the benefits resulting from various decision alternatives (Hirschey and Pappas 1993). Based on this background, a trade-off model, which serves as a supportive tool for policy-formulation and decision making while considering different uses of land and the related benefits and costs was used in this study to assess trade-offs between traditional and new sweet potato technologies under climate change.

CHAPTER THREE

METHODOLOGY

3.0 Introduction

This chapter presents the research methods used in this study. It discusses the research design adopted, target population, sampling procedure and sample size, methods of data collection, and data analysis.

3.1 Trade-Off Analysis Minimum Data (TOA-MD) Model

3.1.1 Theoretical Model

All the studies cited in preceding chapter have been capable of suggesting the relevant factors that influence the adoption of particular agricultural technologies but fall short of providing an estimate of adoption potential and amount of investment or payment that is required to motivate farmers to attain a particular level of adoption. In trying to solve this problem, a tradeoff economic model was applied to implement an *ex ante* evaluation of alternative agricultural systems (Antle and Capalbo, 2001; Thornton et al., 2003; Stoorvogel et al., 2004). However, this model requires highly detailed data that are not available. Antle and Valdivia (2006) developed a minimum-data (MD) model for *ex ante* assessment of the adoption of practices, which can be implemented with minimum data. This method gives an estimate of the rate of adoption of alternative practices based on their economic feasibility, i.e. differences in returns between alternative practices. This method offers a basis on which to assess adoption capability. The model was used to assess the economic viability of adopting dual-purpose sweet potato in Vihiga district, western Kenya by Claessens et al (2007). The model used farm level and plot level socio-economic and bio-physical data to assess the profitability of substituting dual-purpose sweet potato with other crops. Results showed that a number of farmers could benefit economically from adopting dual-purpose sweet potato. The model has also been applied in modeling the supply of the eco-system (Antle and Valdivia, 2006). Analysis of adoption of technologies using trade-off methods considers the following issues; first, the returns from adoption of these technologies vary across farmers due to the heterogeneous soil characteristics existing within the farm fields. Second, farmers are uncertain of returns due to uncertainty about output prices. Thus, adoption capabilities and the investment to increase adoption rates of these technologies among farmers will vary depending on economic and bio-physical factors (Khanna et. al, 1999).

The Tradeoff Analysis, Minimum Data Model (TOA-MD) developed by Antle, and Valdivia (2006) for an ex-ante assessment of the adoption of practices that can be implemented with available bio-physical and economic data was used in this study because it provides an estimate of the rate of adoption of alternative practices based on economic feasibility, (the difference in returns between the observed practices and alternative practices). It also provides a preliminary basis on which the assessment of adoption potential can be implemented at low cost in timely manner. It acknowledges that actual adoption and household decision making are influenced by numerous other factors besides economic feasibility. The process of application of the model is in two phases as illustrated in Figure1 below; Phase one is research priority setting and phase two is research project design and implementation. Phase one usually involves stakeholder workshops, and formulation of hypothesis for potential tradeoff. This is necessary to indentify climate change adaptation mechanisms for running the model. The second phase involves identification of data needs, collection of data, running of the model and construction of trade-off curves for policy analysis.

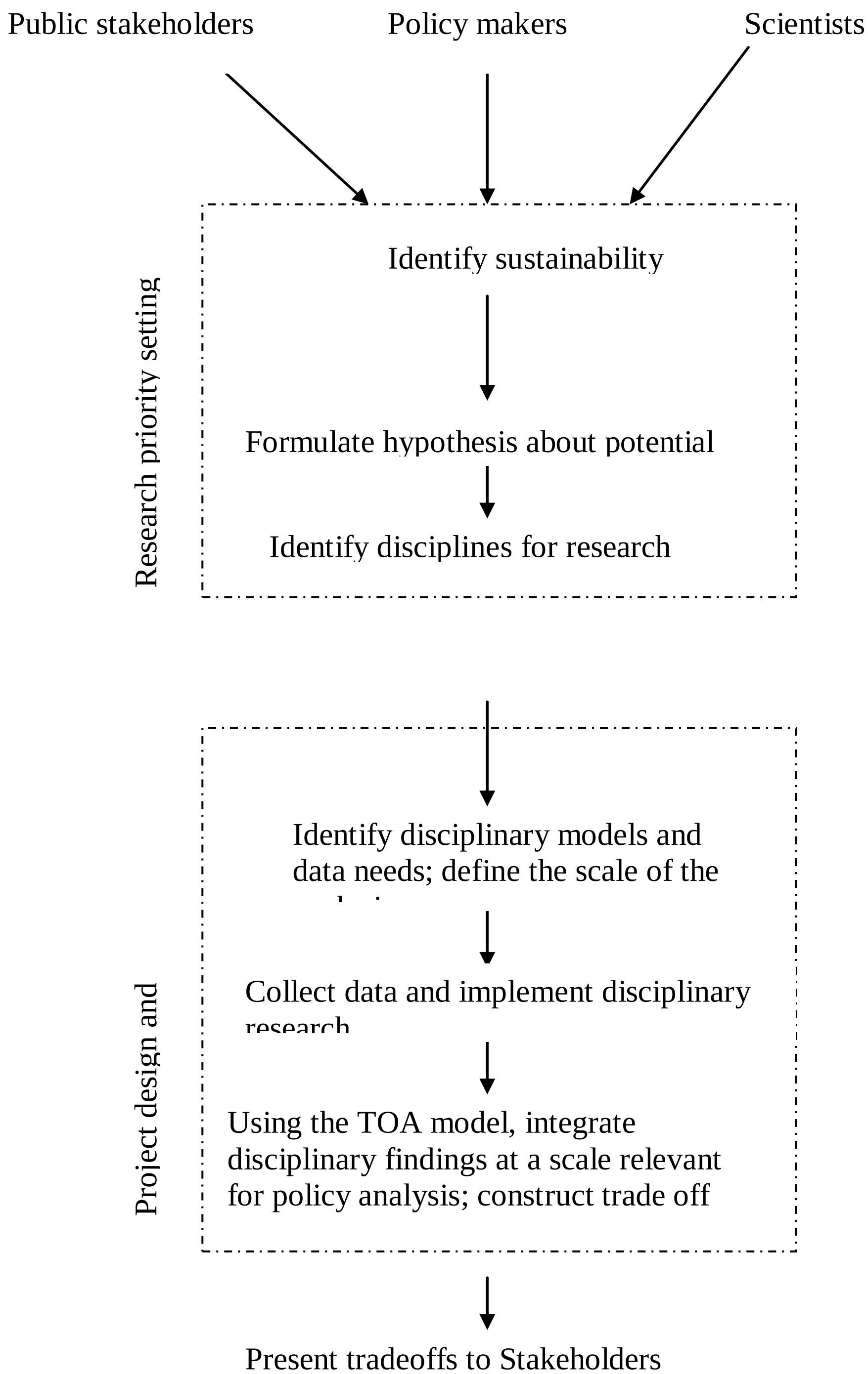

Figure 1: Overview of the linkage and process of tradeoff analysis
Source: Adapted from International Potato Centre by Yangen et al (2000)

The concept of tradeoffs is derived from the idea that resources are scarce and to obtain one of the scarce good, an individual or society collectively must give up some amount of another scarce good. This principle is called opportunity cost. Tradeoff analysis can be used to analyze sustainability of agricultural systems, by quantifying the inter-relationships between sustainability indicators implied by the bio-physical processes and economic behavior of farmers. The economic model is an econometric simulation model describing the decision making process at plot level in terms of land use and input use. The model can only function properly if it is adjusted to and estimated for the local conditions in the study area.

Economic modeling of climate change adaption

Farmers choose practices to maximize expected returns v (p, s, z) ($/ha), where p = output and input prices, s = location, z = system 1, 2 such that he earns v (p, s, 1) from the current system. A farmer can adopt system 2 and earn v (p, s, 2) - TC – A. Where TC = transaction cost, A = other adoption costs. The farmer will choose system 2 if v (p, s, 1) < v (p, s, 2) – TC – A. In running the model adoption costs and transaction costs summed up as Costs. Adoption costs are costs of purchasing the technology while TCs- are cost incurred in order to buy or access the technology e.g. transport and communication costs as in table 1 and 2 below. The opportunity cost of switching from 1 to 2 is δ = v (p, s, 1) - v (p, s, 2) + TC + A. A farmer adopts system 2 if $\delta < 0$. Suppose government or NGO wants to encourage adoption by providing incentive payment PAY (i.e., to reduce negative externalities of system 1, or encourage positive externalities of system 2). This implies that a farmer adopts system 2 if δ < PAY. Opportunity cost varies spatially, so at some sites farms adopt system 1 and at other sites they adopt system 2.

3.1.2 Simulation in the TOA-MD framework

To estimate the spatial distribution of opportunity cost of changing practices, the MD model uses "Complete" data to estimate site-specific inherent productivity (In-prods or INP) and simulate site-specific farm decisions to construct spatial distribution of returns. By design, MD approach estimates mean, variance, covariance of net returns distributions using plot level data. The mean and variance of the opportunity cost is δ = v (p, s, 1)-v (p, s, 2) + TC + A. The MD approach uses available data to estimate mean and variance of δ: E(δ)= E(v_1)— E(v_2)+TC+A. Suppose system 1 has one activity, then: E(v_1) = p_{11} y_{11} — C_{11} is usually observed. E(v_2) = P_{21} Y_{21} — C is estimated using inherent productivity and cost data: Y_{21} = y_{11} {1+ (INP_{21} — INP_{11})/INP_{11}}, In prod = inherent productivity = expected yield at a site with "typical" management. Also, cost of production based on model is a function of yield such that c $\approx \kappa\gamma$ where κ a constant and y is yield. Then v = p.y - c - κ (p-) y and CV of v is equal to CV of y. Recall: δ = v (p, s, 1) – v (p, s, 2) + TC + A, such that variance of opportunity cost is given as $\sigma_{\partial}{}^2 = \sigma_1{}^2 + \sigma_2{}^2 - 2\sigma_{12}$. We observe σ_{12}, and can assume $\sigma_1{}^2 \cong \sigma_2{}^2$, but σ_{12} is difficult to observe, so it is assumed that the correlation is positive and high in most cases. Given that $\sigma_1{}^2 \cong \sigma_2{}^2 = \sigma^2$ then $\sigma_{\partial}{}^2 = 2\sigma^2 - 2\sigma_{12}$ Thus, $\sigma_1{}^2$ and $\sigma_2{}^2$ depend on variances and covariance of returns to each activity. In the MD model, we assume that all correlations between activities within system 1 are equal (ρ_1), and make the same assumption for system 2 (ρ_2). In general, incentive payments are usually calculated as PAY = PES * ES. Where PES = $/unit of ES, ES = services / ha. For adoption analysis, we set ES = 1, then PAY = PES ($/ha). In summary, in the implementation of MD model we used data on mean yields for system 1 and inherent productivity in system 2 estimated using data from system one see table1. Output prices and cost of production for each activity, coefficient variations of returns (yields) for each system and correlation coefficient of returns to activities within each system (ρ_1 and ρ_2) were estimated.

3.2 Application of the TOA-MD to Adaptation to Climate Change

To represent the climate change in this analysis, we consider recent results of Ringler, Zhu, Cai, & Koo, (2010) on climate change impacts on food security using the IFPRI's IMPACT water and food projections model. The model considers three impacts on crop production from climate change: (1) the direct effects on rain fed yields through changes in temperature and precipitation; (2) indirect effects on irrigated yields from changes in temperature and in water available for irrigation (including precipitation); and (3) autonomous adjustments to area and yield due to price effects and changes in trade flows in the economic model (Ringler et al., 2010). Results from this model predict that climate change will reduce sweet potato yield s by 1.06%, cassava by 0.42% and maize 1.92% by 2050 in East Africa. Also, the impact of climate change on prices sweet potato and cassava was predicted to increase 26 and 20 percent respectively and on millet is 5 and 4% percent by 2050 as in table 1 below. It is also important to note that plants with similar photosynthetic metabolic pathways will react similarly to any given climate-change effect in a particular geographic region (Nelson et al, 2009) see table 1 and 2.

Experimental results by Mwanga, (2007) reveal that drought resistant varieties on average, reduces yield loss by 30% while, use virus free planting material reduces yield loss by 56% (Mukasa, et al 2006). We model adoption of drought resistant variety and joint use of drought resistant and use of clean planting material against the current practice of using local varieties and unclean sweet potato vines. Since drought resistance is independent of cleaning vines off viruses (Gibson, et al 2007), we computed the probability of using the drought resistant variety and virus free planting material using independent probabilities concept such that P (AUB) = P (A) + P (B) – P (AnB)= 0.692. This gives us reduction in yield loss using drought resistant variety and clean planting materials reducing. The costs C21 of system two are estimated using C_{11} and other information on changes in practices TC and A. It is estimated that 4 bags of sweet potato vines are enough to plant one hectare and each costs between 10,000 Uganda shillings. So, adoption costs of the planting material on average were estimate at 40,000 Uganda shillings per hectare. The coefficient of variation of the net returns can be assumed to be proportional to coefficient of variation of yields since costs production can be assumed to be proportional to yields (Antle and Calpabo, 2001; Immerzeel, Stoorvogel, & Antle, 2008). The weights with respect to climate change is assumed to be constant or the same because there is slow area expansion (Ringler et al., 2010)

In the Kabale district analysis, three regions or locations were identified and defined based on altitude including Upland, Middle land and low land because altitudinal differences play a key role in influencing the climate and farming practices in particular in Kabale district. Climate variation tends to influence crops that are grown and their yields (Thornton et al, 2010, 2009, and 2007). The angle of slope also affects the type, soil depth, and moisture content of soil and the rate of soil erosion which are very important in influencing productivity, technology adoption and vulnerability of rural households or farmers (Papiernik et al., 2005; Sadler et al., 2005; Su, Zhang, & Nie, 2010) and is key problem to crop yields (Jan, 2000). In the case of Soroti district, analysis was based on land size of the household since lad is general flat and farmers cited shortage of land as one of the main problems affecting agricultural production. Households with more than 4 acres of land were considered better off and those with less land are considered worse off.

3.3 Data and Sources

3.3.1 Description of the Study Sites

The study was implemented in two study sites: Kabale and Soroti Districts. Kabale District lies in the southwestern corner of Uganda between latitudes 1^0S and 1^0 30 S and longitude 29^0 18 E and $30^0$9E (Figure2). It is characterized by very hilly and mountainous terrain lying at a relatively high altitude of 1500-3000 meters above sea level. It has temperate like climate, with a mean annual rainfall of 1000 - 1500mm and temperatures ranging from 10^0c to 23^0c. It is comprised of three counties; Rukiga, Ndorwa and Rubanda and one Municipality. The district has the highest population density in rural Uganda, and pressure on land resources has been a problem since the 1940s resulting into extreme land fragmentation as family plots have been continuously sub-divided through the traditional Kiga system of equal allocation and inheritance to all sons (Lindblade et al 1996). Over the years, the combination of population pressure and land scarcity has also given rise to a tradition of male labour migration and a tendency to allow wives and children to support themselves on the home parcels (Yeld 1969). Another result has been migration and resettlement to neighboring areas over the years. The average agricultural land area is 2.06 hectares and important crops grown include: sorghum, beans, peas, potatoes, sweet potatoes and bananas (Lindblade et al 1996).

Figure 2: Map of Kabale Showing Ikumbya Sub-County.
Source: Uganda Bureau of Statistics 2010

Soroti District lies in the Eastern part of Uganda and located within the coordinates of 1° 41' 8" N and 33° 36' 59" E (Figure 3). It is characterized by a flat terrain with an average altitude of 1081 meters above sea level. The district is located in a semi-arid region dominated by savannah grasslands characterized by the Acacia species. The North moist farmland and north central, bush lands with sandy soils are the main farming area (Egeru and Majaliwa, 2009). The area has a hot and humid climate and receives an annual rainfall of between 1,000mm to 1200mm with temperatures ranging from 18^0C to 30^0C. It has two main rainy seasons between March – May and September – November. Recently the second rains have been characterized by floods. The district has a low population density of about 50 people per square kilometer compared to 246 per square kilometer in Kabale (Banana et al, 1997). However, the rapidly rising population is putting pressure on land resources and is resulting into extreme land fragmentation as family plots have been continuously sub-divided through the traditional system of equal allocation and inheritance to all sons (Banana et al, 1997).

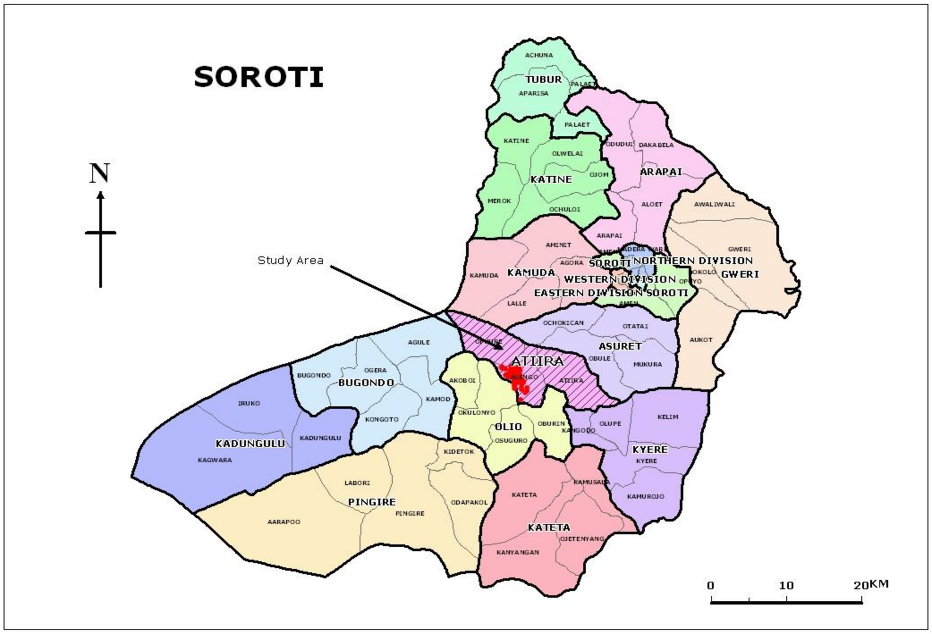

Figure 3: Map of Soroti Showing the Study Area
Source: Uganda Bureau of Statistics 2010

In each of the districts one sub county was selected; in Kabale Ikumbya was selected and Atiira in Soroti in consultation with the District Production department. Stake holders' workshops were conducted comprising of farmers, scientists and policy makers (political leaders) at the sub county. The choice of two study areas was based on the fact that, in both areas, sweet potato is one of the most important food security crops (Scott, 1999).

3.3.2 Data Collection Methods

Primary data, both qualitative and quantitative, were collected. Two methods where used namely, focused group discussions (FGD) through stakeholders in workshops and household farm survey. The target population was rural households that are considered to be most affected by the impact of climate change and also depend on sweet potatoes as the main staple food crop. The stakeholder workshops were conducted at each of sub-counties. The main objectives of the workshops were to obtain information with respect to farmer's knowledge about climate change impacts and adaptation strategies. Critical to this workshop was to determine whether farmers were experiencing the impact of climate change and how they are adapting to climate change. Also, a number of issues were discussed including sources of livelihood, production and farming systems, problems faced by farmers and their coping mechanisms. The workshop was intended for identifying scenarios that are relevant for modeling and analysis of data on climate change adaptation using innovation in potato and sweet potato technologies. Data from household surveys of 120 households from each study site included prices, inputs and outputs (yield), and land allocation. Net returns were computed for different crops and management systems. Average values of the variables were used in the analysis. Data on cost of planting material, climate change impacts (table 1) and resilience of sweet potato variety were collected from scientist at National Agricultural Research Organization (NARO) and other secondary sources. Data used were adjusted to meet TOA-MD excel supported software version.

3.3.3 Data Analysis

To assess and analyze economic feasibility of the adaptation strategies, household survey collected were calibrated to meet TOA-MD model requirement as seen table 2 and 3 below. Base system is current production systems of using local planting material adjusted with climate change impacts by 2050 and the alternative system is a practice aimed at increasing resilience to climate change i.e. use of drought resistant and virus cleaned sweet potato planting material. In table 1 and 2 , system one and system two are the alternative system and adaptation practice in both alternative only increase sweet potato productivity and does not affect other crops. This means that drought resistant variety increases productivity by 30% in system one and by 69.2% in system two.

Table 1: Data Set Used in Modeling Kabale Application

Regions	Crop Activities	Base system									System 1	System 2
Lower slopes		*Cost/ha*	*Yields/ha*	*Climate change yield impacts (%)*	*Price/kg*	*Climate change price impacts*	*Area/ha*	*SD*	*CV*	*Weights*	*Drought Resistant Variety (%)*	*Drought Resistant Variety + Clean Vines (%)*
	Beans	289484	1414.4	11	725	14	10.9	797.3	56.4	0.4	100	100
	Potatoes	301340	6670.8	-1.06	325	26	4.3	4722.8	70.8	0.3	100	100
	Sweet-potatoes	128440	325	-1.06	123.3	26	3.1	4070.8	56.4	0.2	130	169.2
	Sorghum	109809.1	2877.6	1.09	500	4	1.4	2874.9	99.9	0.1	100	100
Middle slopes	**Beans**	125278.4	1708.4	11	725	14	1.4	1440.3	84.3	0.2	100	100
	Potatoes	328510	7561.5	-1.06	325	26	2.6	4976.3	65.8	0.3	100	100
	Sweet-potatoes	0	6290.3	-1.06	123.3	26	2.3	5825.4	92.6	0.3	130	169.2
	Sorghum	114608	3527.2	1.09	500	4	2.2	3337.8	94.6	0.3	100	100
Upper slopes	**Beans**	90985.8	2746.6	11	725	14	2.2	2877.5	105	0.2	100	100
	Potatoes	620175.8	7096.3	-1.06	325	26	3	4712.4	66.4	0.3	100	100
	Sweet-potatoes	88920	5805.2	-1.06	123.3	26	3.1	3297.7	56.8	0.3	130	169.2
	Sorghum	68295.5	1443.8	1.09	500	4	1.7	506.6	35.1	0.2	100	100

Source: Field Survey Data (May 2010)

Table 2: Data Set Used in Modeling Soroti Application

Regions	Crop Activities	Base system									System 1
		Cost/ha	*Yields/ha*	*Climate change yield impacts (%)*	*Price/kg*	*Climate change price impacts*	*Area/ha*	*SD*	*CV*	*Weights*	*Drought Resistant Variety + Clean Vines (%)*
Better-off	**Sweet-potatoes**	171262.4	1602.6	-1.06	200	26	7.9	1895.8	118.3	0.23	169.2
	Sorghum	68703.04	826.7	4	316.7	4	4.1	567.8	68.7	0.12	100
	Millet	159089	1139.1	0.3	316.3	5	3.5	2042	179.3	0.1	100
	Cassava	120836.7	560.9	-0.42	440	20	12.4	423.8	75.6	0.37	100
	G/nuts	695344.1	1141.3	-1.4	1000	7	3.5	2827.4	247.7	0.1	100
	Maize	128194	640.5	-1.92	600	4	1.8	493.2	77	0.05	100
	Cowpeas	64489.23	278.3	-11	900	16	0.6	75.6	27.2	0.02	100
Worse-off	**Sweet-potatoes**	241606.6	3287.2	-1.06	200	26	4.94	3907	118.9	0.27	169.2
	Sorghum	132892.6	1467.7	4	316.7	4	3.1	2042	139.2	0.17	100
	Millet	401171.9	3987.3	0.3	316.3	5	1.7	11662.9	292.5	0.09	100
	Cassava	609988	3526.1	-0.42	440	20	3.6	7761.36	220.1	0.2	100
	G/nuts	385070.9	4024.3	-1.4	1000	7	2.7	11841.9	294.3	0.15	100
	Maize	109072.5	1729.96	-1.92	600	4	1.5	2091.3	120.9	0.08	100
	Cowpeas	191558.7	485.2	-11	900	16	0.7	227.3	46.9	0.04	100

Source: Field Survey Data (March 2010)

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Household and Farm characteristics-Kabale district

The farming activities carried out in Ikumba sub-county in Kabale district are presented in Figure 4, and ranked in terms of contribution to household food security and income as in Appendix Table 2. Important crops were potato, beans, sweet potatoes, and sorghum in their order of decreasing importance. These results are consistent with results obtained from the survey results which show that 30% of crop land is allocated to potato production, 27% to beans production, 26% to sweet potato production and 16% to sorghum production**.** **S**urvey data shows that costs of production are higher in lower slopes but yields are lower compared to both moderate and upper slopes. Also, when compared to moderate slopes, costs are higher and yields lower in steep slopes. In terms of land allocation more land is allocated to sweet potatoes in steep and lower slopes than in moderate slopes while yield variability is high in moderate slopes compared to upper and lower slopes see table 1 above.

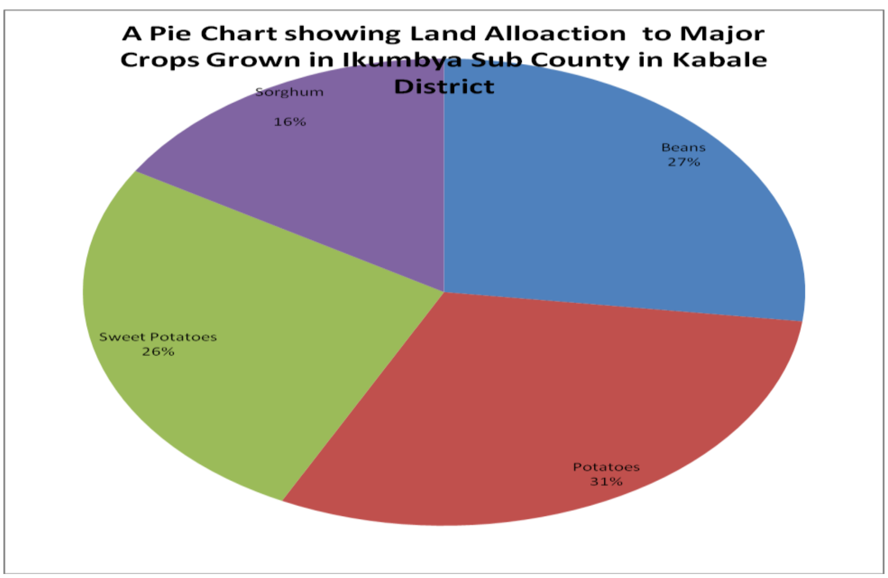

Figure 4: Land Allocation to Major Crops Grown in Ikumbya Sub County in Kabale District.
Source: Field data (May 2010)

In Soroti, major food crops grown in Soroti include cassava, sweet potatoes, sorghum, ground nut, millet, and cowpeas. The cash crops include cassava, groundnuts, sweet potatoes, millet and sorghum. Cassava, sweet potato, and sorghum are the most preferred food crops and are considered as food security crops (Figure 5). Cassava and sorghum are usually mixed to produce the local bread called "ATAP", while sweet potato is popular because it is quick maturing crop that saves people from famine. The data form Soroti show that farmers with less land allocate small land to sweet potatoes, incur high costs and produce more output while those who own more land allocate more land spend less and produce less output. However yield variability is high in worse off farmers than better-off farmers.

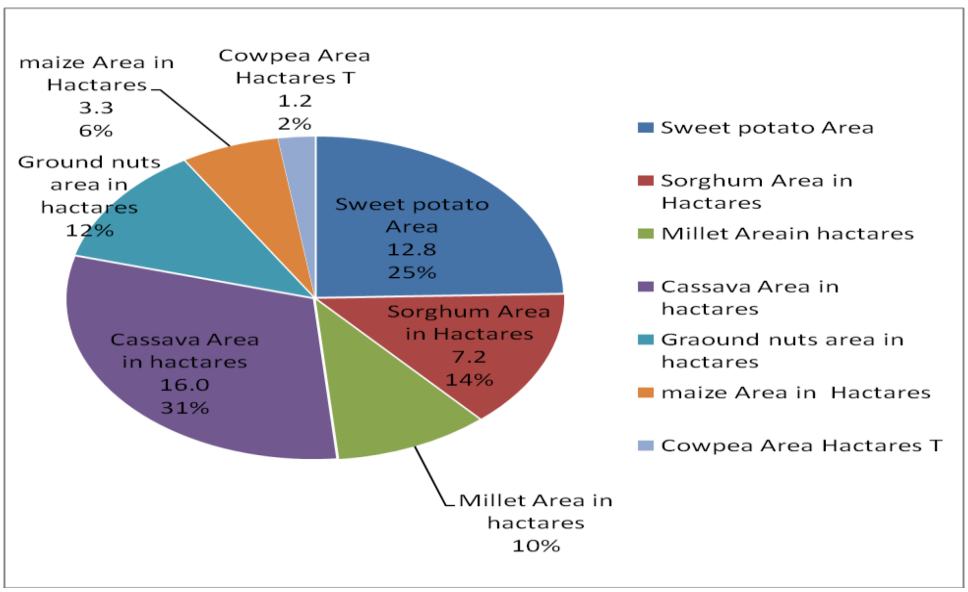

Figure 5: Land Allocation to Different Crops Cultivated in Atiira Sub County, Soroti District. Source: Field data (May 2010)

4.2 Agricultural Production and Climate Variability in Kabale District

The first specific objective of this study was to elucidate adaptation strategies to climate change among sweet potato farmers. To come up with meaningful results, we started gauging if the farmers experience climate change by asking them the major problems they face in farming. Later, we discussed the adaptation strategies used to investigate the impacts of climate change. Results showed that unpredictable rainfall pattern was the main factor affecting agricultural productivity, followed by increased incidence of pest and diseases, declining soil fertility and shortage of land (high population density). Farmers attributed the high incidence of pest and diseases to climate change and declining soil fertility to erosion. Major crop diseases included bacterial wilt of potatoes, root rot of beans, late blight in potatoes and beans, brown spots for passion fruit, fusarium wilt of bananas, and wilt, mold and powdery mildew in sweet potatoes. Pests included weevils in sweet potatoes, cut worms in beans, vegetables and potatoes, aphids in beans and peas and, generally, rats, moles, birds and monkeys. The result has been increased incidence of famine due to poor crop yields, reduced farm incomes, and reduced livestock feed sources. There has been also reduced availability of planting material for sweet potatoes especially for new varieties, and reduced access to water. Soil related problems include soil erosion, low soil fertility, poor tillage practices, lowering of the water table, lack of knowledge on soil and water management, and lack of knowledge on fertilizer application.

Results also show that farmers have adapted differently to climate change. The coping mechanisms for unpredictable rainfall included swamp cultivation during the dry season, cultivation of drought resistant crops, mixed cropping and multiple cropping, cultivation of short duration crops (vegetables, water melon, and cereals), increased usage of water harvesting methods based on traditional dams, flood irrigation, and micro-irrigation for vegetables. For diseases and pests, coping mechanisms included pesticide application, early planting, planting of pest and disease resistant varieties and increased practice of crop rotation. Coping mechanism for land shortage include hiring land, intercropping, use of improved seeds and use of high yielding seeds. Fertilizers are expensive for poor rural farmers and knowledge on use is lacking (Orindi & Eriksen, 2005).

4.3 Agricultural Production and Climate Variability in Soroti District

Farmers generally identified rising temperatures, unpredictable rainfall pattern, and droughts as main factors affecting agricultural productivity in Soroti. This is followed by increased incidence of pests and diseases, declining soil fertility and shortage of land due to increase in population. Farmers attributed the high incidence of pests and diseases and declining soil fertility to drought and floods. The increase in sweet potato pests and diseases has been attributed to rising temperatures (Info Resources, 2008; Bashaasha, 2005; 1999). Time series data for the mean monthly temperature over the years for Soroti show that, temperatures have risen by one degree (figure 6).

During the workshops, farmers stated that, 10 years ago, planting of some crops would start in December and end in February or early March. Today, the first rains start in late March or early April up to late June. The second rains come in August but a marked difference between today's second rains is the too much rain in short period of time that results in floods which destroy crops in the gardens. Also, sweet potato used to be cultivated in the second season because it matures fast, and the harvesting season coincides with the dry season. Planting of sweet potatoes was used as means of opening up land for other crops (millet) in the first rains and for raising the sweet potato vines. Today sweet potatoes are planted during the first rains and even second season. This change, according to farmers, is because of unpredictable rainfall patterns. The first rains are shorter and do not favor some other crops (millet and maize) which are less tolerant to drought.

Data from Uganda Meteorological department supports the farmer's observation. Time series data for mean monthly rainfall shows that first rains started falling between march and April from 1992 -2007 while for 1976-1991 and 1961-1975, the first rains would start in January and steadily rise up to May/ June. Also the second rains were well distributed between 1961 to 1975 over five month July-November while in 1992 to 2007 and 1976 to1991, data show that, between Jan to March rains fluctuate sharply between March to May resulting in much rain within a short period of time (Oxfam, 2008).

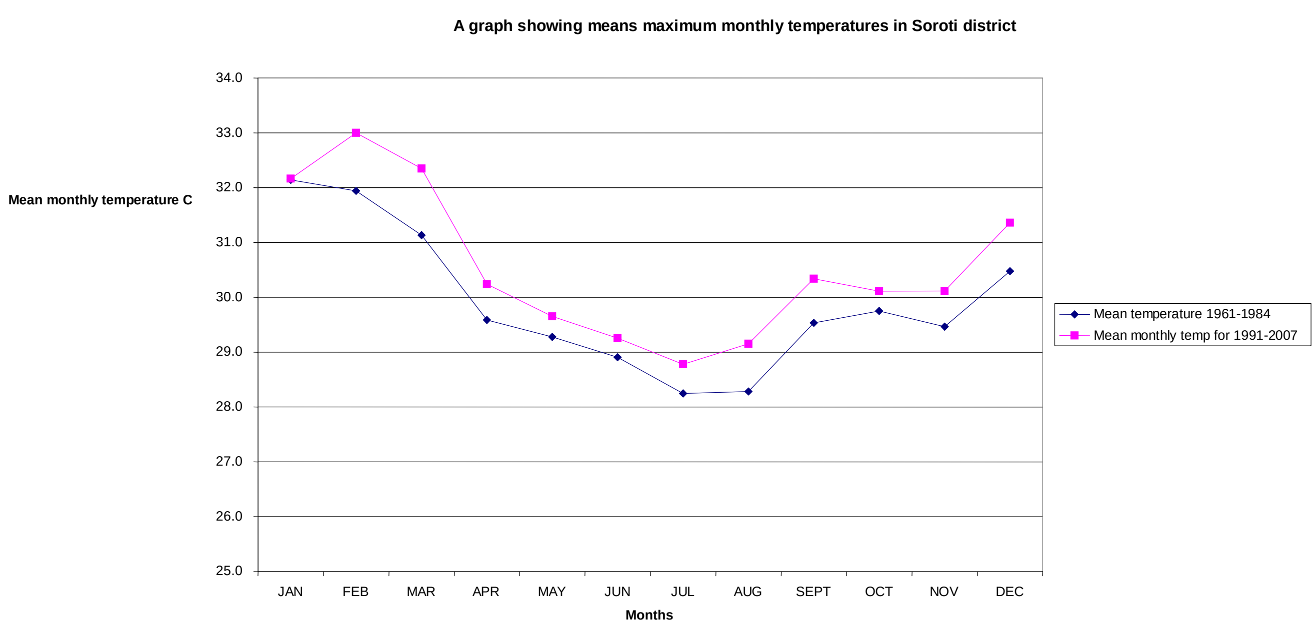

Figure 6: Maximum Monthly Temperatures in Soroti District

Source: Uganda Bureau of Statistics 2009

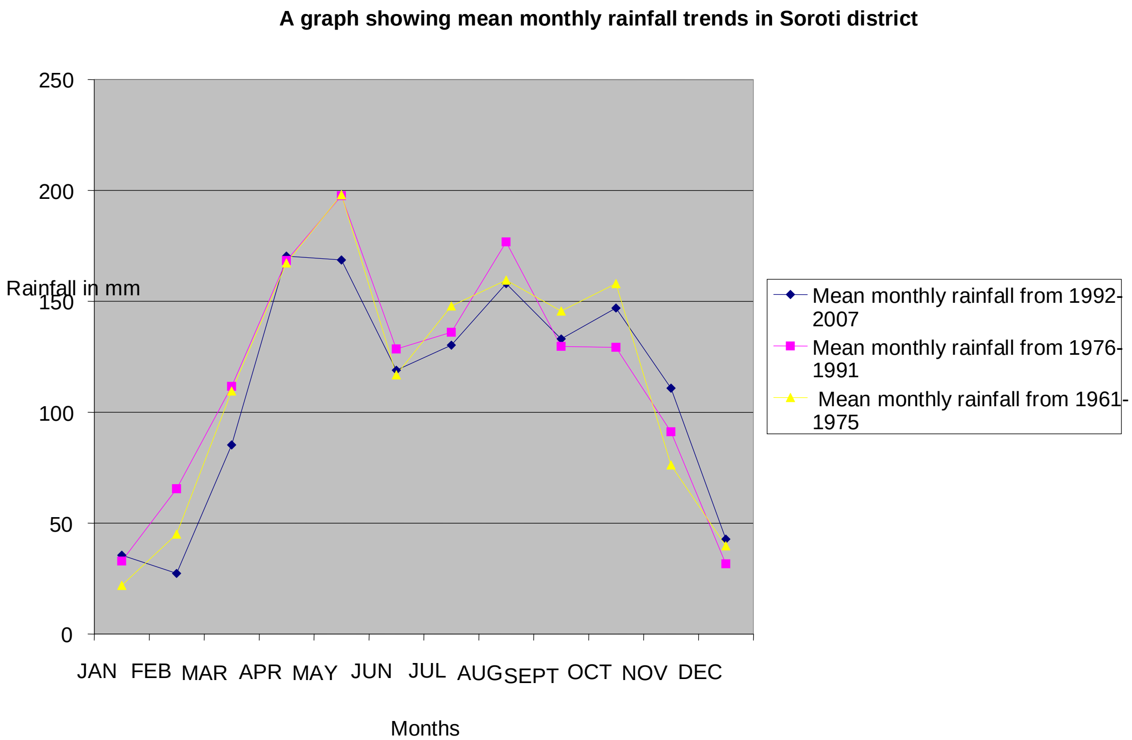

Figure 7: Mean Monthly Rainfall Trends in Soroti District

Source: Uganda Bureau of Statistics 2009

Another reason noted for planting sweet potatoes in first season is that, the market for the first season harvest is very good and prices are high. This could be as result of low production in first season which is a result of limited access to sweet potato vines, which farmers have to buy at high price (CIP, 2001).

Adaptation strategies

Results show that farmers have responded differently in trying to adapt to climate change. To minimize the effect of drought and unpredictable rainfall patterns; farmers cope by cultivating in the swamps, growing of drought resistant crops, practicing mixed cropping and multiple cropping, cultivation of short duration crops (vegetables, water melon, cereals), and planting most crops during first rains. For diseases and pests, coping mechanisms include, spraying with pesticides, early planting, up rooting infected plants, planting pest resistant varieties and practicing crop rotation. Renting land, intercropping, use of improved seeds and use of high yielding seeds were used as coping mechanisms for land shortage while increased usage of kitchen refuse was used to improve soil fertility. The other coping mechanism had been crop rotation but at time of the survey, this was no longer possible because of population pressure and increasing family size (Orindi & Eriksen, 2005). Government way of providing planting material under the NAADS program to ensure that households are food secure but only those who are rich and powerful would access them yet they are the ones who could afford them. The poor, the old and vulnerable groups could not afford and let alone access the new varieties. This, according to extension staff was because planting material would always not meet demand of the increasing population and therefore targeted model farmers who are usually richer and politically powerful.

4.4 MD Trade-off Analysis Results

4.4.1 Virus free and drought resistant Variety

The base system comprises of the current production system where farmers are still planting traditional varieties. Predicted yields using inherent productivity were used to estimate returns for the two new systems and compare them with the current system. The Kabale analysis examines the following scenarios:

(i) Adoption of the new sweet potato variety that is pest and drought resistant versus the traditional practices. This was to test economic feasibility of adopting these technologies

(ii) Adoption of drought resistant varieties that have been cleaned of viruses versus traditional varieties across different slopes so as to test hypothesis that adoption improved sweet potato technologies vary with given agro-ecological zone.

(iii) Adoption of drought resistant varieties that have been cleaned of viruses versus traditional varieties with and without subsidy. To test hypothesis that supplying free planting material of the sweet potato technologies to farmers' increases adoption and resilience to climate change.

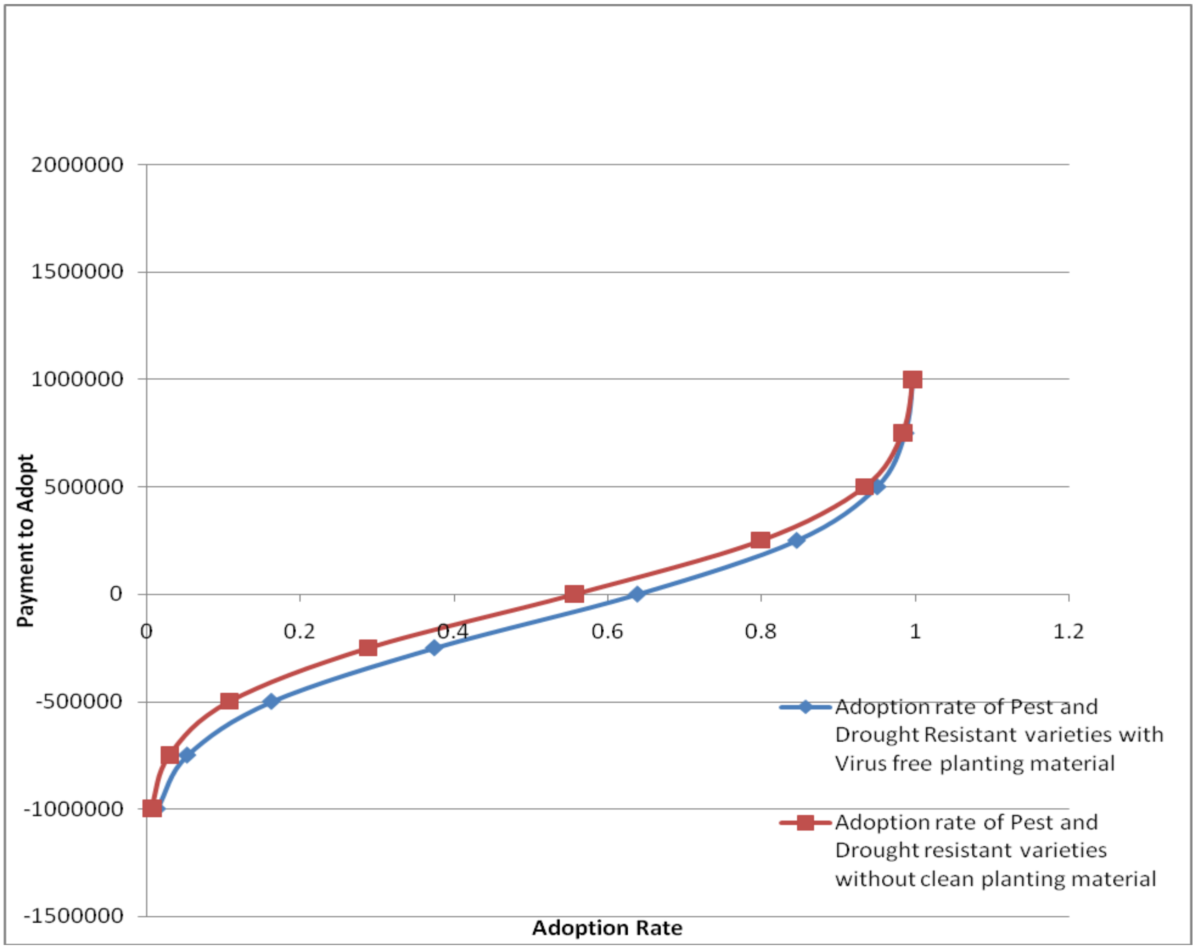

Figure 8: Trade-off Curves showing how much a Farmer is to be paid to attain a given level of Adoption
Source: Field Survey data (May 2010)

The results show that the adoption rate of virus cleaned drought resistant varieties is 65% without compensation, while 57% of the households would plant virus unclean drought resistant varieties without compensation. These results imply that yield increase due to clean planting material would motivate farmers to increase adoption of the technology by 8% (from 57 to 65) **.** Results also indicate that to raise adoption level by 20%, farmers need compensation of about 250000 Uganda shillings per hectare to encourage them to adopt the new technologies. The 250,000 Uganda shillings (US $125) per hactare is to costly (almost an equivalent or even more than the net returns from each hactare of sweet potato). This clearly suggests that, a farmer will not adopt or allocate resources to that technology that maximizes net returns, (Neil and Lee, 2001) hence the problem is not money but returns from a given technology. Therefore, the hypothesis that adoption of improved sweet potato technology is not economically feasible is rejected because farmer's adoption potential of 57% and 65% is good enough and can increase as long as the returns are high enough to recover costs.

4.4.2 Adoption with Subsidy Vs no subsidy under climate change

Figure 9 below, presents the adoption rate of pest and drought resistant with virus free sweet potato when planting material is freely supplied to farmers and adoption rate when farmers buy the planting material under climate change. The results indicate that 71% will adopt pest and drought resistant variety with virus free planting material without any compenstion compared to 73% in case of free planting material. The result shows insignicant difference in adoption rates implying that a sweet potato vine subsidy would achieve little interms of promoting the adoption. This may have a lot to do with the fact that, the cost of the planting material is insignificant comapred to the total benefits from sweet potato production. Thus, farmers will endeavour to obtain planting material with or without compensation. Therefore, the hypothesis that, provision of free planting material has no effect on adoption improved sweet potato technologies was not rejected.

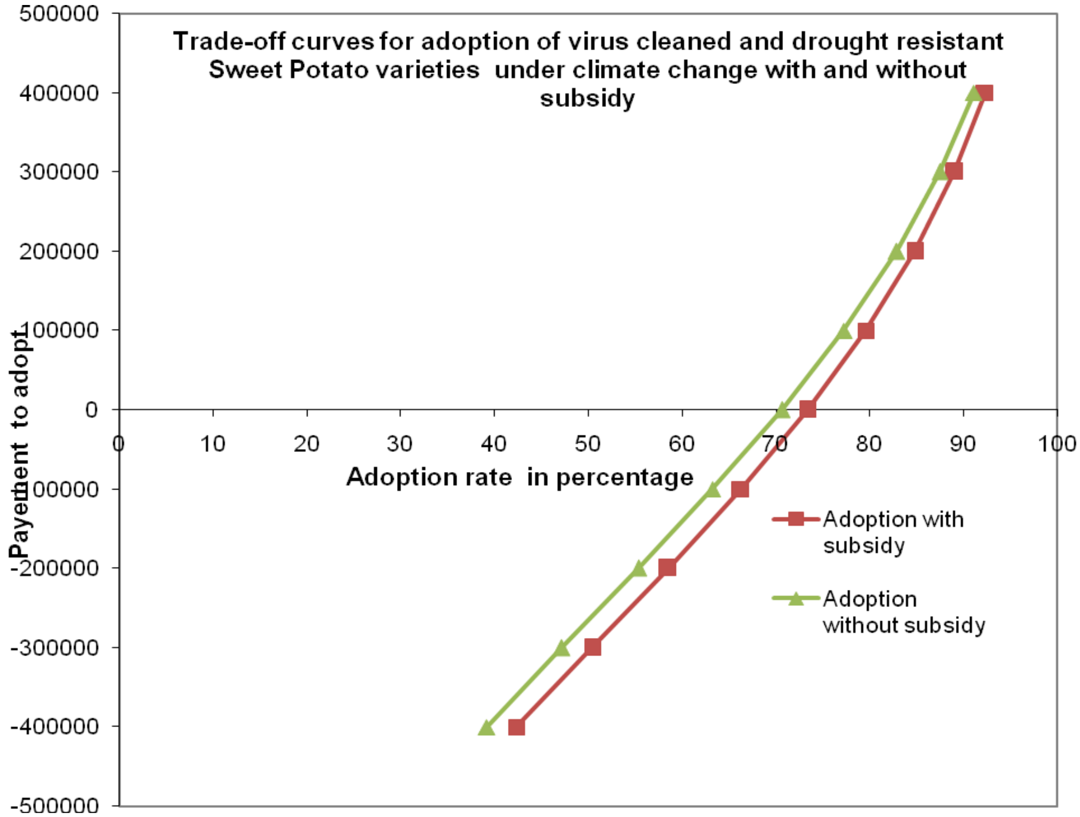

Figure 9: Adoption Potential of Clean Sweet Potato Varieties

4.4.3 Adoption Potential based on different Slopes under climate change

The results in Figure 10 show that, adoption level on lower, middle and upper slopes areas is 71%, 67% and 73% respectively. These are the percentage of households that will not need any payment to adopt virus cleaned drought resistant variety. Results indicate that potential adoption or land allocation to production of sweet potatoes under these technologies varies with slopes. The lowest adoption level is on middle slopes, followed by lower slopes and is highest on upper slopes. The low adoption potential in middle slopes can be attributed to intensive land use competition for settlement and other crops because of good drainage and fair soil fertility. Lower slopes are often used for graying animals and upper slope areas are easily eroded and cannot be used for settlement and few crops can grow. Payment of

200,000 Ugx raises adoption in middle slopes to 77%, lower and in hilly slopes to 84%. Therefore, the hypothesis that, adoption of improved sweet potato technologies does not vary with agro-ecological zones was rejected. These results clearly indicate that, to attain sustainable adoption of agricultural technologies (Sweet potato technologies) in Kabale district, variation in land value based on slope differences needs to be considered. The higher compensation pay required in middle areas to increase adoption rate of sweet potato technology may be a result of competing uses of land. The opportunity cost of allocating land to new sweet potato technology is higher in middle slopes because of competing uses. Results in table 1 above reveal that, land allocated to sweet potato in middle slope is lowest but the yields are highest. The existence of competing uses of land use has negative effect on allocation of land to new sweet potato technologies. As noted by Buckles,(1999) in his study of adoption mucuna system in Honduras, as land was being converted to pastures for cattle production the opportunity costs of keeping land in the mucuna increased. Equivalently, in Kabale, the middle slopes are suitable for settlement and for production of other crops and as such the opportunity costs of allocating land to sweet potato technologies also increases.

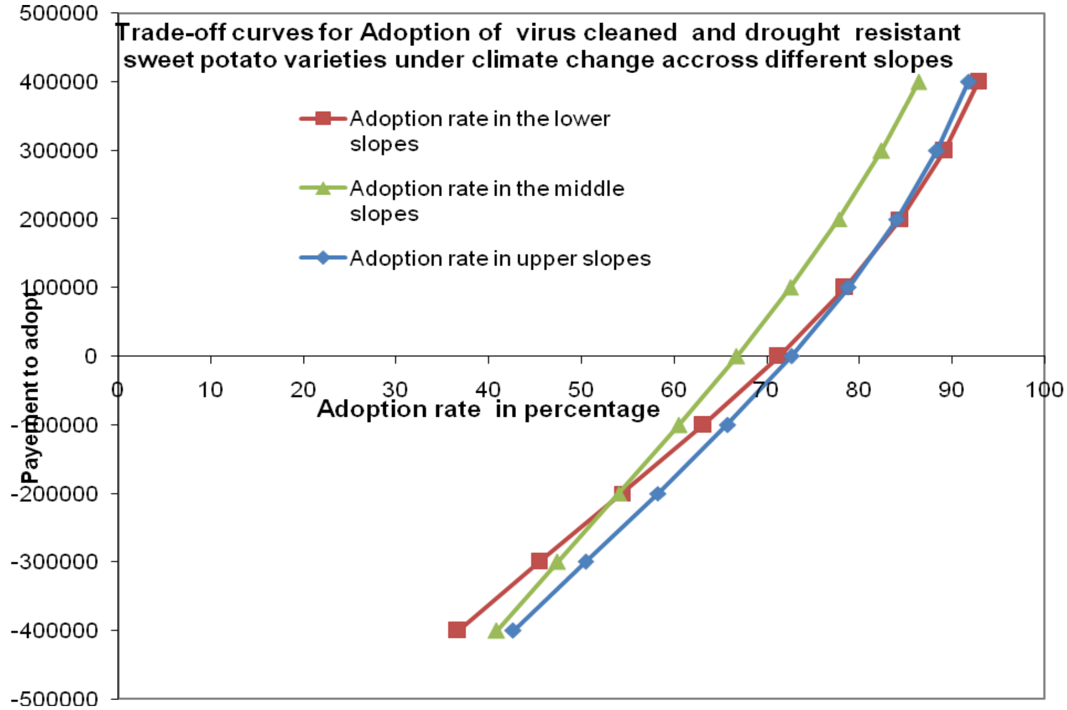

Figure 10: Potential Adoption of use of Clean, Pest and Diseases Resistant Varieties based on Slope
Source: Field Survey data (May 2010)

4.4.4 Potential Adoption of Combined technology of Virus cleaned Drought Resistant Varieties in Soroti District

The analysis in Soroti categorizes farmers by asset ownership proxied by land size. The Worse off- were considered as those households with crop acreage that is less than 0.4 hectares and better off households were those with crop hectares greater or equal to 0.4. Clean planting material of resistant sweet potato varieties versus traditional varieties were the two systems considered for analysis (figure 11) below.

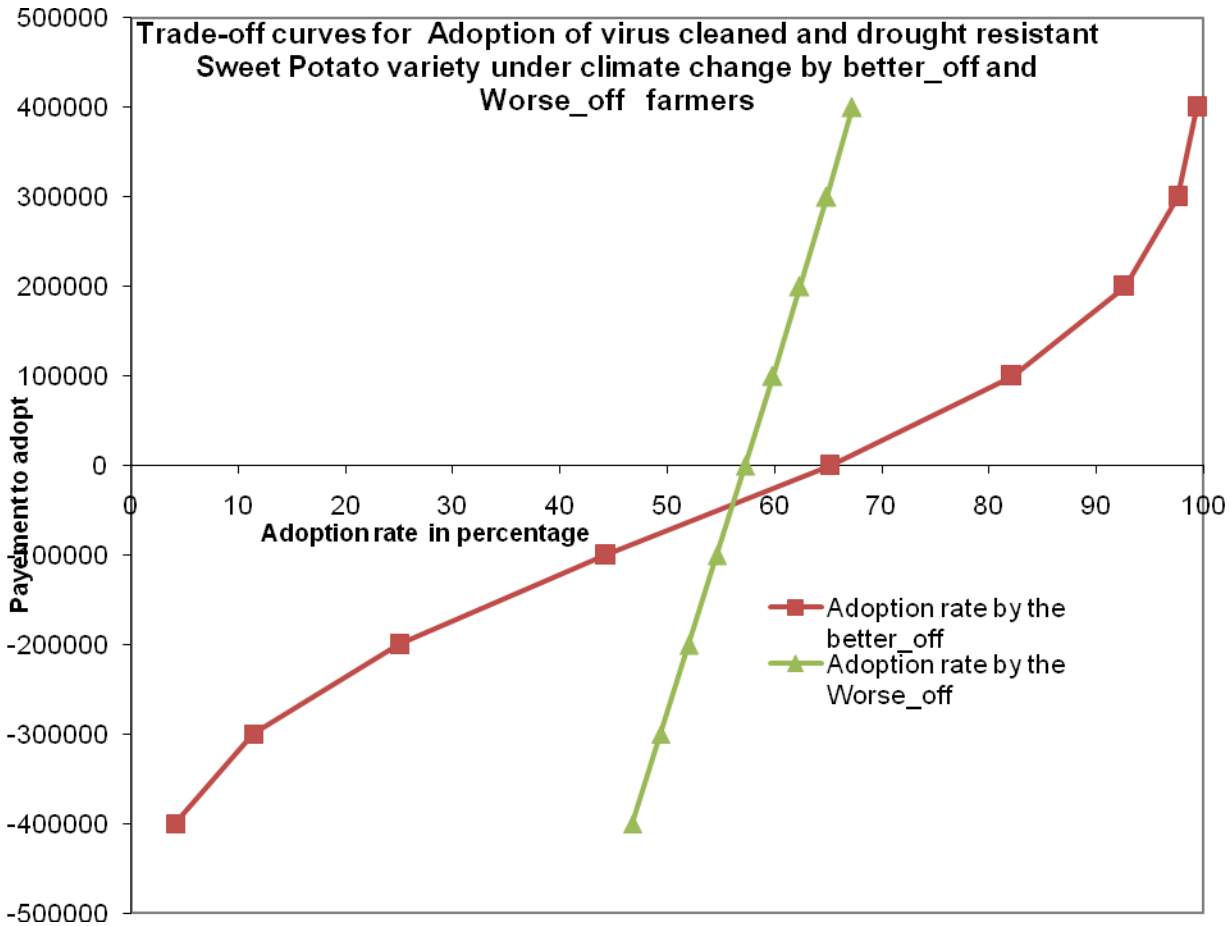

Figure 11: Adoption of the Practice of Virus free and Resistant Sweet Potato in Soroti district
Source: Field Survey data (March 2010)

The results in Figure 11 show that adoption potential for better off farmers is 65% and 57% for those that are worse off. The adoption curve for worse off farmers is inelastic while that of better off is elastic. This implies that farmers with more land command a stronger resource base and hence can take risks with new technology while farmers with less land are risk averse. To increase adoption, high amounts will have to be paid to worse off farmers with less impact on adoption compared to better off farmers. This confirms the hypothesis that, the poor are less likely to adopt climate change adaptation strategies and hence are more vulnerable (Kato, 2009; Orindi and Eriksen, 2005).

CHAPTER FIVE

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

5.1 Summary and Conclusion

The purpose of this study was to assess the economic feasibility of climate change adaptation strategies among the resource poor farmers in Kabale and Soroti districts using TOA-MD model. Specifically, this study was carried out to identify adaptation strategies to climate change among the rural sweet potato farmers; to examine the adoption of improved sweet potato varieties as climate change adaptation strategy, analyze the potential of building resilience to climate change among the resource poor households and to assess the impact of provision of free sweet potato planting material on adoption of sweet potato technologies. The study also aimed to assess whether adoption of improved sweet potato technologies varies according to different slopes or agro-ecological zones. The study hypothesized that adoption of improved sweet potato varieties as climate change adaptation response is not economically feasible; that provision of free planting material has no effect on adoption of these technologies; that adoption of these sweet potato technologies does not vary with given agro-ecological zone and that poor rural households are less likely to adopt climate change adaptation strategies compared to their better off counter parts.

Data were collected using stakeholder’s workshop and a survey of household farms and secondary sources. Focus group discussions were conducted in Kabale and Soroti districts to obtain information regarding coping mechanisms. Participants’ comprised of farmers, policy makers and agricultural extension staff. A survey of a randomly farm household was conducted to collect data on farm yields, prices, inputs and outputs (yield), and crop area. The data were used to calculate the net returns for different cropping systems by each household for input into the TOA-MD. Data on price of clean planting material, and resilience of sweet potato variety was obtained from expert survey with the scientists at NARO (Delphi technique) and literature. The data were used in MD-TOA model for estimating inherent productivity of the alternative systems. Data processing and analysis were done in Ms excel and adjusted to meet MD-TOA excel supported software version.

Results from stakeholders workshop showed unpredictable rainfall pattern, increased incident of pest and diseases, declining soil fertility and shortage of land due to increase in population as main factors affecting agricultural productivity. Farmers attributed the high incidence of pest and diseases to weather changes. Major crop diseases included bacterial wilt of potatoes, root rot of beans, late blight in potatoes and beans, brown spots for passion fruit, Fusarium wilt of bananas, and wilt, mold and powderly mildew in sweet potatoes. Pests included weevils in sweet potatoes, cut worms in beans, vegetables and potatoes, aphids in beans and peas and, generally, rats, moles, birds and monkeys. The impact of these factors has been an increase in famine due to poor crop yields, reduced farm incomes, and reduced livestock feed resources.

Results also indicate that farmers responded differently in trying to adapt to climate change. Adaptation mechanisms or coping mechanisms included swamp cultivation during the dry season, cultivation of disease and drought resistant varieties, mixed and multiple cropping, cultivation of short duration crops (vegetables, water melon, cereals), swamp reclamation, Water harvesting using traditional dams, flood irrigation and, micro-irrigation for vegetables. Other coping mechanism are spraying, early planting, uprooting infected plants, use of pest resistant varieties and practicing of crop rotation.

Results from stakeholder's workshop generally suggest that farmers have already felt the effect of climate change and government has been providing planting material under the NAADS program to ensure that households are food secure. However, it is important to note that some of these coping strategies are unaffordable by all community members. Farmers reported that it is only those who are rich that can afford improved varieties, pesticides and fertilizers. The vulnerable group cannot afford and let alone access these new varieties. Even when these new sweet potato technologies or varieties are brought, only those with power will have access. This is because planting material is primarily for demonstration with little available for distribution to meet the demand of the whole population. This suggests that the impact of climate change depends on the asset base and power relations. Those with small or less asset base and less political connections are likely to be affected most compared to those who are rich and politically connected (Nelson, 2009; Orindi and Eriksen, 2005).

Results from the TOA- MD model suggest that compensating farmers or paying farmers to adopt these sweet potato technologies as response to climate change would be unrealistic and probably very costly for government. Even supply free planting material that is often undertaken by NAADS program has less impact on adoption potential of resistant sweet potato disease and drought resistant varieties. The results of this analysis also suggest that adoption of sweet potato technologies as response to climate change varies with slope or with given agro-ecological zone. The agro-ecological zones with high opportunity costs will have limited adoption potential implying the need for higher investments or compensation for households in order to increase the levels of adaptation to climate change. Therefore, to enhance adoption, policy makers may need to consider other factors that have a potential to encourage sustainable adoption including those that can lower the opportunity costs of land and labour (Ruben, 2005), and creating an enabling market environment (Neill and lee, 2001).There is also need to strive to increase the profitability of sweet potato production. Collectively such measures would motivate farmers to adopt the new technlogies. Analysis of Soroti data reveals that, adoption among the worse off households is low compared to better off households. On the basis of this result we can conclude that with climate change the poor are more vulnerable as they incur higher cost to get higher yields.

Finally, in all scenarios considered above, adoption potential of drought and disease resistant sweet potato varieties is generally high and above 55% and adoption potential under climate change (figure 9) is generally higher than adoption potential without climate change (figure 8).Thus, we can conclude that adoption of drought and disease resistant sweet potato technologies are economically feasible under climate change but will vary depending agro-ecological zones, wealth status and household political connections.

5.2 Recommendation and Policy Implications

The study contributes to the current policy debate on strengthening adaptation strategies to climate change and suggests policy alternatives based on empirical findings of the study. Results indicate that communities have responded differently to climate change and that some adaptation mechanisms are not accessible to the very poor farmers. In relation to sweet potato technologies, results indicate that compensatory pay would not be very helpful in raising adoption of resistant sweet potato varieties as a response to climate change, the adoption potential varies with slopes or agro-ecological zones because of variation in opportunity cost of land use evidenced by variation of yields, land allocation to crops and price difference in crop activities (see table 1).

The climate change policy should therefore aim at enabling both the poor and the rich to benefit from available adaptation strategies. Institutional framework and systems should be strengthened to ensure accountability and fairness in the promotion of climate change adaptation strategies of public nature so as to benefit even the poor. More specifically climate change policy should focus on reducing the opportunity costs and adoption cost involved in adopting these climate change adaptation strategies. The policy should not focus on subsidization but instead ensure that crop technologies are available and that farmers are aware, and can access them. If compensation is to undertaken, then variations in agro-ecological zones need to considered and the poor need to be targeted. Future research should assess joint adoption of different crop technologies for climate change adaptation by poor rural household under climate change across different regions in Uganda. In addition, more studies on impact and feasibility of other adaptation strategies to climate change such as swamp reclamation need to be implemented.

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Appendix I: Survey questionnaire: Participatory development and testing of strategies to reduce climate vulnerability of poor farm households through innovations in potato and sweet potato technologies and enabling policies

Section A1: Household Schedule: Identification

Enumerator Name……………………………………… ………Date of interview ……………..
Name of Respondent…………………………………… 1 District …………………………….. 2 Sub – county ……………………… 3
Parish (LC2)…………………………… 4 Village (LC1)……………………………. 5
Household code ……… 6
Field edit………………….Call back required……………Call back completed…………
Office edit………….. Data entered…………………….

Question 1: Please list the members of your household

PERSON NUMBER	NAME	Relationship to household head: 1. Household head 2. Spouse 3. Child 4. Grandchild 5. Sister 6. Brother 7 In – law 8. Father 9. Mother 10. Other (specify)	Age (years)	Gender 1. Male 2. Female	Education (years in school)	Time involved in farming per day (hours)
7		8	9	10	11	12
13		14	15	26	17	18
19		20	21	22	23	24
25		26	27	28	29	30
31		32	33	34	35	36
37		38	39	40	41	42
43		44	44	45	46	47
48		49	50	51	52	53
54		55	56	57	58	59
60		61	62	63	64	65
66		67	68	69	70	71

Section A2: Land Holdings

A21: Please tell us about your farm, in general (how you allocated land to the different activities this current season: January – July 2009)

Parcel Number	Area (acres)	Tenure	Land Use (Acres or % share of total parcel)								
			Crops	Natural pasture	Improved pasture	Forested	Swamp	Water body	Settlement	Fallow	Other (specify)
72	73	74	75	76	77	78	79	80	81	82	83
84	85	86	87	88	89	90	91	92	93	94	95
96	97	98	99	100	101	102	103	104	105	106	107
108	109	110	111	112	113	114	115	116	117	118	119
120	121	122	123	124	125	126	127	128	129	130	131
132	133	134	135	136	137	138	139	140	141	142	143
144	145	146	147	148	149	150	151	152	153	154	155
156	157	158	159	160	161	162	163	164	165	167	168
169	170	171	172	173	174	175	176	177	178	179	180
181	182	183	184	185	186	187	188	189	190	191	192
193	194	195	196	197	198	199	200	201	202	203	204

Tenure 1= mailo 2 = freehold 3 = kibanja 4 = Customary 5= rented (hired in) 6 = Borrowed 7 = Leased 8 = other (specify)

A22: Please tell us how you allocated your land to the different activities last season: (August – December 2008)

Parcel Number	Area (acres)	Tenure	Land Use (Acres or % share of total parcel)								
			Crops	Natural pasture	Improved pasture	Forested	Swamp	Water body	Settlement	Fallow	Other (specify)
205	206	207	208	209	210	211	212	213	214	215	216
217	218	219	220	221	222	223	224	225	226	227	228
229	230	231	232	233	234	235	236	237	238	239	240
241	242	243	244	245	246	247	248	249	250	251	252
253	255	256	257	258	259	260	261	262	263	264	265
266	267	268	269	270	271	272	273	274	275	276	277
278	279	280	281	282	283	284	286	287	288	289	290
291	292	293	294	295	296	297	298	299	300	301	302
303	304	305	306	307	308	309	310	311	312	313	314
315	316	317	318	319	320	321	322	323	324	325	326
327	328	329	330	331	332	333	334	335	336	337	338

Tenure 1= mailo 2 = freehold 3 = kibanja 4 = Customary 5= rented (hired in) 6 = Borrowed 7 = Leased 8 = other (specify)

Section B1 General Plot Schedule

We would like to record the names of all the crops you planted this and last season. We would also like to estimate the area of each crop cultivated by your household.

Question 1 Please list all the crops that you have grown during this season (January – July 2009).

Parcel number	***Plot number***	Plot share of total cultivated area in the parcel (%)	**Crops grown in the plot**	**Variety type:** 1=improved 2=traditional	**Grown in** 1=pure 2=mixed stand	**If mixed, Grown as** 1=major 2=minor crop	Crop share of total plot area (%)	**If grown as major crop**, list the crops grown along in the mixture		
								First intercrop	Second intercrop	Other intercrops (if any)
339	340	341	342	343	344	345	346	347	348	349
350	351	352	353	354	355	356	357	358	359	360
361	362	363	364	365	366	367	368	369	370	371
372	373	374	375	376	377	378	379	380	381	382
383	384	385	386	387	388	389	39-	391	392	393
394	395	396	397	398	399	400	401	402	403	404
405	406	407	408	409	410	411	412	413	414	415
416	417	418	419	420	421	422	423	424	425	426
427	428	429	430	431	432	433	434	435	436	437
438	439	440	441	442	443	444	445	446	447	448
449	450	451	452	453	454	455	456	457	458	459
460	461	462	463	464	465	466	467	468	469	470
471	472	473	474	475	476	477	478	479	480	481
482	483	484	485	486	487	488	489	490	491	492
493	494	495	496	497	498	499	500	501	502	503
504	505	506	507	508	509	510	511	512	513	514
515	516	517	518	519	520	521	522	523	524	525
526	527	528	529	530	531	532	533	534	535	536
537	538	539	540	541	542	543	544	545	546	547
548	549	550	551	552	553	554	555	556	557	558
559	560	561	562	563	564	565	566	567	568	669
570	571	572	573	574	575	576	577	578	579	580
581	582	583	584	585	586	587	588	589	590	591

Question 2 Please list all the crops that you grew last season (August - December 2008).

Parcel number	***Plot number***	Plot share of total cultivated area in the parcel (%)	**Crops grown in the plot**	**Variety type[1]:** 1=improved 2=traditional	**Grown in** 1=pure 2=mixed stand	**If mixed, Grown as** 1=major 2=minor crop	Crop share of total plot area (%)	**If grown as major crop**, list the crops grown along in the mixture		
								First intercrop	Second intercrop	Other intercrops (if any)
592	593	594	595	596	597	598	599	600	601	602
603	604	605	606	607	608	609	610	611	612	613
614	615	616	617	618	619	620	621	622	623	624
625	626	627	628	629	630	631	632	633	634	635
636	637	638	639	640	641	642	643	644	645	646
647	648	649	650	651	652	653	654	655	656	657
658	659	660	661	662	663	664	665	666	667	668
669	670	671	672	673	674	675	676	677	678	679
680	681	682	683	684	685	686	687	688	689	690
691	692	693	694	695	696	697	698	699	700	701
702	703	704	705	706	707	708	709	710	711	712
713	714	715	716	717	718	719	720	721	722	723
724	725	726	727	728	729	730	731	732	733	734
735	736	737	738	739	740	741	742	743	744	745
746	747	748	749	750	751	752	753	754	755	756
757	758	759	760	761	762	763	764	765	766	767
768	769	770	771	772	773	774	775	776	777	778
779	780	781	782	783	784	785	786	787	788	789
790	791	792	793	794	795	796	797	798	799	800
801	802	803	804	805	806	807	808	809	810	811
812	813	814	815	816	817	818	819	820	821	822
823	824	825	826	827	828	829	830	831	832	833

[1]**Specific name of the varieties for sweet potato grown this current season (Plot no. _________**834 **Sweet potato variety _________________** 835
Plot no. _____________ 836 **Sweet potato variety _____________________** 837 **Plot no. _______** 838 **Sweet potato variety ______________** 839
[1]**Specific name of the sweet potato varieties grown in the previous season (Plot no. _________**840 **Sweet potato variety _____________** 841
Plot no. ______ 842 **Sweet potato variety _________________** 843 **Plot no. ___________** 844 **Sweet potato variety ____________________** 845

Question C1. Family labour use in farm production plots (Current season: January – July 2009)

Activities (specify code)		Crops/livestock													
		Sweet potato			Millet			Cassava			Sorghum		G nuts		other
	Parcel number	846	847	848	849	850	851	852	853	854	855	856	857	858	859
	Plot number	860	861	862	863	864	865	866	867	868	8569	8570	871	872	873
Land clearing	Men x days	874	8475	876	877	878	879	880	881	882	883	884	885	886	887
	Women x days	888	889	890	891	892	893	894	895	896	897	898	899	900	901
	Children x days	902	903	904	905	906	907	909	910	911	912	913	914	915	916
	Hours worked/day	919	920	921	922	923	924	925	926	927	928	929	930	931	932
Planting	Men x days	933	934	935	936	937	938	939	940	941	942	943	944	945	946
	Women x days	947	948	949	950	951	952	953	954	955	956	957	958	959	960
	Children x days	961	962	963	964	965	966	967	968	969	970	971	972	973	974
	Hours worked/day	975	976	977	978	979	980	981	982	983	984	985	986	987	988
Weeding	Men days	989	990	991	992	993	994	995	996	997	998	999	1000	1001	1002
	Women days	1003	1004	1005	1006	1007	1008	1009	1010	1011	1012	1013	1014	1015	1016
	Children days	1017	1018	1019	1020	1021	1022	1023	1024	1025	1026	1027	1028	1029	1030
	Hours worked/day	1031	1032	1033	1034	1035	1036	1037	1038	1039	1040	1041	1042	1043	1044
Harvesting	Men x days	1045	1046	1047	1048	1049	1050	1051	1052	1053	1054	1055	1056	1067	1058
	Women x days	1059	1060	1061	1062	1063	1064	1065	1066	1067	1068	1069	1070	1071	1072
	Children x days	1073	1074	1075	1076	1077	1078	1079	1080	1081	1082	1083	1084	1085	1086
	Hours worked/day	1088	1087	1089	1090	1091	1092	1093	1094	1095	1096	1097	1098	1099	1100
Fertilizer Application/ pesticide application	Men days	1101	1102	1103	1104	1105	1106	1107	1108	1109	1110	1111	1112	1113	1114
	Women days	1115	1116	1117	1118	1119	1120	1121	1122	1123	1124	1125	1126	1127	1128
	Children days	1129	1130	1131	1132	1135	1136	1137	1138	1139	1140	1141	1142	1143	1144
	Hours worked/day	1145	1146	1147	1148	1149	1150	1151	1152	153	1154	1155	1156	1157	1158

Codes for activities:
1 = Land clearing; 2 = Land ploughing; 3 = Planting; 4 = Replanting; 5 = Weeding; 6=Stumping; 7 = Pruning; 8= De – sucering; 9 = De – leafing; 10 = Sheath removal; 11 = Split stems; 12 = Cover corms; 13 = Remove corms; 14 = Ferterlizer application; 15 = Herbicide application; 16 = Pesticide application; 17 = Manure application; 18 = Cutting grass mulch; 19 = Grass mulch application; 20 = crop residue application; 21 = coffee husks application; 22 = Harvesting, 23 = Drying and processing; 24 = marketing

Codes for crops: (1 = bananas; 2 = coffee; 3 = horticultural crops; 4 = maize; 5 = millet; 6 = sorghum; 7 = cassava; 8 = sweet potato; 9 = Irish potatoes; 10 = beans; 11 = ground nuts; 12 = field peas; 13 = cattle; 14 = goats; 15 = other (specify).

Question C2. Family labour use in farm production plots (previous season: August – December 2008)

Activities (specify code)		Crops/livestock													
		Sweet potato			Millet			Cassava			Sorghum		G nuts		other
	Parcel number	1159	1160	1161	1162	1163	1164	1165	1166	1167	1168	1169	1170	1172	1173
	Plot number	1174	1175	1176	1177	1178	1179	1180	1181	1182	1183	1184	1185	1186	1187
Land clearing	Men x days	1188	1189	1161	1190	1191	1192	1193	1194	1195	1196	1197	1198	1199	1200
	Women x days	1201	1202	1203	1204	1205	1206	1207	1208	1209	1210	1211	1212	1213	1214
	Children x days	1215	1216	1217	1218	1219	1220	1221	1222	1223	1224	1225	1226	1227	1228
	Hours worked/day	1229	1230	1231	1232	1233	1234	1235	1236	1237	1238	1239	1240	1241	1242
Planting	Men x days	1243	1244	1245	1246	1247	1248	1249	1250	1251	1252	1253	1254	1255	1256
	Women x days	1257	1258	1259	1260	1261	1262	1263	1264	1265	1266	1267	1268	1269	1270
	Children x days	1271	1272	1273	1274	1275	1276	1277	1278	1279	1280	1281	1280	1281	1282
	Hours worked/day	1283	1284	1285	1286	1287	1288	1289	1290	1291	1292	1293	1294	1295	1296
Weeding	Men days	1297	1298	1299	1300	1301	1302	1303	1304	1305	1306	1307	1308	1309	1310
	Women days	1311	1312	1313	1314	1315	1316	1317	1318	1319	1320	1321	1322	1323	1324
	Children days	1325	1326	1327	1328	1329	1330	1331	1332	1333	1334	1335	1336	1337	1338
	Hours worked/day	1339	1340	1341	1342	1343	1344	1345	1346	1347	1348	1349	1350	1351	1352
Harvesting	Men x days	1353	1354	1355	1356	1357	1358	1359	1360	1361	1362	1363	1364	1365	1366
	Women x days	1367	1368	1369	1370	1371	1372	1373	1374	1375	1376	1377	1378	1379	1380
	Children x days	1381	1382	1383	1384	1385	1386	1387	1388	1389	1390	1391	1392	1393	1394
	Hours worked/day	1395	1396	1397	1398	1399	1400	1401	1402	1403	1404	1405	1408	1407	1408
Fertilizer Application/ pesticide application	Men days	1409	1410	1411	1412	1413	1414	1415	1416	1417	1418	1419	1420	1421	1422
	Women days	1423	1424	1425	1426	1427	1428	1429	1430	1431	1432	1433	1434	1435	1436
	Children days	1437	1438	1439	1440	1441	1442	1443	1444	1445	1446	1447	1448	1449	1450
	Hours worked/day	1451	1452	1453	1454	1455	1456	1457	1458	1459	1460	1461	1462	1463	1464

Codes for activities:
1 = Land clearing; 2 = Land ploughing; 3 = Planting; 4 = Replanting; 5 = Weeding; 6=Stumping; 7 = Pruning; 8= De – sucering; 9 = De – leafing; 10 = Sheath removal; 11 = Split stems; 12 = Cover corms; 13 = Remove corms; 14 = Ferterlizer application; 15 = Herbicide application; 16 = Pesticide application; 17 = Manure application; 18 = Cutting grass mulch; 19 = Grass mulch application; 20 = crop residue application; 21 = coffee husks application; 22 = Harvesting, 23 = Drying and processing; 24 = marketing

Codes for crops: (1 = bananas; 2 = coffee; 3 = horticultural crops; 4 = maize; 5 = millet; 6 = sorghum; 7 = cassava; 8 = sweet potato; 9 = Irish potatoes; 10 = beans; 11 = ground nuts; 12 = field peas; 13 = cattle; 14 = goats; 15 = other (specify).

Question C3. Hired labour use in farm production plots (current season: January- July 2009)

Activities (specify code)		**Crops/livestock**													
		Sweet potato			Millet			Cassava			Sorghum		G nuts		other
	Parcel number	1465	1466	1467	1468	1469	1470	1471	1472	1473	1474	1475	1476	1477	1478
	Plot number	1479	1480	1481	1482	1483	1484	1485	1486	1487	1488	1489	1490	1491	1492
Land clearing	Men x days	1493	1494	1495	1496	1497	1498	1499	1500	1501	1502	1503	1504	1505	1506
	Women x days	1507	1508	1509	1510	1511	1512	1513	1514	1515	1516	1517	1518	1519	1520
	Children x days	1521	1522	1523	1524	1525	1526	1527	1528	1529	1530	1531	1532	1533	1534
	Hours worked/day	1535	1536	1537	1538	1539	1540	1541	1542	1543	1544	1545	1546	1547	1548
	Total cost (U.Shs)	1549	1550	1551	1552	1553	1554	1555	1556	1557	1558	1559	1560	1561	1562
Planting	Men x days	1563	1564	1565	1566	1567	1568	1569	1570	1571	1572	1573	1574	1575	1576
	Women x days	1577	1578	1579	1580	1581	1582	1583	1584	1585	1586	1587	1588	1589	1590
	Children x days	1591	1592	1593	1594	1595	1596	1597	1598	1599	1600	1601	1602	1603	1604
	Hours worked/day	1605	1606	1607	1608	1609	1610	1611	1612	1613	1614	1615	1616	1617	1618
	Total cost (U.Shs)	1619	1620	1621	1622	1623	1624	1625	1626	1627	1628	1629	1630	1631	1632
Weeding	Men days	1633	1634	1635	1636	1637	1638	1639	1640	1641	1642	1643	1644	1645	1646
	Women days	1647	1648	1649	1650	1651	1652	1653	1654	1655	1656	1657	1658	1659	1660
	Children days	1661	1662	1663	1664	1665	1666	1667	1668	1669	1670	1671	1672	1673	1674
	Hours worked/day	1675	1676	1677	1678	1679	1680	1681	1682	1683	1684	1685	1686	1687	1688
	Total cost (U.Shs)	1689	1690	1691	1692	1693	1694	1695	1696	1697	1698	1699	1700	1701	1702
Harvesting	Men x days	1703	1704	1705	1706	1707	1708	1709	1710	1711	1712	1713	1714	1715	1716
	Women x days	1717	1718	1719	1720	1721	1722	1723	1724	1725	1726	1727	1728	1729	1730
	Children x days	1731	1732	1733	1734	1735	1736	1737	1738	1739	1740	1741	1742	1743	1744
	Hours worked/day	1745	1746	1747	1748	1749	1750	1751	1752	1753	1754	1755	1756	1757	1758
	Total cost (U.Shs)	1759	1760	1761	1762	1763	1764	1765	1766	1767	1768	1769	1770	1771	1772
Fertilizer Application/ pesticide application	Men days	1773	1774	1775	1776	1777	1778	1779	1780	1781	1782	1783	1784	1785	1786
	Women days	1787	1788	1789	1790	1791	1792	1793	1794	1795	1796	1797	1798	1799	1800
	Children days	1801	1802	1803	1804	1805	1806	1807	1808	1809	1810	1811	1812	1813	1814
	Hours worked/day	1815	1816	1817	1818	1819	1820	1821	1822	1823	1824	1825	1826	1827	1828
	Total cost (U.Shs)	1829	1830	1831	1832	1833	1834	1835	1836	1837	1838	1839	1840	1841	1842

Codes for activities:

1 = Land clearing; 2 = Land ploughing; 3 = Planting; 4 = Replanting; 5 = Weeding; 6=Stumping; 7 = Pruning; 8= De – sucering; 9 = De – leafing; 10 = Sheath removal; 11 = Split stems; 12 = Cover corms; 13 = Remove corms; 14 = Ferterlizer application; 15 = Herbicide application; 16 = Pesticide application; 17 = Manure application; 18 = Cutting grass mulch; 19 = Grass mulch application; 20 = crop residue application; 21 = coffee husks application; 22 = Harvesting, 23 = Drying and processing; 24 = marketing

Codes for crops: (1 = bananas; 2 = coffee; 3 = horticultural crops; 4 = maize; 5 = millet; 6 = sorghum; 7 = cassava; 8 = sweet potato; 9 = Irish potatoes; 10 = beans; 11 = ground nuts; 12 = field peas; 13 = cattle; 14 = goats; 15 = other (specify).

Question C4. Hired labour use in farm production plots (previous season: (August – December 2008)

Activities (specify code)		Crops/livestock													
		Sweet potato			Millet			Cassava			Sorghum		G nuts		other
	Parcel number	1843	1844	1845	1846	1847	1848	1849	1850	1851	1852	1853	1854	1855	1856
	Plot number	1857	1858	1859	1860	1861	1862	1863	1864	1865	1866	1867	1868	1869	1870
Land clearing	Men x days	1871	1872	1873	1874	1875	1876	1877	1878	1879	1880	1881	1882	1883	1884
	Women x days	1885	1886	1887	1888	1889	1890	1891	1892	1893	1894	1895	1896	1897	1898
	Children x days	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912
	Hours worked/day	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926
	Total cost (U.Shs)	1927	1928	1929	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940
Planting	Men x days	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954
	Women x days	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968
	Children x days	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
	Hours worked/day	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
	Total cost (U.Shs)	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Weeding	Men days	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
	Women days	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
	Children days	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052
	Hours worked/day	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066
	Total cost (U.Shs)	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080
Harvesting	Men x days	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094
	Women x days	2095	2096	2097	2098	2099	2100	2101	2102	2103	2104	2105	2106	2107	2108
	Children x days	2109	2110	2111	2112	2113	2114	2115	2116	2117	2118	2119	2120	2121	2122
	Hours worked/day	2123	2124	2125	2126	2127	2128	2129	2130	2131	2132	2133	2134	2135	2136
	Total cost (U.Shs)	2137	2138	2139	2140	2141	2142	2143	2144	2145	2146	2147	2148	2149	2150
Fertilizer Application/ pesticide application	Men days	2151	2152	2153	2154	2155	2156	2157	2158	2159	2160	2161	2162	2163	2164
	Women days	2165	2166	2167	2168	2169	2170	2171	2172	2173	2174	2175	2176	2177	2178
	Children days	2179	2180	2181	2182	2183	2184	2185	2186	2187	2188	2189	2190	2191	2192
	Hours worked/day	2193	2194	2195	2196	2197	2198	2199	2200	2201	2202	2203	2204	2205	2206
	Total cost (U.Shs)	2207	2208	2209	2210	2211	2212	2213	2214	2215	2216	2217	2218	2219	2220

Codes for activities:

1 = Land clearing; 2 = Land ploughing; 3 = Planting; 4 = Replanting; 5 = Weeding; 6=Stumping; 7 = Pruning; 8= De – sucering; 9 = De – leafing; 10 = Sheath removal; 11 = Split stems; 12 = Cover corms; 13 = Remove corms; 14 = Ferterlizer application; 15 = Herbicide application; 16 = Pesticide application; 17 = Manure application; 18 = Cutting grass mulch; 19 = Grass mulch application; 20 = crop residue application; 21 = coffee husks application; 22 = Harvesting, 23 = Drying and processing; 24 = marketing

Codes for crops: (1 = bananas; 2 = coffee; 3 = horticultural crops; 4 = maize; 5 = millet; 6 = sorghum; 7 = cassava; 8 = sweet potato; 9 = Irish potatoes; 10 = beans; 11 = ground nuts; 12 = field peas; 13 = cattle; 14 = goats; 15 = other (specify).

D. farm inputs

Question D1. What has been your household expenditure on farm inputs this current season (January – July 2009)?

Plot number	Crop (see codes)	Type of input (see codes)	Source 1=home 2=bought 3=given 4=exchange 5=other	Unit measure	Quantity used	Unit price (U.Shs/unit)	Total cost (U.Shs)
2221	2222	2223	2224	2225	2226	2227	2228
2229	2230	2231	2232	2233	2234	2235	2236
2237	2238	2239	2240	2241	2242	2243	2244
2245	2246	2247	2248	2249	2250	2251	2252
2253	2254	2255	2256	2257	2258	2259	2260
2261	2262	2263	2264	2265	2266	2267	2268
2269	2270	2271	2272	2273	2274	2275	2276
2277	2278	2279	2280	2281	2282	2283	2284
2285	2286	2287	2288	2289	2290	2291	2292
2293	2294	2295	2296	2297	2298	2299	2300
2301	2302	2303	2304	2305	2306	2307	2308
2309	2310	2311	2312	2313	2314	2315	2316
2317	2318	2319	2320	2321	2322	2323	2324
2325	2326	2327	2328	2329	2330	2331	2332
2333	2334	2335	2336	2337	2338	2339	2340
2341	2342	2343	2344	2346	2345	2347	2348

Codes for crops/livestock: 1 = maize; 2 = millet; 3 = sorghum; 4 = cassava; 5 = sweet potato; 6 = Irish potatoes; 7 = beans; 8 = ground nuts; 9 = field peas; 10 = cattle; 11 = goats; 12 = other (specify).
Input codes: 1=oxen 2=fertilizers 3=pesticides 4 = animal manure 5 = compost manure 6 = crop residues 7 = other (specify).
Note: Oxen measured in work hours

Question D2. What was your household expenditure on farm inputs last season (August – Dec 2008)?

Plot number	Crop (see codes)	Type of input (see codes)	Source 1=home 2=bought 3=given 4=exchange 5=other	Unit measure	Quantity used	Unit price (U.Shs/unit)	Total cost (U.Shs)
2349	2350	2351	2352	2353	2354	2355	2356
2357	2358	2359	2360	2361	2362	2363	2364
2365	2366	2367	2368	2369	2370	2371	2372
2373	2374	2375	2376	2377	2378	2379	2380
2381	2382	2383	2384	2385	2386	2387	2388
2389	2390	2391	2392	2393	2394	2395	2396
2397	2398	2399	2400	2401	2402	2403	2404
2405	2406	2407	2408	2409	2410	2411	2412
2413	2414	2415	2416	2417	2418	2419	2420
2421	2422	2423	2424	2425	2426	2427	2428
2429	2430	2431	2432	2433	2434	2435	2436
2437	2438	2439	2440	2441	2442	2443	2444
2445	2446	2447	2448	2449	2450	2451	2452
2453	2454	2455	2456	2457	2458	2459	2460
2461	2462	2463	2464	2465	2466	2467	2468
2469	2470	2471	2472	2473	2474	2475	2476

Codes for crops/livestock: 1 = maize; 2 = millet; 3 = sorghum; 4 = cassava; 5 = sweet potato; 6 = Irish potatoes; 7 = beans; 8 = ground nuts; 9 = field peas; 10 = cattle; 11 = goats; 12 = other (specify).
Input codes: 1=oxen 2=fertilizers 3=pesticides 4 = animal manure 5 = compost manure 6 = crop residues 7 = other (specify).
Note: Oxen measured in work hours

E: Income and Credit

During the past 6 months, have you sought to obtain or used credit for farm production or for other purposes? (Yes or no) 2477

If yes:

Purpose Credit Sought	Did you obtain it? 1= yes 2= no	How long did it take to obtain the loan (number of days)	Source of credit 1= money lenders 2= cooperative 3= farmer group 4= Commercial 5= NGO 6= Government 7=Other (specify)	Amount borrowed Last time (U.Shs)	Amount of interest payment	How long did/will it take to pay back the loan?	What use was it put to? 1= buy fertilizer 2= buy manure 3= buy mulch 4=hire labour 5= other (specify)
Sweet potato Production/Potato production	2478	2479	2480	2481	2482	2483	2484
Other farm production	2485	2486	2487	2488	2489	2490	2491
Food clothing , medical, school	2492	2493	2494	2494	2495	2496	2497
Special events (wedding baptism)	2498	2499	2500	2501	2502	2503	2504
Other (specify	2505	2506	2507	2508	2509	2510	2511

F: Farm output and sales

Question F1. Please tell us what the crop harvest and sales (Both fresh and dry) were for all the crops in your other plots this current season (include intercrops) (January – July 2009)

Parcel no.	**Plot no.**	**Crop grown including intercrops**	**Crop output**		**Given away (Number of units)**	**Crop sales**		
			Unit measure	**Number units**		**Number of units**	**Unit price (U.Shs)**	**Income (U.Shs)**
2512	2513	2514	2515	2516	2517	2518	2519	2520
2521	2522	2523	2524	2525	2526	2527	2528	2529
2530	2531	2532	2533	2534	2535	2536	2537	2538
2539	2540	2541	2542	2543	2544	2545	2546	2547
2548	2549	2550	2551	2552	2553	2554	2555	2556
2557	2558	2559	2560	2561	2562	2563	2564	2565
2566	2567	2568	2569	2570	2571	2572	2573	2574
2575	2576	2577	2578	2579	2580	2581	2582	2583
2584	2585	2586	2587	2588	2589	2590	2591	2592
2593	2594	2595	2596	2597	2598	2599	2600	2601
2602	2603	2604	2605	2606	2607	2608	2609	2610
2611	2612	2613	2614	2615	2616	2617	2618	2619
2620	2621	2622	2623	2624	2625	2626	2626	2627
2628	2629	2630	2631	2632	2633	2634	2635	2636

Codes for crops/livestock: 1 = maize; 2 = millet; 3 = sorghum; 4 = cassava; 5 = sweet potato; 6 = Irish potatoes; 7 = beans; 8 = ground nuts; 9 = field peas; 10 = cattle; 11 = goats; 12 = other (specify).

Question F2. Please tell us what the crop harvest and sales (Both fresh and dry) were for all the crops in your other plots last season (include intercrops) (August - December 2008)

Parcel no.	**Plot no.**	**Crop grown including intercrops**	**Crop output**		**Given away (Number of units)**	**Crop sales**		
			Unit measure	**Number units**		**Number of units**	**Unit price (U.Shs)**	**Income (U.Shs)**
2637	2638	2639	2640	2641	2642	2643	2644	2645
2646	2647	2648	2649	2650	2651	2652	2653	2654
2655	2656	2657	2658	2659	2660	2661	2662	2663
2664	2665	2666	2667	2668	2669	2670	2671	2672
2673	2674	2675	2676	2677	2678	2679	2680	2681
2682	2683	2684	2685	2686	2687	2688	2689	2690
2691	2692	2693	2694	2695	2696	2697	2698	2699
2700	2701	2702	2703	2704	2705	2706	2707	2708
2709	2710	2711	2712	2713	2714	2715	2716	2717
2718	2719	2720	2721	2722	2723	2723	2725	2726

Codes for crops/livestock: 1 = maize; 2 = millet; 3 = sorghum; 4 = cassava; 5 = sweet potato; 6 = Irish potatoes; 7 = beans; 8 = ground nuts; 9 = field peas; 10 = cattle; 11 = goats; 12 = other (specify).

G. Other income

G1: Please tell us if you received other income from other sources in the previous month

Type of Income	**Type of activity**	**Period** **1 = daily** **2. Weekly** **3. Monthly**	**Amount of income received (U. Shs)**
Agricultural wages	2727	2728	2729
Non agricultural wages	2730	2731	2732
Salaries	2733	2734	2735
Self non – farm employment	2736	2737	2738
Renting land	2739	2740	2741
Renting buildings	2742	2743	2744
Interest	2745	2746	2747
Remittances	2748	2749	2750
Gifts	2751	2752	2753
Other (specify)	2754	2755	2756
	2757	2758	2759
	2760	2761	2762
	2763	2764	2765

G2: Please tell us what your other farm production this current season (January – July 2009)

Production activity	Unit	stock Output	Sales				Given away
			Quantity	Unit price (U. shs)	Income (U. shs)		Quantity
Animals (stock)							
Cattle	2766	2767	2768	2769	2770	2771	2772
Local	2773	2774	2775	2776	2777	2778	2779
Improved	2780	2781	2782	2783	2784	2785	2786
Exotic	2787	2788	2789	2790	2791	2792	2793
Other animals	2794	2795	2796	2797	2798	2799	2800
Goats	2801	2802	2803	2804	2805	2806	2807
Sheep	2808	2809	2810	2811	2812	2813	2814
Chicken	2815	2816	2817	2818	2819	2820	2821
Ducks	2822	2823	2824	2825	2826	2827	2828
Pigs	2829	2830	2831	2832	2833	2834	2835
Rabbits	2836	2837	2838	2839	2840	2841	2842
Other products (output)							
Milk	2843	2844	2845	2846	2847	2848	2849
Eggs	2850	2851	2852	2853	2854	2855	2856
Trees	2857	2858	2859	2860	2861	2862	2863
Poles	2864	2865	2866	2867	2868	2869	2870
Timber	2871	2872	2873	2874	2875	2876	2877
Firewood	2878	2879	2880	2881	2882	2883	2884
Other (specify)	2885	2886	2887	2888	2889	2890	2891
	2892	2893	2894	2895	2896	2897	2898

Appendix II: Food and Cash Crops ranked in terms of Importance in Ikumba Sub-county

Crop	General rank	Food crop	Cash crop
Irish potatoes	1	1	1
Beans	2	2	2
Sweet potatoes	3	3	6
Sorghum	4	5	3
Vegetables (cabbage, tomatoes and carrots)	5	4	5
Fruit trees	6	6	4

Appendix III: Food and Cash Crops ranked in terms of Importance in Atiira sub-county

Crop	Food crop rank	Cash crop rank
Maize	3	3
Cassava	1	4
Sorghum	2	5
Rice	8	2
Sweet potatoes	4	
Beans	7	
Ground nuts	6	
Millet	5	6
Bananas	9	
Cotton		1