University of Alberta

Gender-differentiated Innovations in Response to Climate Change: Evidence from Smallholder Agriculture in 4 countries in East Africa.

By

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A thesis submitted to the Faculty of Graduate Studies and Research
in partial fulfillment of the requirements for the degree of Master of Science

in

Agricultural and Resource Economics

Department of Resource Economics and Environmental Sociology

Spring 2014

Edmonton, Alberta

Dedication

To my mother Medelinah, and in loving memory of my brothers Luckson and Morrison.

Abstract

We investigate gender differentiated innovations regarding maize production among households in Ethiopia, Kenya, Tanzania and Uganda. We find that innovation is positively influenced by access to information assets and on farm water, amount of land, and number of income sources, with Kenya and Tanzania generally having more innovations than Uganda. The most common reasons cited for innovations are improving land productivity and availability, responding to amounts and patterns of rainfall, and increasing crop yields. Some types of innovations vary depending on which gender is responsible for production. Males and females have, respectively, positive and negative impacts on some innovations. Moreover, for some types of innovations, when men, or both men and women, receive forecast information, there is more innovation relative to households that received no information. However, in households where women receive information, some types of innovations decrease. Results also show that some gendered headship structures influence some innovations.

Acknowledgements

I will forever be thankful to my advisors, Professor Martin Luckert and Professor Sandeep Mohapatra for their invaluable assistance and expert guidance throughout this study. I remember all those lengthy meetings that we had from the initiation of this study till its fruition. I am definitely going to miss the special times and the inspiring moments that I had with you guys. This study has benefited from suggestions and comments made by my external examiner Varghese Manaloor. I am grateful for his valuable input.

Special thanks go to Professor Brent Swallow, the Department Chair, who secured funding for this study from Climate Change and Food Security (CCAFS) organization. I am grateful for the financial support, resources, and data from CCAFS. Without the financial support and resources from CCAFS, this study would not have been realised. My sincere gratitude goes to the CCAFS team of enumerators who sacrificed their invaluable time in collecting data used in this study.

I am grateful for the precious moments which I had with my friends, classmates and staff members in the Department of Resource Economics and Environmental Sociology. I am greatly indebted to my family for their guidance, sacrifices and deepest care. Lastly, but not least, my fiancée Nomhle Beauty Mpolase has been the pillar of my strength throughout this study. She has my special thanks for her encouragement and priceless support. Above all, I give honour to the Almighty God. This document would not exist at all without His wisdom and guidance.

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Chapter One: Introduction

1.1 Background and Relevance

Farmers in smallholder agriculture are continuously facing new challenges in the form of social, political, economic and environmental change (IPCC, 2012). The challenges include continuing high population growth, food price spikes and declining soil fertility. Farming households also have poor market access and constrained access to land (Yamano et al. 2011). Climate change adds another complexity on top of these challenges (Kristjanson et al. 2012). Climate change affects agriculture through higher temperatures, greater crop water demand, more variable rainfall and extreme climate events such as heat waves, floods and droughts (Gornall et al. 2010). Rising temperatures and changing precipitation patterns affect crop growth, livestock performance, water availability and the functioning of eco-system services (IPCC, 2007). According to Adger et al. (2007), vulnerability to the risks posed by climate change may also worsen ongoing social and economic challenges for those societies which are largely dependent on resources that are sensitive to changes in climate. Repeated exposure to extreme events and other indicators of climate variability and change further exacerbate vulnerability by undermining the resilience of the asset base and eroding adaptive capacity of farmers (IPCC, 2012).

Numerous innovative solutions are being practiced by farming households in response to climate change amongst other intervening factors. The farming households experiment, adapt and innovate, in order to address the challenges they face (Chambers et al., 1989; Sanginga et al., 2009). These innovations[1] aim to increase the value and productivity of assets such as land, labour or capital. Such innovations also attempt to mitigate climatically induced uncertainty of

[1] In this context, innovation refers to the changes that farming households have made with respect to a wide range of practices relating to maize crop production in recent years. A detailed description of the concept of innovation is given in chapter 2.

production through specific agricultural practices and land use management strategies (Cooper et al., 2008; Below et al., 2010; Kristjanson et al., 2012; Nkonya et al., 2012). Innovation of technologies at the local level is crucial for enhancing adaptive capacity of farmers (Chhetri, et al., 2012). The farming households integrate traditional knowledge and new technologies in their innovations (McLean, 2010).

Another dimension of innovations in the presence of climate change is that they could differ between genders (Carr, 2008; Below et al. 2010). There are a number of reasons why innovations between men and women may be different. Climate change and gender can influence the assets that an individual has, perceptions to risk and potential innovation. Women may be more vulnerable to the risks posed by climate change due to gender restrictions on ownership of assets and opportunities (Adger et al., 2007). In comparison with men, women may face limited access to decision making and economic assets that compound the challenges of climate change (FAO, 2011). Rural women tend to have less access than men to productive resources, services and opportunities, such as land, livestock, technology, financial services and education (FAO, 2011). Different access to and control of resources may limit women's ability to innovate (Janice et al., 2010; Djoudi and Brockhaus, 2011). According to Care (2010), men are more likely to have access to new technologies, power to use them and are therefore, better equipped to innovate. On the other hand, women often have unique skills and traditional knowledge that can also inform innovation.

Climate change is also considered to have gender-differentiated effects because gender roles result in different actions taken by women and men (Ilahi, 2000; Seebens, 2010). According to Chaudhury et al. (2012), climate change impacts men and women differently due to differences in social positioning and the various roles each play. Men usually prepare land, irrigate crops, harvest and transport produce to market (FAO, 2012). Women are often primary natural resource users and managers, for example, collecting firewood, forest products and water (Valerie et al, 2002). Men often have a larger role in growing market oriented crops while women tend to grow household oriented crops (Blackden, 2004; Koopman, 1993; Randolph, 1988). Care (2010) highlighted that climate change does not only constrain poor women, but marginalised men also face similar constraints.

Doss and Morris (2001) highlighted the importance of identifying the causes of gender-differentiated adoption of agricultural innovations. They noted that if men and women innovations are different even when they face same constraints, then tailoring research strategies to ensure that technologies are developed that meet their different needs may be necessary. If innovations between men and women are different due to different constraints such as unequal ownership of assets, then it may be vital to work on improving women's access to these assets. Improved understanding of the differences between women and men in relation to their innovations is crucial in identifying and addressing potential impact of climate change (see Hannan, 2009).

1.2 Research Objectives and Questions

The above review suggests that gender is a critical factor in understanding the innovative actions that households undertake in response to climate change. In order to understand barriers to innovation, and to contemplate policies and practices to overcome such barriers, it is important that we further understand the determinants of such innovation.

The main objective of this study is to investigate the influences of gender regarding innovations in maize production in the context of climate change among farming households in East Africa. We focus on innovations in maize production because, it is the most important crop cited by households surveyed in East Africa. We explore on changes in production and investment actions of households, as shaped by gender dimensions of access to assets and decision-making. In pursuit of this goal, the following research questions will be investigated:

i. How do household characteristics influence innovations?
ii. Do farming households in east African countries in the study region differ in their innovations?
iii. How do gender differentiated roles in maize production influence innovations?
iv. What are the major reasons cited by households for their innovations in maize production?
v. How does gender differentiated access to forecast information influence innovations?
vi. How do household headship structures influence innovations in maize production?

1.3 Approach and Data

In our analysis, each household faces a choice of different innovative activities related to changes in the climate. These activities are not mutually exclusive in that each household may choose one, or a number of, innovations in various combinations. The data disclose which combinations of activities have been undertaken. We model this data by first, estimating a count negative binomial regression. The count sums the number of agricultural innovations, and ranges from 0 (i.e. the household has not undertaken a single type of innovation) to 46 (implying the household has undertaken all 46 types of innovations included in the survey). Secondly, we extend our analysis by using a probit model (Maddala, 1983) to investigate these choices. But in the second case, we collapse the innovations from 46 into 9 aggregated categories.

The main categories of independent variables used in both analyses follow from the research questions above (i.e. household characteristics, study site control variables, reasons for innovations cited by households, gender differentiated roles in activities, gender differentiated access to forecast information, and gendered household headship structures). The dataset used for this study was collected by the Climate Change and Food Security (CCAFS) organization in 2010/2011, through a baseline household survey. 700 households were interviewed, spanning 35 villages in Kenya, Uganda, Tanzania and Ethiopia. The same dataset was used by Kristjanson et al. (2012), to explore the relationship between innovativeness and food security, but did not consider the role of gender on innovation, which is the focus of this study.

1.4 Contribution

There is a scarcity of information on gender and innovation within the context of climate change (Kingiri, 2010). This study contributes to the limited research on the different gender dimensions of climate change. We attempt to fill a gap identified by many, that human and gender dimensions have been neglected in climate change adaptation and responses (Crowden, 2003; World Bank, FAO and IFAD, 2009; McCright, 2010; FAO 2011; Skinner, 2011; World Bank, 2012; IPCC, 2012). The findings of this study are crucial to informing policy decisions by contributing towards the understanding of economic behaviour of both women and men in the face of climate change.

Chapter 2: Literature Review on Innovations in Smallholder Agriculture

2.1 Concepts of innovation

The concept of innovation has been made operational through various definitions used by social scientists. Rogers (2003) defined an innovation as ‘a new idea, object, practice or improved technology introduced in response to a certain need’. Innovations are techniques or technologies that are new to a particular locality but may be widely practised elsewhere (World Bank, 2008). An innovation is something new that farmers have developed themselves or came from outside and is being used or applied in farming to solve problems (Reij & Waters-Bayer, 2001). Spielman (2005) mentioned that innovation refer to how households make use of new or existing knowledge and technology in their decisions.

Innovative farmers try out new value-adding agricultural or natural resource management practices, using wisdom, local and external knowledge (Prolinnova, 2006). They search for information from several sources and integrate elements of the information into social or economic practices that change their behaviors and practices (Spielman, et al., 2008). The ability to recognize the value of new information, assimilate it, and apply it to production and investment activities is determined by prior related knowledge (Cohen & Levinthal, 1990). The formal and informal institutions influence the practices and behaviors of farmer innovators (Spielman, et al., 2008). Institutions affect the economic behavior of individuals by providing incentives or placing restrictions (Islam, 2001). In our context, innovative farmers are those that have made changes to their production and investment actions or economic behaviour in the recent past in maize production.

2.2 Types of innovations in smallholder agriculture

Classifying innovations according to the form of innovation or separating out specific innovations is challenging because many innovations are interconnected and mutually reinforcing (Reij & Waters-Bayer, 2001). For example, a new pesticide may increase yield, reduce economic risk, and reduce environmental protection (Sunding & Zilberman, 1999). Given that innovations are diverse and intergrated, categorizing them according to various criteria is helpful (Sunding and Zilberman, 1999). Innovations may differ from one another in terms of technical, economic and social characteristics (Argawal, 1983). According to Sunding and Zilberman (1999), innovations can be categorized according to their form and, impact on economic agents, environment and markets. Categorizing innovations based on form, include mechanical, biological, chemical, agronomic, biotechnological and informational innovations. Classifying innovations according to their impact include yield-increasing, cost-reducing, quality-enhancing, risk-reducing, environmental protection increasing, and shelf-life enhancing

Below et al. (2010) classified adaptation practices of African small scale farmers into following categories: changes in farm management, diversification beyond farm, different crops, different varieties, different dating of farm practices, irrigation, water conservation techniques and conservation agriculture. The most common innovation strategies in Africa are changing the types of crops (Nkonya et al., 2012). Kristjanson et al. (2012) reported that innovations among farming households in East Africa include varietal changes, planting changes, soil and land management changes, water management-related changes, introduction of purchased, improved agricultural inputs. Innovation indicators identified by Van Rijn et al. (2012) in Sub Saharan Africa include soil and water management; soil and fertility management innovation; crop management innovation; post-harvest innovation. Critchley et al. (1999) identified technical categories of innovations in East Africa which include water harvesting; organic matter management; gulley control/harnessing; small scale irrigation; soil harvesting; drainage; soil conservation and indigenous pesticides. To sum up, we note from the above that farmers are conducting different kinds of innovations in agriculture.

2.3 Drivers of innovations in agriculture

2.3.1 General drivers of innovations

In the theory of induced innovations, Hayami and Ruttan (1985) associated the emergence of innovations with economic conditions. According to Sunding and Zilberman (1999), the search for new innovations is an economic activity that is affected by economic conditions. Scarcity and economic opportunities are likely to drive the emergence of new innovations. For example, food shortages or high prices of agricultural commodities will likely lead to the introduction of a new high-yield variety. Hayami and Ruttan (1985) indicated that the search for innovations is influenced in part by the farmer's expectation for better output and the alleviation of constraints to production. Constraints to crop and animal production due to climate change are the driving forces for farmer led innovations (Prolinnova, 2006). Chhetri et al. (2012) indicated how climate change may induce the emergence of new innovations. Climate change may affect crop production through unfavourable conditions such as changing growing season length and water availability. Such changes may provide appropriate signals to farmers and their supporting institutions to induce technologies suitable for the new environment.

According to Sunding and Zilberman (1999), emergence of new innovations requires technical feasibility, new scientific foundation and knowledge that will provide the technical base for the new technology. The appropriate knowledge base and supporting institutions provide the necessary environment for innovations (Sunding and Zilberman, 1999; Kingiri, 2010). According to Berdegu (2005), institutions are crucial in determining the speed, magnitude and quality of innovation processes. Specific policies and institutions are required to induce innovation, provide resources to those seeking to innovate and facilitate them in getting benefits from their innovations (Sunding and Zilberman, 1999; Shiferaw et al., 2007; Spielman, et al., 2008). Informal institutions such as cultural endowments, social norms and values may influence innovation processes (Hayami & Ruttan, 1985; Spielman, 2005).

Sunding and Zilberman (1999) indicated that utilization of innovations is governed by two main processes, that is, adoption and diffusion. Adoption is the uptake of an innovation while diffusion is the process by which an innovation is spread among potential adopters (Rogers, 2003). Diffusion is the process through which an innovation is communicated over time among the members of a social system through certain channels (Rogers, 1995). Innovations are communicated from national research systems to farmers by extension services (Biggs, 1990). Such communication alters the probability of farmers adopting an innovation (Wejnert, 2002). The diffusion of innovations is determined by characteristics of both the adopters and the innovation (Rogers, 1995; Wejnert, 2002; Oldenburg & Glanz, 2008).

Farmers do not adopt innovations simultaneously as they appear on the market (Diederen et al., 2003). The adoption of an innovation by different farmers may involve a time lag. The first adopters of an innovation are generally few and they in turn influence others to adopt it (Schmittlein and Mahajan, 2013). Rogers (1995, 2003) described the adopter categories associated with the process of innovation adoption as innovators, early adopters, early majority, late majority, and laggards. According to Cain & Mittman (2002), when other people see the innovation in use, more will use it if it is better than the one it supersedes. When diffusion reaches a level of critical mass, it will spread quickly and eventually slow to a saturation point.

Rogers (1995, 2003) described five main characteristics of the innovation which influence the adoption of innovations. These are relative advantage, compatibility, trialability, observability, and complexity. Relative advantage is the farmer's perceived increase or decrease in benefits of the suggested innovation in comparison to current practices. Oldenburg & Glanz (2008) stated that if an innovation is seen as better than the one it succeeds, it will be adopted. Also, Reij and Waters-Bayer (2001) indicated that the spread of innovations is influenced in part by the costs and benefits of the innovation as perceived by the farmer. Compatibility refers to how well the suggested innovation can be incorporated into the current system of production. According to Aubert and Hamel (2001), innovations that are more likely to be adopted are those that compatible with the intended users' values, norms, beliefs and perceived needs. Trialability is the ease of testing an innovation before fully implementing it.

Observability measures how well the farmer can observe the benefits associated with adopting an innovation within a given time frame. An innovation is likely to be adopted if it has easily identifiable and visible benefits to others (Oldenburg & Glanz, 2008). Complexity refers to the difficulty in understanding and implementing the new practice. According to Oldenburg & Glanz (2008), innovations that are more complex are less successfully adopted whilst those that are perceived as easy to use have higher chances of being adopted. Farmers prefer to adopt those innovations that satisfy their security needs, are less complex, require less time to use and are less labour demanding (Bangura, 1983). Chamala (1987) indicated that farmers tend to select from the package of practices developed by scientists, those that are consistent with their needs and socioeconomic status. Oldenburg and Glanz (2008) also highlighted that innovations which can be broken down into parts and adopted incrementally are more likely to be adopted.

Innovations can be driven by financial motive as well as a general concern with production and information from various sources (Critchley et al., 1999).

Population pressure on a limited natural resource base was reported by Reij & Waters-Bayer (2001) to be an important incentive for innovating among farming households. Millar (1994) highlighted that experimentation among farmers are driven by peer pressure, problem solving efforts, adaptive trials and curiosity. According to Critchley et al. (1999), specific technical factors may cause uneven spread of innovations between peoples and locations. They mentioned that the variability in innovativeness in soil and water management may be caused by topography. More sloping landforms tend to stimulate more innovation compared to least sloping places.

2.3.2 Specific drivers of agricultural innovation

According to Hendrix and Glaser (2007), climate change is likely to increase extreme weather events such as droughts, desertification and severe precipitation events all of which may affect access to resources. The people who are likely to be exposed to the worst of the climate change impacts are the ones least able to cope with the associated risks (Smit, 2001). Therefore, the biophysical, socioeconomic environment and the household resource endowments jointly determine the innovative actions available to farmers. The initial innovative capabilities are determined by the household resource endowments while the socioeconomic environment shapes the resource use patterns and the ability to relax initial constraints (Shiferaw et al., 2007). The availability of resources and the entitlement of individuals to call on those resources determine their vulnerability and adaptive capacity to effects of climate change (Adger et al., 2003).

2.3.2.1 Gender specific drivers of agricultural innovation

Doss (2001) indicated that access to labour, land, other agricultural inputs, preferences concerning output among farmers is influenced by gender. As noted by Otzelberger (2011), gender inequalities, roles, needs and preferences may influence the specific ways in which climate change affects males and females and the ways in which they develop strategies to adapt to or mitigate climate change. Gendered allocation of resources and distributional decisions among and within households determine innovation processes (Quisumbing and Maluccio, 2000; Doss, 2001; Doss and Morris, 2001; Bardasi et al, 2007; World Bank, FAO and IFAD, 2009). The gender differentiated innovations may occur in agriculture due to unequal or constrained access to resources between men and women (Doss, 2001; World Bank, FAO and IFAD, 2009). Gender inequalities constrain women more than men in competitiveness and entrepreneurship (Bardasi et al, 2007). Due to existing inequalities in access to resources and wealth between men and women, resource scarcity may constrain women innovations in the presence of climate change (FAO, 2011).

2.3.2.1.1 Gender and labour allocation

According to Doss (2001), lack of labour is a major constraint to agricultural production among poor households in Africa. A farmer's access to labor especially during the peak demand for labor, will affect the choices of activities and technologies. Ben Achour (1988) stated that there is a positive relationship between the availability of family labour and the adoption of a new technology. Labor availability usually leads to successful adoption due to the need for additional labor when new technology is adopted (Doss and Morris, 2001). Rukuni & Eicher (1994) highlighted that shortage of male labor due to migration to cities in search of better employment opportunities affects agricultural productivity. In a study in Sub Saharan Africa, Doss and Morris (2001) found that women have greater difficulty than men in obtaining labor, especially male labor needed for land preparation activities. Also, labour is often allocated more in plots owned by men as compared to women (Seebens, 2011; Udry, 1996). According to Seebens (2011), women have limited opportunities in finding paid employment outside the household. As a result, women have little income to help them negate the labour constraint.

A division of labor by gender in agriculture based on crop, task or both exists in many parts in Africa (Doss, 2001; Ilahi, 2000). African women have been found to be relatively more receptive to innovations than men since they play a larger role than men in agriculture as farmers (Chipande, 1987; FAO/WFP, 2007). According to Quisumbing & Pandolfelli (2009), women in poor households are engaged in various livelihood activities and childcare responsibilities. The various livelihood activities limits women's capacity to engage effectively in productive activities which often require a minimum fixed time before being profitable (Seebens, 2011). Quisumbing & Pandolfelli (2008) found that these gender roles and responsibilities are not only dynamic but respond to changing economic circumstances. Doss (2001) mentioned that the extent to which the changing economic conditions affect gender roles and innovation between genders is not always clear, and it is hard to predict a priori what will occur.

2.3.2.1.2 Gender differentiated access to land and land tenure

According to Doss (2001), access to land and tenure security has been found to affect decisions about technology adoption. Deininger and Nagarajan (2006) reported that property rights which govern the use of a particular plot of land affect farmers' adoption and subsequent use of different technologies on that land. Gosh (2010) also mentioned that the size of cultivated arable land is an important factor which influences the farmer's technology adoption decision. Sen (1983) reported that the most innovative farmers were those having small and medium sized land. Shiferaw and Bantilan (2004) mentioned that land shortages may induce farmer innovation in conservation practices or methods that improve land productivity. However, Itharat (1980) proposed that farmers who have a large amount of land used for agricultural production are the most innovative.

Many studies have found a link between land ownership and gender. Women either own smaller plots than men or they are landless (Feder and Umali, 1993; Lastaria-Cornhiel, 1997; Davidson, 1988). Women are found to be disadvantaged in both statutory and customary land tenure systems (Agarwal 1994; Lastarria-Cornhiel 1997). Women may lose cultivation rights with the death of their husband, in societies where customary land rights prevail and where access to land is channelled through marriage. Families are likely to claim back land because land is considered as being transferred to a son and not to his wife (Seebens, 2011). According to Quisumbing & Pandolfelli (2009), lack of legal knowledge and weak implementation may limit women's ability to exercise their rights even when legislation is in place to strengthen women's property rights.

2.3.2.1.3 Gender and water allocation

The level of agricultural production is determined by access to water (Augustin et al., 2012). According to IFAD (2012), changing economic and climate conditions affect the decisions and subsequent adjustments that men and women make in allocating water. Consequently, the level of access to water enables women or men to use their labour more effectively. Abdellatif (2007) reported that women's access to water is poor and they have difficulties coping with drought since they depend on small scale irrigation. Poor water access and quality affect the amount of labour that women must spend to collect, store, protect and distribute water (FAO, 1997).

When new irrigation schemes are introduced, poor women are often excluded from irrigation projects and they lose their rights to land (Quisumbing & Pandolfelli, 2009). Women's water needs for their production and domestic purposes are usually not considered when irrigation schemes are introduced (Quisumbing et al., 1995). Upadhyay, (2003) found that women in South Asia are denied access to water, institutional membership and irrigated land. Men often control irrigation water and prevent women from participating in water committees and thereby restrict their involvement and decisions on the allocation of communal water (Quisumbing et al., 1995; Chen, 2000). Men and women often have different priorities for how water is used due to their different productive and reproductive responsibilities (Quisumbing & Pandolfelli, 2009).

2.3.2.1.4 Gender and access to extension

The adoption and spread of an innovation is influenced by whether the farmers are aware of its intended impacts. The level of awareness is affected by many factors including access to extension services (Reij & Waters-Bayer, 2001). Extension is the process of engaging with individuals, groups and communities so that people are more able to deal with issues affecting them and opportunities open to them (Coutts et al., 2005). Davis (2009) defined agricultural extension as the entire set of organizations that support farmers and facilitate their efforts to solve problems. Farmers need diverse information on best practices and technologies for crop production, and postharvest aspects such as processing, marketing, storage, and handling (Glendenning et al., 2010). Farmers need to have access to climatic information, forecasts, adaptive technology innovations, or markets through extension and information systems in order to respond effectively to climate change (Davis, 2009).

Extension help link farmers to markets and other players in the agricultural value chain to obtain information, skills, and technologies to improve their livelihoods. According to Shiferaw et al. (2007), access to extension systems create incentives to invest in options that expand future production and consumption possibilities. Farmer's contact with extension services influences uptake of new technologies since extension agents provide improved inputs and technical advice (Doss & Morris, 2001). Female and male farmers often have different extension needs due to gender division of labour by crop and task (Quisumbing & Pandolfelli, 2009).

Women are restricted in their access to extension services in many regions of the world (Seebens, 2011). Quisumbing et al. (1995) reported that in many Sub Saharan countries, male farmers have greater contact with extension services than do female farmers despite women's prominent role in agriculture. Women face the following constraints in accessing extension services: Many places have cultural restrictions which prevent male extension officers from meeting with women farmers. Women’s mobility is limited by the domestic responsibilities, hindering them from attending meetings and training away from home. Women are less likely than men to speak the national language, and extension services are not often offered in the local language. There are very few female extension agents. Doss (2001) indicated that extension agents might prefer to visit farmers with more land or those who have already adopted improved technologies and these farmers happen to be men. The lack of extension services hinders the production and investment actions of women in agricultural production (Seebens, 2011). Quisumbing & Pandolfelli (2009) mentioned that untargeted dissemination of extension services is more likely to benefit men than poor women.

2.3.2.1.5 Gender and access to credit

Agricultural inputs such as fertilizer, seed, and extension services or other sources of information are usually financed by credit (Doss, 2001). Lower credit availability reduces access to agricultural inputs (Seebens, 2011). Women’s ability to obtain credit is usually affected by their restricted access to land since banks often require land as collateral (Migot-Adholla et al., 1991). According to Quisumbing et al. (1995), the transaction costs involved in obtaining credit such as transportation costs, paper work and time spent maybe higher for women than for men due to higher opportunity costs from foregone activities. Women also tend to be involved in the production of relatively low return crops that are not included in formal lending sector. Alarcon and Bodouroglou (2011) indicated that insufficient credit denies women access to modern agricultural inputs and technologies such as improved seeds, fertilizer, pesticides and mechanical tools and equipment. As a result, women apply less fertilizer, obtain lower yields and incomes (Quisumbing & Pandolfelli, 2009). Lack of credit and information about correct application of fertilizer may hinder women to innovate in agriculture (Seebens, 2011).

2.3.2.1.6 Gender and access to end product markets

Access to output markets and output prices in part define the production feasibility set and determine the livelihood and investment strategies. Farmers lack the incentives to adopt interventions when markets are absent. (Shiferaw et al., 2007). According to Pender and Kerr (1998), market access is constrained in many rural areas by the poor transport and communication infrastructure which lead to high transport costs. The high transport costs and limited market opportunities in turn affect adoption of sustainable agricultural technologies.

Female farmers face many gender-specific barriers in accessing markets. Such barriers include lack of information on prices and transport (Quisumbing & Pandolfelli, 2009). Blackden and Bhanu (1999) indicated that in most cases, means of transport such as bicycles, donkeys or ox carts are under the control of the husband and thus not available for women. Women end up marketing their output outside market boundaries due to physical harassment by market officials and high costs of permits (Barham and Chitemi 2008). Seebens (2010) also mentioned that women may face sexual harassment when applying for licenses. Women often fail to seek the best prices for their output due to time constraints (Barham and Chitemi, 2008).

Men's farmer groups are more successful in searching and accessing new output markets than female groups because men are more likely to be approached for their products by agricultural companies or other actors (Quisumbing & Pandolfelli, 2009). Women are usually driven out of their subsistence oriented sectors to help men in their commercial crops when prices for commercial crops are rising (Wold, 1997). On the other hand, men typically move into women's activities when these activities become profitable (Doss, 2001). Savane (1986) mentioned that in some countries marketing is done by men who also control the earned income even though women often contribute largely to crop production.

2.3.2.1.7 Gender differentiated access to forecast information and innovation

According to Suarez et al. (2009) forecast information affect the decisions of individuals engaged in economic activities. Forecast information may allow land, labor and capital to adjust optimally to expected conditions. Forecast information enables farming households to devise appropriate coping and or adaptation mechanisms (Hammer 2000; Megistu, 2011). For example, forecasts can help farmers decide what type of crops to plant and when, what precautionary measures to take, whether to diversify or not, thereby avoiding risks (Sivakumar et al. 2000). The potential benefits of seasonal climate forecasts can be maximised if farmers receive the forecasts early enough, perceive it as reliable, and have the means available to take action (O' Brien et al., 2000).

Assessing the type of information farmers receive, differentiated by gender and the extent to which farmers use this information is valuable in understanding information gaps and how to address them (Kyazze et al., 2012). Realising that access to forecasts is unequal is essential for understanding and improving user responses (Vogel and O'Brien, 2006). Women are less likely to have access to official information that might enable them to assess disaster risks, and this makes it much more difficult for them to respond to disaster scenarios (Morrow, 1999). A study done by Archer's (2003) work in Limpopo Province, South Africa showed that gender and position within the household influenced access to information and the preferred delivery mechanism. Women were found to have less access than men to timely weather forecast information due to the medium through which such information was channeled. In Burkina Faso, participatory workshops that disseminated climate forecast information were attended mostly by men and some men found to reserve spaces at the workshop for male farmers.

As a result, women did not have as much access to the forecast information as men. (Roncoli et al., 2009 in Goh, 2012).

Gender may also shape the way forecast information is shared among households. A study by Roncoli et al. (2002) in Burkina Faso, showed that farmers shared forecast information with members of the community through social gathering, meetings, social groups, churches and by chiefs. Those who did not trust the forecast information did not share it with anyone. Kayze et al. (2012) reported that majority of the elderly people in Uganda were not willing to share agricultural related information they received from other places with others unlike, young men who were reported to freely share information.

There are many factors that might affect use of forecast information. According to O'Brien et al. (2003), constraints to the capacity to respond to forecast information lie in economic and social structures, rather than only in a lack of information. In addition to information, people need access to resources necessary to give them strategic alternatives among which they can choose (Luseno, et al., 2003). Access to productive resources such as land, credit is a key factor for successful uptake and use of seasonal forecast information for resource poor farmers (Archer, 2003).

2.3.2.1.8 Gender and risk preferences

According to Shiferaw et al. (2007) risk preference is an important factor conditioning adoption and adaptation of technologies in agriculture. A key factor in the adoption of technologies is the risk perceived by the primary producer about the technology in question (Hawkins et al. 1982). According to Pannel et al. (2000), a farmer faces risk and uncertainty about the economic and environmental consequences of his actions due to his limited ability to predict for example, weather, prices and biological responses to different farming practices. The nature of agricultural production means that a significant degree of risk is always involved and the risk may assume different proportions when a new practice is being considered (Hawkins et al. 1982). Factors such as climate, crop diseases, soil types, crop species, irrigation, marketing policies and technology interact to form and alter the uncertainties of alternative farming practices (Pannel et al., 2000).

Jedlicka (1979) indicated that people will be resistant to change if they do not understand the nature of the risks involved with a new venture they may be considering. Smallholder farmers are generally risk averse and face constant difficulties in buffering various risks triggered by from health, climatic and socioeconomic shocks. They tend to avoid technologies that increase variability or uncertainty of their income stream (Shiferaw et al., 2007). According to Guerin and Guerin (1994), attitudes to risk are subjective and vary between individuals. Individual farmers tend to choose reliable enterprises for their own particular geographic and climatic location thereby reducing risk.

Gender inequality may make women in poor households more risk averse than men (Arndt & Tarp, 2000). In Mozambique, Arndt and Tarp (2000) found that improvements in cassava technology greatly favored women, since cassava is considered a low-risk insurance crop. Wealthier farmers are able to bear risk and are more likely to try new technologies (Doss and Morris, 2001). A study done in Zimbabwe by Mehra & Rojas (2008) explained differences between women and men in risk-taking behavior and adoption of new technologies. The results suggested that women may have had a lower tolerance for risk and were slower to adopt new technologies due to unequal ownership and control of resources. In a study to measure risk aversion from experimental data in Northen Zambia, Mette et al. (2004) found that women were more risk averse than men.

2.3.2.1.9 Household structure and agricultural innovation

According to Doss (2001), agricultural productivity and technology adoption is affected by the gender of the household head. Households can be classified based on the gender of the household head. Classifying households into male and female-headed household can disguise important differences within the two groups, with implications for intrahousehold resource allocation (Indies & Kingston, 1994). Comparing female and male headed households provides limited information about gender because it ignores the majority of men and women who live and farm in those households (Doss, 2001).

Horrel (2008) indicated that female headship arise from a variety of causes such as widowhood and divorce. Female-headed households can be further subdivided into dejure and defacto. De jure female-headed households are those in which a woman is considered the legal and customary head of household (Kennedy and Peters, 1992). Dejure households are those in which women are the main decision-makers and it can result from widowed, divorce and women who are unmarried (Seebens, 2011). The female head of household is likely to have control over most household income and assets in de jure households (Kennedy and Peters, 1992).

De facto female-headed households describe a household in which the husband is not physically present for most of the time (Seebens, 2011). De facto headship is a result of, for instance, the illness of a spouse or his migration to an urban area to find employment opportunities (Buvinic et al, 1983; Horrel, 2008). Migration of healthy adult men in Africa results in fewer men being available in rural areas for agricultural work (Doss, 200; Kennedy and Peters, 1992). According to Kennedy and Peters (1992), husbands in defacto households or other male relatives may play a role in basic decision making and make contributions to household incomes. De facto female heads may receive high levels of remittances than de jure female heads (Horrell & Krishnan, 2007). Doss and Morris (2001) reported that female farmers in female-headed households own and cultivate smaller plots than female farmers in male-headed households.

Heterogeneity exists in female and male headed households in terms of the gender and ages of other family members. The heterogeneity can potentially influence the productive capacity of a household (Dassanayake et al., 2013). Greater heterogeneity among male and female headship structures makes it difficult to disentangle the causal relationships among headship structures and technology adoption (Doss, 2001). According to Dassanayake et al. (2013), the heterogeneity among household headship types may imply distinctly different constraints, both outside and inside the household, for the use of productive resources. For example, a female headed household can face external and internal gendered constraints External gendered constraints originate from outside the household such as lower average earnings than men, less access to remunerative jobs and productive resources such as land, capital and technology (Buvinic and Gupta, 1997; Seebens, 2011). The presence of a male spouse or other adult males in the household may alleviate the external gendered constraints (Dassanayake et al., 2013). According to Seebens (2011), a woman may not face any restrictions in the wider society, but may be restricted by her husband within the household. These restrictions that occur inside the household are internal gendered constrains and may limit women in engaging in agricultural activities (Dassanayake et al., 2013). Therefore, the presence of male spouse may increase the internal gendered constraints with implications on innovation.

2.4 Analytical methods in literature used to investigate innovations

In order to characterise and model innovation, we reviewed literature on methods used to investigate innovations. We find that scholars have used different approaches in identifying innovations and main elements that influence innovation in agriculture. The approaches used seek to either understand the different forms of innovations being undertaken or to identify the factors that influence those innovation and the relationships among them. A few studies which attempt to model innovation adoption incorporate gender in their analyses.

Table 2.1 summarizes the different approaches for measuring innovations in agriculture and industry. Critchley et al. (1999); Reij & Waters-Bayer (2001); Below et.al (2010) used descriptive analysis in identifying the different kinds of innovations being undertaken by farming households in Africa. In their analyses, Van Rijn et al. (2012) used ordinary linear regression and Poisson regression models in analysing the relationship between social capital and innovation in Sub Saharan Africa. The dependent variable used by Van Rijn et al. (2012) in the Poisson model was a sum of the agricultural innovations adopted by farmers. Also, Kristjanson et al. (2012) used a sum of innovations as a dependant variable in the general linear models (glm) and log-linear models in the analyses of determinants of innovativeness among farming households in East Africa.

Studies like Diederen et al. (2002) looked at factors that make a farmer adopt an innovation by using an ordered probit model. They noted that farmers are driven to innovation adoption due to firm characteristics and to factors that characterise the environment within which the farm operates. In modelling the determinants of responses to climate change, Nkonya et al. (2012) used a probit model. A multivariate probit model was used by Galia and Legros (2004) to identify the most important barriers to innovation faced by firms in France. One of the barriers identified were lack of information technologies and on markets. Many adoption studies in agriculture use logistic regressions in the case of binary dependent variables (Polson and Spencer, 1991; Adesina, et al., 2000). The logistic regressions produce similar estimates like the probit regressions. The main difference between the logit and the probit models lies in the distribution of errors. In logit models, errors are assumed to follow standard logit distribution while the errors of the probit models are assumed to follow the standard normal distribution (see Maddala, 1983; Verbeek, 2004).

Table 2.1 Analytical methods used to investigate innovations

Authors	Analytical method
Reij & Waters-Bayer (2001): An initial analysis of farmer innovators and their innovations. Farmer Innovation in Africa.	Descriptive analysis
Critchley et al. (1999): Promoting Farmer Innovation; Harnessing local environmental knowledge in East Africa.	Descriptive analysis
Below et.al (2010): Micro-level practices to adapt to climate change for african small scale farmers.	Descriptive analysis
Van Rijn et al. (2012): Social capital and agricultural innovation in Sub-Saharan Africa.	Ordinary least square regression pooled country model country specific model Poisson regression
Determinants of innovativeness in farming households identified by Kristjanson et al. (2012) in East Africa.	General linear models (glm) and log- linear models.
Diederen et al. (2002): Modernisation in agriculture: what makes a farmer adopt an innovation?	Ordered probit model
Nkonya et al. (2012): Determinants of response to climate change: Climate Risk Management through Sustainable Land Management in Sub-Saharan Africa	Descriptive analysis Probit model
Mohnen et al. (2006): A comparison of innovativity across seven European countries.	Tobit model
Horbach, J. (2007): Determinants of environmental innovation — New evidence from German panel data sources.	Random-effects probit regression Binary probit regression Multinomial logit regression
. Galia and Legros (2004): Estimating obstacles to innovation in postponed projects.	Multivariate probit model
. Adoption studies in agriculture: Polson and Spencer, 1991; Adesina, et al., 2000; Gockowski, and Ndoumbe (2004)	Logistic regression models

Source: cited studies

In our study, we first employ a count model and then a probit model to determine the gender differentiated innovations in the presence of climate change.

According to Gardner et al. (1995), analysing count data using ordinary linear regression is problematic because of the nature of these regression methods. These regressions can either be a model for the mean which says how the expected value of the dependant variable depends on a set of regressors, or a model for the dispersion of the dependent variable scores around that expected value. The linear model linking the expected count to the regressors is likely to produce negative predicted values and the validity of hypothesis tests depends on assumptions about variance of scores that are not likely to be met in count data.

The dependent variable in ordinary linear regression is assumed to be continuous, normally distributed, and linearly related to the independent variables. These assumptions are usually not met in count data because smaller values are much more observed than larger values and zero is usually the most commonly observed value. Count data consist of discrete values instead of continuous values. The shortcomings of the ordinary linear regressions in modelling count data, has led to use of alternative nonlinear models. One such model used for count data is negative binomial regression (Dhavale, 1989; Schmittlein et al., 1985; Crepon and Duguet, 1997). Count data can be collapsed into binary responses representing either the occurrence (1) or absence (0) of innovations. The dichotomized data can then be modelled by either probit or logistic regression (Gardner et al., 1995).

Chapter Three: Study Site and Data Collection

3.1 Description of the study area

One of our objectives is to find out how the changes to production and investments being made by farmers i.e. innovativeness differ among the study sites in East Africa. Therefore, we try to understand the characteristics of the sites chosen in these countries by looking at differences in factors which affect farming activities, weather, constraints faced in farming and sources of livelihoods. Such characteristics will help us understand the major causes for the observed innovations in a particular country.

Our study is based in four East African countries namely, namely, Ethiopia, Kenya, Tanzania and Uganda. The economies of these countries are largely dependent on agriculture. The majority of the land is occupied by smallholder farmers who dominate agriculture by producing most of the crop and livestock products. Challenges faced by smallholder farmers in East Africa include: low productivity; lack of access to markets; credit and technology; volatile food and energy prices (Kimaru and Jama, 2005; Salami et al., 2010). A description of the study sites chosen in the four East African countries is given below.

Study sites were selected in the four countries as described in the sampling section below. The study site selected in Ethiopia in the survey was Borana, located in southern Ethiopia and a semi-arid region with bimodal rainfall patterns ranging between 500–600 mm per year. The long rains fall between March and May and the short rains between September and November (Kamara et al., 2005). According to Desta et al. (2011), agriculture in Borana is largely characterised by pastoralism. Inadequate water availability due to the spatial and temporal distribution of rainfall affects crop and livestock production in Borana (Kamara et al., 2005). According to Desta et al. (2011), all households in Borana produce some crops under rainfed agriculture. The most important food crops in Borana are maize, beans and wheat. In recent years, households in Borana have made changes to their farming practices by shifting to shorter cycle and/or drought tolerant varieties.

The site selected in Kenya in the survey is Lower Nyando Basin which is located in the western part of the country (Mango et al., 2011). According to Kristjanson et al. (2012), the average rainfall in Lower Nyando Basin is approximately 1900 mm per year, with bimodal, peaks in April-May and August-September. Lower Nyando Basin is a humid to sub-humid zone. Most of the surveyed households in Lower Nyando produce food crops and rely mostly on livestock production for their livelihoods. According to Mango et al. (2011), crop production is done mainly for subsistence needs of the family members. The households that do sell produce usually sell vegetables and/or small livestock and animal produce. The three most important crops cited in Lower Nyando are maize, sorghum and beans. According to Kristjanson et al. (2012) the major resource constraints faced in agriculture are soil erosion, declining soil fertility and water. The majority of households reported that they made changes in their farming practices over the last ten years to at least three of their most important crops (Mango et al., 2011).

In Tanzania, Lushoto District, which is located in West Usambaras in the north east of the country, was selected. According to Kamara et al. (2005), Lushoto has a cool climate of between 18°- 23°C with the maximum occurring in March and minimum in July. Lushoto District has an average rainfall of approximately 1200–1300 mm per year which falls in a bimodal pattern (Kristjanson et al., 2012). Lushoto, farming household cultivate crops based on the rainfall patterns. These patterns include, *vuli* (the short rains) from October to December; *masika* (the long rains) from March to June, and *mluati* (the intermediate rains) from July to September (Kamara et al., 2005). The main crops cultivated are maize, beans and tomatoes (Kristjanson et al., 2012). Lyamchai et al. (2011), reported that farming households in Lushoto made numerous changes in land use and crop management in recent years. Such changes include the introduction of new, higher yielding and disease resistant varieties of major crops such as maize, cassava, beans, bananas and tomatoes.

In Uganda, two sites were selected in the survey, namely Albertine Rift located in western Uganda and Kagera Basin which is located in southern Uganda. The climate of Albertine Rift is tropical, with an average rainfall of 1400 mm per year, which peaks from March to May and September to November (Eilu et al., 2004; Krisjanson et al., 2012). According to Krisjanson et al. (2012), the farming systems in Albertine Rift include highland agro-forestry, mid-hill coffee/tea, and small-scale mixed farming/commercial to dryland small-scale agriculture/ agropastoralism along lake. The most important crops grown in Albertine Rift are cassava, beans and sweet potatoes. The major resource constraints faced are soil erosion and declining soil fertility.

The second area in Uganda, Kagera Basin has rainfall variability with a high of greater than 1400 mm along Lake Victoria and less than 1000 mm in Western Rakai and Isingiro (Kristjanson et al., 2012). Smallholder farming systems are rainfed and annual production of crops occurs along the lake. The livelihoods of people living in Rakai District are largely derived from crops, livestock and natural resources (Kyazze and Kristjanson, 2011). Bananas, beans and maize are the most important crops grown in Rakai. The major resource constraints in agriculture are heavy deforestation due to search for charcoal and firewood, reduced river flow and drought. Changes made by farmers in the recent past, include a shift to use of higher yielding varieties, drought tolerant varieties, disease and pest-resistant varieties. The major changes made are in bean and maize production and these include introduction of shorter cycle varieties and intercropping (Kyazze and Krisjanson, 2011).

3.2 Sampling and Data collection

The dataset used in this study was collected by the Climate Change and Food Security (CCAFS) organization in 2010/2011, through a survey in East Africa. The aim of the survey was to understand the kinds of farming practice changes households have been making in the previous ten years and the reasons for those changes (Desta et al., 2011; Lyamchai et al., 2011; Kristjanson, et al., 2012). Information gathered included the socio-economic and demographic characteristics of these farming households, basic livelihood and welfare indicators, agriculture and natural resources management practices and strategies, access to and use of climate and agricultural-related information, and current risk management, mitigation and adaptation practices (Desta et al., 2011; Lyamchai., 2011; Kristjanson, et al., 2012).

Kristjanson et al. (2012) described how sampling was done in the CCAFS baseline household survey. They noted that since the study was designed to look at household and community level indicators and processes, both households and communities (villages) were used as study units. In choosing the study sites, many stakeholders including NGOs, government agents and farmers' organizations were involved. The following criteria was used in selecting the study sites: the presence of a variety of key biophysical and agro-ecological gradients, agricultural production systems; a gradient of anticipated temperature and precipitation changes; established agricultural research partners; long-term socio-economic and weather data; a network of regional partners to facilitate scaling up; and sites that have mitigation and/or carbon sequestration potential.

The sites were also judged using expert opinion in order to represent a wide range of conditions faced by many rural farming households across each region. The survey team leaders and their teams were trained together in order to enhance the comparability of results across the research sites. According to Kristjanson et al. (2012), the sample sizes were chosen based with the objective of measuring large changes in the chosen indicators over a five-to-ten-year period. In order to capture heterogeneity across villages, the sample was drawn across a large number of randomly selected sites, with relatively few households per village. Table 3.1 below shows the study sites, number of villages and number of households within villages selected in the survey.

Table 3.1 Study sites selected in East Africa

Study sites	**Number of villages**	**Number of households**
Ethiopia (Borana)	7	140
Kenya (Nyando)	7	139
Tanzania (Lushoto)	7	140
Uganda (Albertine rift)	7	140
Uganda (Kagera Basin)	7	140
Total	**35**	**699**

Source: Desta et al., 2011; Mango et al., 2011; Lyamchai et al., 2011; Kyazze and Kristjanson, 2011; Kristjanson et al., 2012.

A total of 699 households spanning 35 villages in Kenya, Uganda, Tanzania and Ethiopia were interviewed using the same questionnaire. The basic sampling unit used in Kenya, Uganda and Tanzania was a rectangular block of land measuring approximately10 km by 10 km and in Ethiopia the rectangular block was approximately 30 km by 30 km (Kristjanson, et al., 2012). After choosing and mapping the blocks, all villages within the block were enumerated. Seven villages were then randomly chosen within the block, and in turn 20 households within each village were randomly chosen (Kristjanson, et al., 2012). In Ethiopia, interviews were carried out in 7 villages and 140 (Desta et al., 2011). In Kenya, the survey was carried out in 7 villages, with 139 households (Mango et al., 2011). Data was collected in Lushoto, Tanzania from 7 villages and 140 households in January 2011 (Lyamchai et al., 2011). The CCAFS household survey was carried out in late 2010/early 2011 in 7 villages, with 140 households, in Rakai District, located in the South Western region of Uganda (Kyazze and Kristjanson, 2011). In Albertine Rift, western Uganda, interviews were also carried out in 7 villages with 140 households (Kristjanson et al., 2012).

From 699 households surveyed, a total of 492 households indicated that their most important crop was maize. Since our study is focused on innovations in maize production, we use those 492 households in our analysis because these are the households who are maize producers.

3.3 Type of data collected

Since we are interested in identifying the gender-differentiated innovations in response to climate change, the major variables in our analysis are innovativeness and gender. Therefore, the data collected consisted of the innovations that farmers were making and the different gender variables that could influence those innovations. The data collected from farming households was about the innovative changes made in their farming practices in recent years. The innovative changes included different kinds of activities such as soil, water and land use management; varietal changes and planting changes. These activities are not mutually exclusive in that each household may choose one, or a number of innovations in various combinations. The combinations of activities undertaken were disclosed by the collected data.

In our data, we have 3 different kinds of gender variables that were collected which include: household headship structure; who is responsible for producing a given product in agriculture; climate and weather information received by gender in a given household. An important aspect of this study was to find the role of headship structures on innovation. Therefore, in each household, data was collected from an adult male or female about who the head was and the person who was responsible for making agricultural decisions. The possible responses were divided into 5 broad headship structures (see Appendix A- Section I:

Household Respondent and Type). These headships structures include: Male headed, with a wife or wives; Male headed, divorced, single or widowed; Female headed, divorced, single or widowed; Female headed, husband away, husband makes most household/agricultural decisions; Female headed, husband away, wife makes most household/agricultural decisions; Child headed (age 16 or under)/Orphan.

Information on gender differentiated roles was collected from households. First, households were asked about the products they produced from their farm during the last 12 months and how the products were used (see Appendix A - Section III: Sources of Livelihood Security). The list of possible products included raw food crops. Second, the households were asked who does most of the work in the production of the food crop, in this case, maize crop production. The possible responses were: man; woman; female child; male child; several; and other. This study sought to identify the impact of gendered access to forecast information on innovation. Therefore, the data collected from households was gender differentiated access to climate and weather information or not (see Appendix A- Section VIII: Climate and Weather Information). Climate and weather information collected consisted of five categories which include: Forecast of drought, flood, frost, cyclone, tidal surge or other extreme event; Forecast of pest or disease outbreak; Forecast of the start of the rains; Forecast of the weather for the following 2-3 months; Forecast of the weather for today, 24 hours and/or next 2-3 days. If the household did receive information, they were then asked about who received the information within the household. The possible responses for information receivers were men, women or both.

Asset information collected includes financial, physical, natural and social capital for a given household. Financial capital refers to access to funds which are used to finance agricultural activities. Households were asked about their income sources and if they have access to credit. The number of income sources included off farm income, loan income, farm income and access to agricultural credit. Physical capital refers to assets that are used for transport, information, energy and production. Natural capital refers to the total amount of land owned and rented in hectares by a given household. Social capital is measured by the total number of agricultural social groups that a given household is a member of. The demographic data collected include household size, household workers (active labour i.e. household members who are above 5 years of age and less than 60 years old), and the highest education level achieved by any household member.

Chapter 4: Specification and results of the negative binomial regression model

4.1 Introduction

In order to examine the gender differentiated innovations in maize crop production in the presence of climate change, we first use a count data specification of innovation. The count sums the number of innovations from a list of changes that households could have undertaken in recent years in their farming practices. In this chapter, we first present the empirical specification of the negative binomial regression model that fits count data on household innovations. Second, we describe the variables that are used in the model, such as households' reasons for innovating, gender roles within households, gendered access to climate and weather forecast information, headship structures and socioeconomic characteristics of households. Third, we discuss expectations of the signs of coefficients for the explanatory variables. Fourth, the empirical results and conclusions from estimating the econometric model are presented.

4.2 Empirical Specification of the Count Negative Binomial Regression Model

Given the difficulties in characterising and measuring innovations, as highlighted in the literature review, we start by using a count model to investigate the influences of gender on innovativeness of farming households. According to Cameron and Trivedi (1986), the kind of data available in some situations necessitates the use of count data models. In other situations the nature of economic decision processes may actually lead to econometric models of variables naturally measured as counts. Count data may include numerous zero counts and integer values. Therefore, specific econometric methods are required (Crepon and Duguet, 1997).

The shortcomings of the ordinary linear regressions in modelling count data, as highlighted in the literature review, has led us to use alternative nonlinear models. One such model used for count data is the Poisson regression (Schmittlein et al., 1985; Crepon and Duguet, 1997). However, the Poisson model can produce incorrect estimates of its variance terms, and misleading inferences about the regression, unless restrictive assumptions are met (Gardner et al., 1995). An alternative is the negative binomial regression model (Dhavale, 1989; Schmittlein et al., 1985; Greene, 1994; Ramaswamy et al., 1994**;** Crepon and Duguet, 1997). In the following paragraph we begin with the basic Poisson model as motivation for the negative binomial regression.

Following the work of Van Rijn et al. (2012), we let y_i represent the count of innovative changes in production and investment actions of household i. For a given explanatory variables x_i, the random variable (y_i) is assumed to be conditionally Poisson with parameter λ_i (see Verbeek, 2004). According to Zhang et al. (2009), the probability density function of a count random variable y_i can then be written as:

$$f(y_i|\lambda_i) = \frac{\exp(-\lambda_i)\lambda_i{}^{y_i}}{y_i!} \tag{4.1}$$

Equation 4.1 implies that the probability of observing y_i, given the explanatory variables x_i is equal to:

$$\Pr(y_i|x_i) = \frac{\exp(-\lambda_i)\lambda_i{}^{y_i}}{y_i!} \tag{4.2}$$

The explanatory variables x_i enter the parameter λ_i, under an exponential form: $\lambda_i = exp(x_i{}'\beta)$, where β is the coefficient to be estimated. The exponentiation insures a positive mean (Greene, 1994). The conditional expectation of counts, given explanatory variables, is therefore given by:

$$E(y_i|x_i) = \exp(x_i'\beta) = \lambda_i \quad (4.3)$$

This Poisson regression specification is restrictive in terms of capturing the variance of the observed counts as the conditional mean and variance of y_i, given the explanatory variables are equal (Cameron and Trivedi, 1986):

$$E[y_i] = Var[y_i] = \lambda_i \quad (4.4)$$

Count data often show over-dispersion[2] and the traditional Poisson regression specification cannot account for this over-dispersion (see Cameron and Trivedi, 1986; Ramaswamy et al., 1994; Land et al., (1996); Ver Hoef et al, 2007). The negative binomial rationalizes over-dispersion with a model that assumes that, at the level of the individual, outcomes are indeed Poisson distributed, but all the individuals do not have the same mean rate. Instead the individual rates are assumed to be gamma distributed in the population (Land et al., 1996). In order to introduce heterogeneity in the relationship between the expected counts and the right-hand-side variables, the negative binomial regression model includes a random term reflecting unexplained between subject differences (McCullagh and Nelder, 1983; Ramaswamy, 1994; Gardner et al., 1995). Therefore, the conditional expectation of counts, given explanatory variables and random term is:

$$E(y_i|x_i, v_i) = \exp(x_i'\beta)v_i \quad (4.5)$$

In the negative binomial model, v_i is assumed to be strictly positive, independently and identically drawn from a gamma distribution, and estimation proceeds by maximum likelihood (Hausman et al., 1984; Zhang et al., 2009). According to Cameron and Trivedi (1986), the Wald and the Likelihood ratio test are one of the specification tests to be performed on the negative binomial regression model. Under the null and alternative hypotheses:

[2] Over dispersion is where the variance of the counts is greater than the mean.

$$H_0 = u_i = \lambda_i \tag{4.6}$$

$$H_1 = \lambda_i(1 + \alpha\lambda_i) \tag{4.7}$$

The variance of y_i equals u_i, when y_i is Poisson distributed. Therefore, the tests of H_0 against H_1 are based on tests for α = 0. We use the likelihood ratio, test that alpha equals zero to compare our negative binomial regression model to a Poisson one.

The following full empirical specification for the count negative binomial regression model is used to find the influences of gender on innovativeness in the presence of climate change.

$$\boldsymbol{y_i|x_{1i} \dots \dots x_{6i} = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \beta_3 x_{3i} + \beta_4 x_{4i} + \beta_5 x_{5i} + \beta_6 x_{6i} + \varepsilon_i}$$

(4. 8)

Where innovativeness (y_i) is a count of changes in production and investment actions of household *i* in maize crop production and is dependent on explanatory variables $x_{1i} \dots \dots . x_{6i}$:

x_{1i}, is a vector of socioeconomic characteristics of household *i*.
x_{2i}, is the site where household *i* is found.
x_{3i}, is a vector of the reasons cited by household *i* for the total changes made in production of maize crop.
x_{4i}, is a vector of gender roles in household *i* in maize crop production (e.g. who does maize production in a given household).
x_{5i}, is a vector of forecast information received by gender in household *i*.
x_{6i}, is headship structure for household *i*.
$\beta_1, \beta_2, \beta_3, \beta_4, \beta_5$ and β_6 are associated parameters of x_{1i}, x_{2i}, x_{3i}, x_{4i}, x_{5i} and x_{6i}, respectively.

β_0 is the constant term, and

ε_i is the random error term.

In the next section, we describe in detail each of the variables employed in the negative binomial regression model.

4.3 Description of variables

Following the empirical specification of the negative binomial regression model, Table 4.1 provides a description of the variables employed in the model. The variables included in the model are chosen based on the research questions and the review of literature on agricultural innovations.

Table 4.1: Description of variables

Variables	Definitions
Dependent variable	
Innovativeness (y_i)	Refers to the total number of innovative changes made in maize production in the last 10 years i.e. between the years 2000 and 2010. The list of innovative changes identified is given in Table 4.2 below.
Independent variables	
1. Household characteristics (x_{1i})	
On farm water	1= Has on farm water (e.g. borehole, pond etc.) 0 = does not have any source of on farm water.
Total land	Total available land (own and rented land) in hectares.
Social capital	Count of different agriculture/natural resource management oriented groups someone in a household is a member of[1].
Information assets	Count of information related assets owned by household from a list of: radio, television, cellphone, computer and internet access[2].
Production assets	Count of production related assets[3]
Income sources	Count of income sources that household *i* has[4]
Household size	Total number of people in the household.
Education	Refers to the highest level of education achieved by any resident household member. The categories are:
Primary	1 = Someone in the household has primary

	education. 0 = No primary education for anybody in the household
Secondary	1 = Someone in the household has secondary education. 0 = No secondary education for anybody in the household
Post-secondary	1 = Someone in the household has post-secondary education. 0 = No post-secondary education for anybody in the household
No formal education	*(omitted/reference category)*
2. Site control variables (x_{2i})	Refers to a country where the study site is found.
Ethiopia,	1= Ethiopia, 0 = otherwise
Kenya	1= Kenya, 0 = otherwise
Tanzania	1 = Tanzania, 0 = otherwise
Uganda	*(omitted/reference category).*
3. Reasons (x_{3i})	Refers to the reasons for the innovative changes made in maize crop production: 1= yes; 0 = no, for each reason
Better yields *Market opportunities* *Amount and pattern of rainfall* *Land productivity and availability* *Labour availability* *Pests and diseases* *Extension services and policy*	The reason variables are the aggregated categories derived from components described in Table 4.7 below.
4. Gender roles (x_{4i})	Refers to who is responsible for doing most of the activities in maize crop production. The categories are:
men	Most of the activities in maize crop production done by men: 1 = yes, 0 = otherwise
women	Most of the activities in maize crop production done by women: 1 = yes, 0 = otherwise
both men and women	Most of the activities in maize crop production done by both men and women *(omitted/reference category)*
5. Gendered access to forecast information (x_{5i})	
i. Extreme weather forecast	Refers to who received extreme weather forecast information in a given household. The categories are:
men	Extreme weather forecast information received by men: 1 = yes, 0 = otherwise
women	Extreme weather forecast information received by women: 1 = yes , 0 = otherwise
both men and women	Extreme weather forecast information received by

	both men and women: 1= yes , 0 = otherwise
none	Did not receive any extreme weather forecast information *(omitted/reference category)*
ii. Pest and disease forecast	Refers to who received pest and disease forecast information in a given household. The categories are:
men	Pest and disease forecast information received by men: 1 = yes, 0 = otherwise
women	Pest and disease forecast information received by women: 1 = yes, 0 = otherwise
both men and women	Pest and disease forecast information received by both men and women: 1 = yes, 0 = otherwise
none	Did not receive any pest and disease forecast information *(omitted/reference category)*
iii. Weather forecast	Refers to who received weather forecast information in a given household. The categories are:
men	Weather forecast information received by men: 1 = yes, 0 = otherwise
women	Weather forecast information received by women: 1 = yes, 0 = otherwise
both men and women	Weather forecast information received by both men and women 1 = yes, 0 = otherwise
none	Did not receive any weather forecast information *(omitted/reference category)*
6. Household headship structures (x_{6i})	Refers to different household headship structures. The headship structures are listed from *i* to *v* in terms of decreasing male spouse presence in the household and in household/agricultural decisions[5].
i. Male headed, with wife present	Male headed, with a wife or wives: 1= present and active; 0 = otherwise
ii. Male headed, with no wife	Male headed, divorced, single or widowed, 1 = present and active, 0= otherwise
iii. Female headed, husband away and active	Female headed, husband away, husband makes most household/agricultural decisions: 1 = husband way and active in decision making, 0 = otherwise
iv. Female headed, husband away and not active	Female headed, husband away, wife makes most household/agricultural decisions: 1 = husband way and not active in decision making, 0 = otherwise
v. Female headed, no husband	Female headed, divorced, single or widowed *(omitted/reference category)*

[1] The list of components used to generate 'social capital variable is given in Table 4.3 below.
[2] The list of information assets is given in Table 4.4 below.
[3] The list of production related assets is given in Table 4.5 below.
[4] The list of possible income sources is given in Table 4.6 below.
[5] The data only specifies who the decision maker is for headship structures *iii* and *iv*. Since households *i* and *ii* are male headed, we assume that males are the main decision makers in agricultural/household decisions. Also, we assume that females are the main decision makers in agricultural/household decisions in headship structure *v* (reference category), since the households are female headed.

4.4 Details and construction of variables

The following section presents more details about the variables, including how a number of the variables were constructed.

4.4.1 Innovativeness (y_i)

The dependent variable is innovativeness, which is a count of the number of types of changes that households said they made in their farming practices in the past ten years, i.e. between the years 2000 and 2010. The count sums the number of agricultural innovations, and ranges from 0 (if the household has not undertaken a single type of innovation) to 46 (if the household has undertaken all 46 types of innovations included in the survey).

Table 4.2 shows the summary statistics of all the different types of innovations used in generating our 'innovativeness' variable. The mean count of innovation per household is 6.95 with large amount of variation (the coefficient of variation[3] =1.86) in the data. Besides the count at the bottom of Table 4.2, the 5 most common types of innovations undertaken based on their means were: *introduced new variety of crops (*0.46)[4], *planting higher yielding variety* (0.46), *introduced intercropping* (0.53), *earlier land preparation* (0.60), and *earlier planting* (0.58).

Table 4.2 Innovation indicators identified in maize production in East Africa

Types of innovations	Mean	Standard deviation
1. Introduced any new crop	0.25	0.43
2. Testing any new crop	0.04	0.19
3. Stopped growing a crop (totally)	0.10	0.29
4. Stopped growing a crop (in one season)	0.16	0.37
5. Introduced new variety of crops	0.46	0.50
6. Planting higher yielding variety	0.46	0.50

[3] The coefficient of variation (C_v) is the ratio of the standard deviation $\boldsymbol{\sigma}$ to the mean $\boldsymbol{\mu}$: $(C_v) = \frac{\sigma}{\mu}$ It is a measure of the extent of variability in relation to mean of the population.

[4] The number in brackets is the mean of a particular innovation undertaken by households.

7. Planting better quality variety	0.41	0.49
8. Planting pre-treated/improved seed	0.31	0.46
9. Planting shorter cycle variety	0.39	0.49
10. Planting longer cycle variety	0.08	0.28
11. Planting drought tolerant variety	0.28	0.45
12. Planting flood tolerant variety	0.06	0.24
13. Planting salinity-tolerant variety	0.01	0.09
14. Planting toxicity-tolerant variety	0.00	0.05
15. Planting disease-resistant variety	0.15	0.37
16. Planting pest-resistant variety	0.13	0.34
17. Testing a new variety	0.05	0.21
18. Stopped using a variety	0.21	0.41
19. Expanded area	0.33	0.47
20. Reduced area	0.09	0.29
21. Started irrigating	0.04	0.18
22. Stopped irrigating	0.00	0.06
23. Stopped burning	0.04	0.20
24. Introduced intercropping	0.53	0.50
25. Introduced crop cover	0.01	0.11
26. Introduced micro-catchments	0.07	0.25
27. Introduced/built ridges or bunds	0.02	0.13
28. Introduced mulching	0.06	0.23
29. Introduced terraces	0.11	0.32
30. Introduced stone lines	0.03	0.16
31. Introduced hedges	0.07	0.25
32. Introduced contour ploughing	0.08	0.26
33. Introduced rotations	0.17	0.37
34. Introduced improved irrigation (water efficiency)	0.01	0.10
35. Introduced improved drainage	0.02	0.15
36. Introduced tidal water control management	0.00	0.00
37. Introduced mechanized farming	0.01	0.09
38. Earlier land preparation	0.60	0.49
39. Earlier planting	0.58	0.50
40. Later planting	0.08	0.28
41. Started using or using more mineral/chemical fertilisers	0.10	0.31
42. Started using manure/compost	0.26	0.44
43. Stopped using manure/compost	0.02	0.14
44. Started using or using more pesticides/herbicides	0.05	0.21
45. Started using integrated pest management	0.01	0.08
46. Started using integrated crop management	0.03	0.18
Innovativeness	**6.95**	**12.91**
Coefficient of variation		**1.86**

4.4.2 Household characteristics (x_{1i})

We construct a number of household characteristic variables (x_{1i})). We use similar household characteristic variables as used by Nkonya et al. (2012) in their analyses. These characteristics include: household size; education; and access to social groups on farm water, total land, credit, social capital, information assets, production assets, income sources, education and household size (see Table 4.1 for the household characteristics (x_{1i})).

The presence of *on farm water* may enhance production and innovation especially in the dry season (see Ayuk, 1997). Water shortages were found in Kenya and India to stimulate innovative measures which seek to save water for production purposes among farming households (Critchley and Brommer, 2003). We construct the *on farm water* variable by identifying if a household has on farm water sources from the following list: irrigation; tanks/infrastructure for water harvesting; dams and water ponds; boreholes; water pumps; inlet or water gate. We began by looking at different types of available water sources, but some of them were so small that we went from a count into a dummy variable. Therefore, a yes response means a household has at least one of the water sources and zero otherwise.

Ayuk (1996) used membership in village groups as an explanatory variable in analyzing adoption of agroforestry in Burkina Faso. Nkonya et al (2012) measured *social capital* as membership of households in groups/organizations such as production, marketing, savings and credit groups. We measure *social capital* as the sum of groups that any household member belongs to. Table 4.3 shows the kind of groups used to generate our *social capital* variable. The mean count of *social capital* per household is 0.64 with large amounts of variation as shown by the coefficient of variation of 3.78.

Table 4.3 Descriptive statistics of the components used to generate the social capital variable

Social capital groups	**Mean**	**Standard Deviation**
Tree nursery/tree planting	0.05	0.21
Forest product collection	0.01	0.08
Water catchment management	0.05	0.21
Soil improvement activities	0.04	0.18
Crop introduction/substitution	0.02	0.13
Irrigation	0.02	0.14
Savings and/or credit	0.22	0.42
Marketing agricultural products (i.e. livestock, crops, tree or fish)	0.05	0.22
Productivity enhancement (i.e. livestock, crops, trees or fish)	0.10	0.30
Seed production	0.02	0.15
Vegetable production	0.04	0.19
Others related to soil, land or water management	0.03	0.17
Social capital count	**0.64**	**2.40**
Coefficient of variation		**3.78**

Quibria et al. (2003), Lio and Liu (2005) used information and communication technology (ICT) measures such as computers, laptops, internet, cellphones, and telephone lines in their studies. Access to information assets can help farmers to gain information on the market, improve their decision making on market transactions and enhances their bargaining power (Lio and Liu, 2005). We measure *information assets* by summing up information related assets owned by households from a list of: radio, television, cellphone, computer and internet access. The descriptive statistics of components used to generate our *information assets* variable is shown in Table 4.4. The radio and cellphones are the major sources of information as indicated by the mean of 0.65 and 0.5, respectively. The mean count of *information assets* per household is 1.23 and the coefficient of variation of 1.09.

Table 4.4 Descriptive statistics for the components used to generate the information assets variable

Components of *information assets*	Mean	Standard Deviation
Radio	0.65	0.48
Television	0.07	0.25
Cellphone	0.50	0.50
Computer	0.002	0.05
Internet access	0.004	0.06
***Information asset* count**	**1.23**	**1.34**
Coefficient of variation		**1.09**

According to Bratton (1986), farming households deploy different kinds of production assets. Taken together, the assets form the basis on which the production potential of the household depends. In our study, we concentrate on production assets because we believe these are more important for innovations. The *production assets* variable is found by summing up a number of production related assets owned by a household. These descriptive statistics of the asset components used to generate our production *asset* variable is shown in Table 4.5. The mean count of production assets per household is 0.406 with large amounts of variation as shown by the coefficient of variation of 3.85.

Table 4.5 Descriptive statistics for the components used to generate the production assets variable

Components of *production assets*	Mean	Standard Deviation
Bicycle	0.238	0.426
Motorcycle	0.049	0.216
Car	0.010	0.100
Solar panel	0.028	0.166
Mechanical plough	0.002	0.045
Grinding mill	0.006	0.078
Generator (electricity or diesel)	0.014	0.119
Battery (car battery for power)	0.037	0.188
Water pump or Treadle pump	0.018	0.134
Biogas digester	0.002	0.045
Boat	0.002	0.045
Production assets count	**0.406**	**1.562**
Coefficient of variation		**3.85**

Income diversification has been shown to be important source of innovation (Reardon et al., 1994: Barret et al., 2001). Income diversification can be measured by summing up the number of sources from which the household derives income, including the farm (Evans and Ngau, 1991; Kristjanson et al., 2012). We construct the *income sources* variable by summing up the number of income sources available to a given household. The descriptive statistics of the components used to generate the *income sources* variable are shown in Table 4.6. The most common sources of income are: employment on someone else's farm with a mean of 0.35; business (0.34); remittances or gifts (0.35); loan/credit from an informal source (0.12). The mean count of *income sources* per household is 1.53 and has a large coefficient of variation of 2.04.

Table 4.6: Descriptive statistics for the components used to generate the income sources variable

Components of *Income sources*	**Mean**	**Standard Deviation**
Employment on someone else's farm	0.35	0.48
Other paid employment (e.g. salary)	0.13	0.34
Business (other than farm products)	0.34	0.47
Remittances or gifts	0.35	0.48
Payments for environmental services	0.02	0.15
Other payment from projects/ government including benefits in kind (e.g. pensions, aid, subsidies, etc.)	0.07	0.25
Loan/credit from a bank or other formal institution (microfinance, projects/programs, registered group)	0.08	0.27
Loan/credit from an informal source (moneylender, relative, etc.)	0.12	0.33
Renting out your farm machinery (e.g. tractor, thresher, pump, etc.) or animals for traction	0.03	0.17
. Renting out your own land	0.04	0.19
***Income sources* count**	**1.53**	**3.12**
Coefficient of variation		**2.04**

4.4.2 Construction of 'reasons' variables (x_{3i})

Households were given a list of 25 possible reasons for the changes made in their farming activities and they had to respond to each reason by giving yes/no response. In this study, the reasons (x_{3i}) were collapsed from the list of 25 into the following 7 categories to help reduce the number of variables included in our analyses. Table 4.7 shows the original reasons and how they were aggregated into 7 categories.

Table 4.7 Components of the reasons variables

Components	**Reasons (x_{iu})**	**Mean**	**Standard deviation**	**Coefficient of variation**
1. Better yields	*Better yields*	0.52	0.50	0.97
2. New opportunity to sell 3. Better price	*Market opportunities*	0.24	0.43	1.80
4. More erratic rainfall 5. Less overall rainfall 6. More overall rainfall 7. More frequent droughts 8. More frequent floods 9. Later start of rains 10. Earlier start of rains	*Amount and pattern of rainfall*	0.54	0.50	0.93
11. Land is less productive 12. Land is more productive 13. Less land 14. More land 15. Higher salinity	*Land productivity and availability*	0.49	0.50	1.02
16. Insufficient labour 17. Unable to hire labour (expensive) 18. Unable to hire labour (not available) 19. Sufficient labour 20. Able to hire	*Labour availability*	0.39	0.49	1.24
21. More resistant to pests/disease 22. New pests/disease have come	*Pests and diseases*	0.21	0.40	1.97
23. Government project told us to 24. Government/project showed us how 25. Policy changes	*Extension services and policy*	0.15	0.36	2.37

The most common reasons for innovations undertaken based on the means are: *better yields* with a mean of 0.52; *amount and pattern of rainfall* with a mean 0.54; *land productivity and availability* with a mean of 0.49; *labour availability* with a mean of 0.39.

4.4.3 Gender roles (x_{4i})

In agricultural activities, gender may determine who does what. In our analysis, gender roles, refers to the gender of the person who is responsible for doing most of the activities/tasks in maize production. These roles may differ within households in that, in some households maize production may be largely done by either males, females or both. We represent the gender roles (x_{4i}) as dummy variables, and the reference category is *both males and females* involved in maize production.

4.4.4 Gendered access to forecast information (x_{5i})

We use forecast of information (**(x_{5i})** as one of the explanatory variables in our analysis. Stewart (1997), Suarez et al. (2009) mentioned that forecast information can affect the decisions of individuals engaged in economic activities. Forecast information may allow land, labor and capital to adjust optimally to expected conditions. Forecast information is important because it enables farming households to devise appropriate coping and or adaptation mechanisms (Hammer 2000; Megistu, 2011). Nkonya et al. (2012) used access to climatic information as one of their explanatory variables in their analysis of climate risk management through sustainable land management in Sub-Saharan Africa.

We have 5 different components of forecast information in our data (see Table 4.8). In our analysis, we classify the forecast information from 5 components into 3 categories **(x_{5i})** which are: i) extreme weather forecast ii) pests and diseases forecast iii) weather forecast. Our data reveals that forecast information **(x_{5i})** can be accessed by males, females, both and in some cases no one in the household receives information (see Table 4.1). We use '*none'* as our reference category. The descriptive statistics of information receiver for each category of forecast information ($\boldsymbol{x_{5i}}$) is shown in Table 4.8.

Table 4.8 Components of forecast information

Components	**Forecast information ($\boldsymbol{x_{5i}}$)**	**Mean**	**Standard deviation**	**Coefficient of Variation**
1. Forecast of drought, flood, frost, cyclone, tidal surge or other extreme event.	Extreme event forecast			
	men	0.25	0.43	1.72
	women	0.17	0.37	2.18
	both men and women	0.24	0.43	1.79
	none (omitted/reference category)	0.34	0.47	1.38
2. Forecast of pest and disease outbreak	Pest and disease forecast			
	men	0.11	0.32	2.91
	women	0.13	0.34	2.62
	both men and women	0.21	0.40	1.91
	none (omitted/reference category)	0.55	0.50	0.91
3. Forecast of the start of the rains. 4. Forecast of the weather for the following 2-3 months. 5. Forecast of the weather for today, 24 hours and or/next 2-3 days.	Weather forecast			
	men	0.12	0.33	2.75
	women	0.11	0.31	2.82
	both men and women	0.41	0.49	1.20
	none (omitted/reference category)	0.36	0.48	1.33

Most of the households did not receive forecast information (*none*) as shown by the highest means of 0.34, 0.55, and 0.36 for each of the 3 categories of forecast information. *Both men and women* received more forecast information on average for each of the 3 categories compared to either *men* or *women*. *Men* received more information for extreme event forecast (0.25) and weather forecast (0.12) compared to *women*. On the other hand, *women* received on average more pest and disease forecast (0.13) than *men* (0.11).

4.5 Summary statistics and expected signs of variables

Based on the empirical specification in equation 4.9, Table 4.9 presents the summary statistics and expected signs of variables used to populate that regression.

Table 4.9: Summary statistics and expected signs

Variables	Mean	Standard Deviation	Expected signs
Dependent variable			
Innovativeness	6.949	12.906	
Independent variables			
1. Household characteristics (x_{1i})			
On farm water	0.30	0.46	+/-
Total land	4.71	4.91	+/-
Social capital	0.64	2.40	+/-
Information assets	1.23	1.34	+/-
Production assets	0.41	1.56	+/-
Household size	6.33	3.21	+/-
Income	1.53	3.12	+
Primary	0.11	0.31	+
Secondary	0.53	0.50	+
Post-secondary	0.27	0.44	+
2. Site control variables (x_{2i})			
Ethiopia	0.26	0.44	
Kenya	0.28	0.45	
Tanzania	0.24	0.43	
Uganda (omitted/reference category)			
3. Reasons (x_{3i})			
Better yields	0.52	0.50	+
Market opportunities	0.24	0.42	+
Amount and pattern of rainfall	0.53	0.50	+
Land productivity and availability	0.49	0.50	+
Labour availability	0.39	0.40	+
Pests and diseases	0.21	0.36	+
Extension services and policy	0.15	0.46	+
4. Gender roles (x_{4i})			

men	0.33	0.47	+
women	0.24	0.43	-
both men and women (omitted/reference category)	0.35	0.48	
5. Gendered access to forecast information (x_{5i})			
i. Extreme weather forecast			
men	0.25	0.43	+
women	0.17	0.37	+
both men and women	0.24	0.43	+
none (omitted/reference category)	0.34	0.47	
ii. Pest and disease forecast			
men	0.11	0.32	+
women	0.13	0.34	+
both men and women	0.21	0.40	+
none (omitted/reference category)	0.55	0.50	
iii. Weather forecast			
men	0.12	0.33	+
women	0.11	0.31	+
both men and women	0.41	0.49	+
none (omitted/reference category)	0.36	0.48	
6. Household headship structures (x_{6i})			
1. Male headed, with wife present	0.71	0.46	+/-
2. Male headed, with no wife	0.02	0.14	+/-
3. Female headed, husband away and active	0.02	0.15	+/-
4. Female headed husband away and not active	0.03	0.17	+/-
5. Female headed, no husband (omitted/reference category)	0.22	0.41	

In the context of climate change, access to and control of assets such as secure land and water, education, and social capital can help farming households adapt to increasing variability of production (Goh, 2012). A limited household asset endowment is likely to lead to nonresponse or to limited effectiveness of responses to climate change (Nkonya et al., 2012). In our study we use asset measures such as *on farm water*, *total land, information assets*; *production assets*. These asset measures are defined in table 4.1 and they can either be complements or substitutes in innovation. According to Daly (2005), if a factor is a complement in innovation, then a decrease in that factor will limit innovation. If factors are substitutes in innovation, then a decrease in that factor will not limit innovation since it will be substituted for another. Therefore, we expect the signs of *on farm water, total land, information assets; production assets,* to be either positive or negative.

Household size refers to the total number of people who live in a given household. Household size could be a complement or substitute for innovation. According to Adesina et al. (2000), large families with more labor supply are expected to be innovative since family labor is the major source for many households. According to Diederen et al. (2003), more labour resources enable farming households to adopt innovations readily. Large families are also more likely to face lower per-capita land availability and high dependency ratios for food requirements. They may thus prefer to extend cultivated area to meet food requirements. Less labour may inhibit adoption of innovations (Doss, 1999). On the other hand, less labour may cause household to innovate by adopting labour saving technologies and practices (see Sambrook, 2003). Therefore, there is no expectation on the sign of *household size*.

According to Deffuant (2001), the local farm community, neighbouring farmers and social networks in the local farm community play a significant role in adoption of innovations. Involvement in agricultural groups (*social capital*) increases the likelihood of adopting innovations (Diederin et al. 2003; Cramb, 2005; Van Rijn et al., 2012). According to Cramb (2005), beyond a certain group size, an additional member may actually diminish the value of the network to existing members because of the increased difficulty of maintaining trust. Individual acts such as absenteeism, shirking, theft that undermine trust and cooperation can affect the *social capital* of households. Therefore, there is no expectation on the sign of *social capital*.

Households may diversify their incomes to compensate for cropping outcome variation and risk. Diversification can help compensate for lack of credit markets, poor harvests and smoothen food consumption (Reardon et al., 1992). Income diversification can help households to manage the risks associated with innovation, and hence enhance innovations in agricultural activities (Evans and Ngau, 1991). Households that are entirely dependent on farm income may be more cautious about adopting innovations or making other changes affecting production than households which derives only part of its income from farming and can turn to alternative income sources when necessary (Shahabuddin et al.,1986; Nkonya et al., 2012). Therefore, the coefficient on *income sources* variable is expected to be positive.

According to Diederen et al. (2003), *education* is an indicator of innovative capabilities. In the CCAFS survey, *education* was measured as the highest level of education achieved by any resident household member. A farmer with a higher level of education may be more likely to take advantage of the training and information, and be better able to innovate than one with less education (Siebert et al., 2006). Therefore, farming households with members who are educated may have higher chances of adopting innovations compared to ones with no formal education. We expect the sign on the coefficients of *primary*, *secondary* and *post-secondary education* to be positive relative to *no formal education*.

All of the reasons variables *(x_{3i})* are the yes/no responses cited by households for changes made in agricultural activities. We expect the sign of all the *reasons variables* to be positive because the question asked the households the reasons for the changes made. All these reasons should be posistive if they are important in influencing innovativeness. By including the reasons in our model, we are looking for the most important reasons for changes made. These reasons were chosen by CCAFS and are supported by a number of literature sources, some of which are summarised in the following paragraphs.

Shiferaw et al. (2007) indicated that *better yields* and *market opportunities* may provide incentive to farmers to innovate. Farmers may have the incentives to adopt technologies when markets are present. According to Nkonya et al. (2012), farmers physically away from markets may face high transport costs in accessing markets. The high transport costs and limited market opportunities in turn affect adoption of sustainable agricultural technologies (Pender and Kerr, 1998). Therefore, their probability of adopting innovations may be reduced.

Rainfall amount and pattern affect the decision of crop selection and the output of agricultural production (Mahmudul et al., 2010). The effect of *amount and pattern of rainfall* on agriculture can be twofold. Too much rainfall such as floods, cyclones or too little rainfall such as droughts can negatively affect agricultural activities. An optimum amount of rainfall is usually vital for crop production.

Access to land affords farmers the ability to practice agriculture. The *total land* available and its productivity can influence innovativeness of farming households. For example, farmers with smaller amounts of land were found to be more innovative (Sen, 1983) while studies such as Itharat (1980), found out that farmers with larger amounts of land, were more likely to innovate more than farmers with less land.

Labour availability has been identified as one of the factors influential in determining the adoption of agricultural innovations (Zeller et al., 1998). According to Marenya and Barret (2007), family labour is important in the adoption of agricultural activities since many low income households may not afford to hire labour. Labour constraints can occur especially during the peak planting season, when family labor is not sufficient and when households are unable to pay for hired labor (Zeller et al., 1998). Problems of moral hazard may need significant monitoring thereby raising the cost of hired workers beyond the wage rate that households can observe. Therefore, lack of sufficient family labour and inability to hire labour may affect the innovative activities of household.

Smallholders usually operate in a resource-poor environment in terms of access to inputs such as pesticides (Sibanda et al., 2000). As a result, farmers apply fewer pesticides and may incur losses due to presence of *pests and diseases*. Farmers may innovate in order to reduce the possibilities of their crops being lost to pest and diseases. On the other hand, farmers may be discouraged to innovate in the presence of pests and diseases.

Adoption of innovations is highly dependent on access to technologies and information (McCulloch et al., 1998). Lack of information can affect agricultural activities of smallholders since acquiring and processing information may involve large fixed costs (Narrod, et al., 2009). *Extension services and policy* are likely to increase awareness about new technologies and up to date information which in turn can influence innovation (Deffuant, 2001; Adesina et al., 2000).

Regarding gender differentiated roles (x_{4i}), the signs of the coefficients of *men* and *women* are expected to be positive and negative, respectively, relative to the reference category of *both men and women*. The environment in which women work in may constrain them more than men. Women may be less likely to adopt a technology because of either lack of rights or secure land rights (Tonye et al., 1993). Other studies suggest that women may be less innovative due to the time constraints that they face (Seebens, 2011). Also, women may not control the produce and income from their agricultural activities (Doss, 1999).

Regarding gendered access to forecast information (x_{5i}), households that did not receive forecast information *(none)* may be constrained in their agricultural activities since access to forecast information can help farmers to develop coping mechanisms to climate challenges (Sivakumar et al., 2000; Mengistu, 2011). Compared to the reference category (*none*), households with access to information are likely to be more innovative than those without information. Therefore, relative to the reference category, we expect *women*, *men*, *both men and women* to have positive coefficients. When *women* receive forecast information, their innovative actions may be constrained due to unequal ownership of assets that help compound climate change and cultural restrictions they may face in using the information they receive (Seebens, 2011). Therefore, we expect *men, both men and women* to have larger coefficients than *women*.

Regarding different household headship structures (x_{6i}), recall that, as highlighted in literature review in chapter 2, the presence of a male spouse, or other adult males in the household may alleviate the external gendered constraints (see Dassanayake et al., 2013). Also, the presence of male spouse may increase the internal gendered constraints with implications on innovation. Because these constraints work in opposite directions as male presence increases, we have no expectations regarding the signs on these variables.

4.6 Results of the negative binomial regression model

Table 4.10 presents the results from the regression model. We only discuss significant results below. Our results show that our model has a number of significant variables with expected signs. The Wald chi-square ($\chi2$) statistic tests that all of the estimated coefficients are equal to zero, which is a test of the model as a whole. Our results show that the P-value for the Wald chi-square ($\chi2$) test is 0.000, which indicates that all of the estimated coefficients are not equal to zero. Therefore, from the p-value, we conclude that our count negative binomial model is statistically significant. The likelihood ratio test of alpha equals zero compares our negative binomial regression model to a Poisson one. The chi-squared value is 13.03 and the p-value (for the Wald chi-square ($\chi2$)) is 0.000. Therefore we reject the null hypothesis that alpha is not equal to zero and we can conclude that our count negative binomial model is more suitable for our analysis than the Poisson model.

In Table 4.10, the coefficient of *total land* is positive and statistically significant at the 5% level. This result implies that an increase in *total land* of households increases the number of innovations. Our results suggest that *information assets* do have a positive significant impact on innovativeness. Also, *income sources* are positively associated with innovativeness. This result implies that diversification of income increases innovativeness of households. Regarding site control variables (Table 4.10), the coefficients of *Kenya* and *Tanzania* are positive suggesting that the number of innovations of farming households in both countries is higher than the reference category (*Uganda*).

Table 4.10 Parameter estimates of the count negative binomial regression model for the factors influencing innovativeness among farming households in East Africa.

Dependent variable = Innovativeness		
Independent variables	**Estimated coefficients**	**Standard errors**
1. Household characteristics (x_{1i})		
On farm water	0.034	0.049
Total land	0.012**	0.005
Social capital	-0.017	0.019
Information assets	0.066**	0.028
Production assets	-0.001	0.030
Household size	0.001	0.007
Income sources	0.046**	0.02
Primary	0.050	0.087
Secondary	0.004	0.095
Post-secondary	0.047	0.115
2. Site control variables (x_{2i}) (*Uganda - omitted/reference category)*		
Ethiopia	-0.011	0.093
Kenya	0.360***	0.076
Tanzania	0.444***	0.075
3. Reasons (x_{3i})		
Better yields	0.409***	0.055
Market opportunities	0.076	0.058
Amount and pattern of rainfall	0.490***	0.066
Land productivity and availability	0.222***	0.064
Labour availability	0.021	0.064
Pests and diseases	0.116**	0.052
Extension services and policy	-0.011	0.071
4. Gender roles (x_{4i}) *(both men and women - omitted/reference category)*		
men	0.016	0.066
women	0.026	0.058

5. Gendered access to forecast information (x_{5i})		
i. Extreme weather forecast *(none - omitted/reference category)*		
men	0.135*	0.077
women	0.129	0.085
both men and women	0.071	0.088
ii. Pest and disease forecast *(none - omitted/reference category)*		
men	0.042	0.087
women	-0.137	0.088
both men and women	-0.070	0.086
iii. Weather forecast *(none - omitted/reference category)*		
men	0.103	0.084
women	-0.025	0.102
both men and women	0.183**	0.074
6. Household headship structures (x_{6i}) *(omitted/reference category – 5. Female headed, no husband)*		
1. Male headed, with wife present	0.033	0.052
2. Male headed, with no wife	-0.183	0.18
3. Female headed, husband away and active	0.196	0.173
4. Female headed, husband away and not active	0.235*	0.121
Constant	0.440***	0.12
Ln alpha	-3.099***	0.337
alpha	0.044	0.015
Number of Observations = 492		
LR chi2(36) = 473.89		
Prob > chi2 = 0.000		
Pseudo R2 = 0.166		
Likelihood-ratio test of alpha=0: chibar2(01) = 12.75 Prob>=chibar2 = 0.000		

*** p<0.01, ** p<0.05, * p<0.1

The reason variables, as per our expectation, are generally positively related to innovativeness. The most important reasons are *better yields, amount and pattern of rainfall, land productivity and availability,* and *pests and diseases,* as shown by positive and statistically significant coefficients. Our findings are consistent with those of Critchley et al. (1999), Reij and Waters-Bayer (2001). Critchley et al.

(1999) found that the reasons for innovations among farming households were to increase/maintain: crop yields; productivity of land. The reasons for innovations found by Reij and Waters-Bayer (2001) were to increase/improve yields, lack of land/ improve use of land, pest/disease/weed control in plants.

Regarding gendered access to extreme event forecast information (Table 4.10), as per our expectation, the coefficient of *men* is positive suggesting that relative to the reference category *(none)*, when *men* receive information, the number of innovations increases. Relative to the reference category *(none)*, when weather forecast information is received by *both men and women*, as per our expectation, the number of innovations increases. Overall, we find that there is no significant difference in the number of innovations between households where *women* receive any type of forecast information and *none*. However, when *men* or *both men and women* receive forecast information, our results indicate that the number of innovations increase relative to *none*.

Results (Table 4.10), show that a female headed household with husband away and wife making most household/agricultural decisions *(female headed, husband away and not active)* is positive and statistically significant at a level of 5%. This result suggests that the number of innovations of a household that is *female headed, husband away and not active* are higher than those of the reference category (*female headed, no husband)*. A possible explanation for our result is that, as we go from the reference category to household which is *female headed, husband away and not active,* some external gendered constraints are relieved but the internal gendered constraints are increased. In this case it appears as though relaxing the external gendered constraints outweigh the increase in internal gendered constraints resulting in an overall positive effect on the number of innovations.

4.7 Summary and conclusion

Our analysis shows that access to resources such as *total land*, *information assets*, and *income sources* increases innovations. Regarding site controls, we find evidence that there are significant differences among the study sites. Our results show that being in *Kenya* and *Tanzania* increases the number of innovations compared to *Uganda* which is the reference category.

We find evidence that the main reasons for innovativeness among farming households are *better yields*, *amount and pattern of rainfall*, *land productivity and availability*, *pests and diseases*. Regarding gendered access to forecast information, when *men* receive extreme weather forecast information, we find that the numbers of innovations are higher compared to households that did not receive similar information *(none)*. When *women* receive weather forecast information, the numbers of innovations are not different from *none*. However, when they are together, *both men and women* have higher innovations compared to *none*.

Regarding headship structures, we find evidence that a female headed household with a husband away and wife making most of household/agricultural decisions is likely to be more innovative compared to a household headed by a female who is divorced, single or widowed. We do not find any significant influence of other headship structures on innovativeness of households.

In this chapter, we identified factors influencing innovativeness among smallholder farmers using a count model. However, our measure of innovativeness is a count of innovations that households have been undertaking over the recent ten years. But some of these innovations may be more important than others. Adding the innovations together in a count model might cloak important differences between them. In the next chapter, we seek to extend our analysis by investigating the factors that influence different types of innovations.

Chapter 5: Probit regression model specification and results

5.1 Introduction

In the last chapter, we identified factors influencing innovativeness among smallholder farmers using a negative binomial regression model, where our measure of innovativeness is a count of innovations that households have been undertaking over the recent ten years. But some of these innovations may be more important than others. Summing the number of innovations in a count model might cloak important differences between them. In this chapter, we extend our analysis by using a probit model to examine how different types of innovations are influenced by the same explanatory variables used in chapter 4.

In the literature review, we reviewed a number of studies that looked at specific innovations through specific economic processes. But in this chapter, we are interested in pursuing innovations more generally. Therefore, we do not model specific economic processes. Instead, we do an exploratory analysis that seeks to identify gender effects over a range of innovations. The literature of innovations basically uses reduced form models to investigate innovations irrespective of the type of innovation. Therefore, following the innovation studies, we use the same variables and apply them in a range of innovations.

In this study we investigate household headship structures, gender differentiated roles; and gendered access to climate and weather forecast information. By doing an exploratory analysis, we hope to encourage more causal focused studies on gender differentiated innovations in agriculture. Since our study covers a broad area of four countries in East Africa, and looks at 9 different categories of innovations, our results may not be perfectly identified compared to more causal focused studies that look at a smaller area and one specific innovation. But our results will shed light on important relations of policy interest about gender and innovations.

In this chapter, we first present the empirical specification of the probit model. Second, we describe how we collapse the 46 innovations used in our previous count model into 9 broad categories. Third, we discuss the econometric problems associated with modelling innovations using a probit model. Fourth, we present the empirical results and conclusions.

5.2 Empirical Specification of the Probit Regression Model

In our analysis, each household faces a choice of different innovative activities *(j)* that could have been undertaken. These activities are not mutually exclusive in that each household may choose one, or a number of, innovations in various combinations.[5] The data disclose which combinations of activities have been undertaken. The response for each possible activity is either yes (i.e. undertaken) or no (i.e. not undertaken). Therefore, we use a probit model (Maddala, 1983) to investigate these choices. But yes/no responses for different activities within a given household are not independent observations. Therefore, each independent variable is interacted with an alternative specific constant for each household in order to control for the impact of having each household making multiple choices. In effect, we treat the multiple observations for each household as a panel data set. The innovations are treated as a panel and modelled as latent variables by a standard probit model (Maddala, 1983; Amemiya, 1985). The choice of explanatory variables is based on a review of factors affecting adoption of agricultural innovations in smallholder agriculture presented in chapter 2. We use the same explanatory variables that were employed in the count model in chapter 4 which include: reasons for innovations cited by households, gender of the household head and who makes decisions, gender-specific access to resources, gendered roles in activities, and country where the study site is found.

[5] This feature of the choice set precludes estimating the regression in a multinomial framework.

Following the work of Galia and Legros (2004); Mohnen et al. (2006), our probit model assumes an underlying latent variable y_{ij}^{*} for household i to undertake activity *j* in maize crop production. Therefore, y_{ij}^{*} can be rewritten as:

$$y_{ij}^{*} = \alpha_j + \beta_j' x_{ij} + u_{ij}, \tag{5.1}$$

Where y_{ij}^{*} = latent variable y_{ij}^{*} for household *i* to innovate in activity *j*.

$i = 1, \dots \dots, n$

$j = 1, \dots \dots \dots, m$

x_{ij} = a vector of explanatory variables.

β_j' = a vector of parameters to be estimated.

u_{ij} = are random disturbances which are assumed to be $IN(0, \sigma^2)$ and has covariance matrix with diagonal elements equal to 1.

The effect of omitted variables is included in the model by u_{ij}. The omitted variables are due to the lack of appropriate data and our limited knowledge of the innovative process (Mohnen et al., 2006). Following the work of Davidson and Mackinnon (2004), we can say that Equation 5.1 indexes the perceived net utility of a household *i* associated with innovating in activity *j*. If innovating in activity *j* is likely to result in positive net utility, the activity will be undertaken; otherwise, it is not undertaken. In other words, we can observe $y_{ij} = 1$ if the incentives to innovate are large enough for the household *i* to actually innovate in activity *j* (Mohnen et al., 2006). Therefore, we can define y as:

$$y_{ij} = 1 \; if \, y_{ij}^{*} > 0, \text{and 0 otherwise} \tag{5.2}$$

From Davidson and Mackinnon (2004), we can say that the probability of observing $y_{ij} = 1$ is:

$$\Pr(y_{ij} = 1) = \Pr(y_{ij}^* > 0) = \Pr(x_{ij}\beta + u_{ij} > 0$$
$$= \Pr(u_{ij} > -x_{ij}\beta) = \Pr(u_{ij} \leq x_{ij}\beta) = \Phi(x_{ij}\beta) \quad (5.3)$$

For a probit model, $\Phi(x_{ij}\beta) = F(x_{ij}\beta)$, with $\Phi\ (x_{ij}\beta)$ being the cumulative standard normal distribution function (see Dey and Astin, 1993; Davidson and MacKinnon, 1982). Davidson and Mackinnon (2004), Verbeek (2004) indicated that since the $\Pr(y_{ij} = 1|x_{ij}) = F(x_{ij}B)$, the contribution to the likelihood function for observation *ij* when y_{ij} = 1 is $F(x_{ij}\beta)$. Similarly, for observation *ij* when y_{ij} = 0, the contribution to the likelihood function is $(1 - F(x_{ij}\beta))$. Following Verbeek (2004), our likelihood function for the entire sample can be written as:

$$L(\beta) = \prod_{i=1}^{N} P\{y_{ij} = 1|x_i j;\beta\}^{y_{ij}} P\{y_{ij} = 0|x_{ij};\beta\}^{1-y_{ij}}, \quad (5.4)$$

The likelihood function is a function of β as shown by included β in the expressions for the probabilities. If we substitute $P\{y_{ij} = 1|x_{ij};\beta\} = F(x_{ij}'\beta)$ and taking logs of the likelihood function in equation 5.4 gives us the following log likelihood function:

$$log\ L(\beta) = \sum_{i=1}^{N} y_{ij}\ \log F(x_{ij}'\beta) + \sum_{i=1}^{N}(1 - y_{ij})\log(1 - F(x_{ij}'\beta)). \quad (5.5)$$

When we substitute F from equation 5.5 with a cumulative standard normal distribution function we get equation 5.6.

$$\log L\ (\beta, \sigma^2) = -\frac{N}{2}\log\ (2\pi\sigma^2) - \frac{1}{2}\sum_{i=1}^{N}\frac{(y_{ij} - \beta x_{ij})^2}{\sigma^2} \quad (5.6)$$

In order to get parameter estimates, we maximize the log likelihood function in equation 5.6 with respect to β and σ^2 using maximum likelihood method. For more information on the specification of probit model, see for example, Davidson and Mackinnon (2004); Verbeek (2004).

The following full specification for the probit model is used to find the influences of gender on different innovative activities of farming households.

$$\boldsymbol{y_{ij} = \beta_0 + \beta_{1j}(x_{1i} \times a_j) + \beta_{2j}(x_{2i} \times a_j) + \beta_{3j}(x_{3i} \times a_j) + \beta_{4j}(x_{4i} \times a_j) + \beta_{5j}(x_{5i} \times a_j) + \beta_{6j}(x_{6i} \times a_j) + \varepsilon_{ij}} \tag{5.7}$$

Where the latent propensity of household *i* to undertake activity *j* in maize crop production is given by y_{ij}. The outcome variable y_{ij} is dependent on:

$x_{1i} \times a_j$, which is a result of interacting a vector of socioeconomic characteristics (x_{1i}) of household *i* with activity specific constants a_j.

$x_{2i} \times a_j$, which is a result of interacting a vector of the site (x_{2i}) where household *i* is found with activity specific constants a_j.

$x_{3i} \times a_j$, which is a result of interacting a vector of the reasons (x_{3i}) cited by household *i* for innovating in maize crop production with activity specific constants a_j.

$x_{4i} \times a_j$, which is a result of interacting a vector of the gender roles (x_{4i}) in household *i* in maize crop production (e.g. who does maize production in a given household) with activity specific constants a_j.

$x_{5i} \times a_j$, which is a result of interacting a vector of climatic and weather forecast information (x_{5i}) received by gender in household *i* with activity specific constants a_j.

$x_{6i} \times a_j$, which is a result of interacting a vector of headship structures (x_{6i}) for household *i* with activity specific constants (a).

$\beta_{jk}, \beta_{jl}, \beta_{jm}, \beta_{jn}, \beta_{jo}$ and β_{jp} are associated parameters of $x_{1i} \times a_j$, $x_{2i} \times a_j$, $x_{3i} \times a_j$, $x_{4i} \times a_j$, $x_{5i} \times a_j$, and $x_{6i} \times a_j$, respectively.

β_0 is the constant term.

ε_{ijc} is the random error term.

Note that each of the 35 independent variables used in the count model are interacted with 9 activity specific constants (a_j) which control for the impact of having each households making multiple choices. Therefore, the full list of variables included in the probit model is 315 (i.e. 35 variables x 9 activity specific constants). In this chapter, we have a large sample size since each of the 492 households faces a choice of 9 possible innovations that could have been undertaken. Therefore, we have 9 observations per household and the total sample size is 4428 (9 innovations x 492 households).

In the next section, we describe in detail how we specify y_{ij}. The expected signs and a description of the independent variables used in the probit model, are the same as employed in the count model in chapter 4.

5.3 Components used to generate the dependant variable (y_{ij})

Given the structure of our empirical model, looking at 46 innovations would imply that we have to analyse how the explanatory variables influences each of the 46 innovations. Each household would be facing a choice of 46 possible innovations that could have been undertaken. Such an analysis when considering the interaction terms would be huge and difficult to interpret. Therefore, we collapse the 46 innovations into 9 categories of innovations[6] (j).

Categorizing agricultural innovations is challenging since most of the innovations are integrated and mutually reinforcing (Sunding and Zilberman, 1999; Reij & Waters-Bayer, 2001). In order to collapse the 46 innovations into 9 innovation

[6] In our analysis, we collapse the innovations into 9 categories, indicating whether the activities had been undertaken or not as described above. According to Gardner et al. (1995), reducing counts to a number of categories wastes information and may weaken statistical power. The choice of cut point in defining categories may also affect the results.

categories, we first looked at how agricultural innovations have been classified in literature. We found that Van Rijn et al. (2012) categorised agricultural innovations in Sub Saharan Africa into the following: soil and water management; soil and fertility management; crop management; post-harvest innovations; other product enhancing innovations. Critchley et al. (1999) identified technical categories of innovations in East Africa which include: water harvesting; organic matter management; gully control/ harnessing; and other agronomic practices. Adaptation practices identified by Below et al. (2010) in Africa include the following categories: diversification beyond farm; different crops and varieties; different dating of farm practices; irrigation; water conservation techniques; conservation agriculture.

Table 5.1 shows how we collapsed the 46 innovations (used in our previous count model in chapter 4) into 9 distinct innovation categories. If one or more of the innovations is undertaken by the household, the broader innovation category is assigned a value of 1 in the probit model. Descriptive statistics of the 9 innovation categories are also given in Table 5.1. The most common innovations among the households are: use of better varieties as reflected by a mean of 0.678; land preparation and management with a mean of 0.762; crop management with a mean of 0.611; temporal adjustments with a mean of 0.695. The least common innovation is pest management with a mean of 0.052.

Table 5.1 Components of nine innovation categories used in the probit model

Innovations used in the count model	**Innovation categories (*j*) used in the probit model**	**Mean**	**Standard Deviation**	**Coefficient of Variation**
1. Introduced new crop 2. Testing new crop	*1. Introduction and testing of new crops*	0.270	0.444	1.645
3. Stopped growing a crop totally 4. Stopped growing a crop in one season 5. Stopped using variety 6. Stopped burning 7. Stopped using manure/compost 8. Stopped irrigating	*2. Stopped an activity*	0.410	0.492	1.199
9. Introducing new variety crops 10. Testing a new variety 11. Higher yielding variety 12. Better quality variety 13. Pretreated/improved seed 14. Flood tolerant variety 15. Drought tolerant variety 16. Disease resistant variety 17. Pest resistant variety 18. Salinity-tolerant variety 19. Toxicity-tolerant variety	*3. Use of better varieties*	0.678	0.467	0.689
20. Started using more pesticides/herbicides 21. Started using or using more pesticides/herbicides	*4. Pest management*	0.052	0.222	4.277
22. Started using or using more mineral/chemical fertilisers 23. Started using manure/compost	*5. Soil fertility management*	0.296	0.456	1.543

24. Introduced crop cover 25. Started irrigating 26. Introduced improved drainage 27. Introduced micro catchments 28. Introduced or built ridges or bunds 29. Introduced mulching 30. Introduced improved irrigation (water efficiency)	*6. Water use and management*	0.184	0.387	2.109
31. Expanded area 32. Reduced area 33. Earlier land preparation 34. Introduced terraces 35. Introduced stone lines 36. Introduced hedges 37. Introduced contour planting 38. Introduced mechanized farming 39. Earlier land preparation	*7. Land preparation and management*	0.762	0.426	0.558
40. Introduced intercropping 41. Started using integrated crop management 42. Introduced rotations	*8. Crop management*	0.611	0.488	0.798
43. Earlier planting 44. Later planting 45. Planting shorter cycle variety 46. Planting longer cycle variety	*9. Temporal Adjustments*	0.695	0.460	0.662

5.4 Econometric problems associated with analysing innovations using a probit model

In our analysis, aach independent variable is interacted with activity specific constants. Such interactions may lead to multicollinearity problems. According to

Marsh et al. (2004), multicollinearity exists when a set of highly related explanatory variables are used to predict a dependent variable. Muticollinearity leads to inaccurate estimates of coefficients and standard errors as well as inference errors. A large sample size can offset the problems caused by multicollinearity (Mason and Perreault, 1991). In this chapter, we use a large sample size with 4428 observations (9 innovations per household x 492 households).

5.5 Probit regression results

The discussion of our results is divided into five sections corresponding to the research questions given in chapter 1. We discuss only the significant results of each innovation. First, we describe the influences of household characteristics on innovations. Second, we discuss the role of study site location on innovations. Third, we discuss the influences of gender differentiated roles on innovations. Fourth, we discuss the influences of gendered access to climatic and weather information on innovations. Fifth, we discuss the influence of household headship structures on innovations.

The estimated coefficients indicate the effect of a given variable on the latent propensity of innovating, while the marginal effects estimate the probability of innovating. The discussion of results below focuses on the sign of the estimated coefficients. The sign on the estimated coefficient of a given variable represents the effect that variable has on the latent utility of innovating. We do not report marginal effects since the effect (sign) stays the same whether we focus on the latent propensities or the marginal effects.

Our results in tables 5.2-5.7 below show that most of the estimated coefficients are significant with the expected signs. The likelihood ratio chi-square of 2535.62 with a p-value of 0.000 tells us that the probit model as a whole is statistically significant.

5.5.1 Influences of household characteristics on innovations

Table 5.2 below presents the results on the influence of household characteristics on innovations. The estimated coefficient on each household characteristic refers to the influence of each characteristic on the latent propensities of households to undertake a given innovation, ceteris paribus.

There are a number of innovations for which we do not find any significant influence of household characteristics. For those innovations that do have significant household characteristics, our results show a lot of variability. Specifically, our results show that depending on the type of innovation, the influence of *total land*, *income sources*, *primary education*, *post-secondary education*, and *household size* can either be positive or negative. These results are somewhat surprising for the education variables, because we expect that, compared to *none*, educated individuals would have a higher likelihood of undertaking some type of innovations. One interpretation of this result is that people who are educated may believe that some types of innovations are not beneficial – that is, the perceived costs from undertaking them could be higher than the perceived benefits. Our results also show that there is some consistency across education levels for specific innovations. Specifically, *we find that primary education* and *secondary education* each are negatively associated with *use of better varieties* and *soil fertility management*. On the other hand, both *primary education* and post-*secondary education* are positively association with *land preparation and management.*

The most universal household characteristic is *on farm water*, positively influencing four innovations out of nine. We also find that *information assets* positively influence some innovations suggesting complementary relationships. On the other hand, we find that *social capital* and *secondary education* each negatively influence one type of innovation. We do not find any significant influence of *production assets* on innovations.

Table 5.2 Influences of household characteristics on innovations

Innovation	*On farm water*	*Total Land*	*Social capital*	*Information assets*	*Production assets*	*Income sources*	*Primary education*	*Secondary education*	*Post-secondary education*	*Household size*
1. Introduction and testing of new crops	0.334** (0.163)	0.017 (0.016)	-0.005 (0.061)	0.196** (0.0920)	-0.086 (0.104)	-0.141** (0.069)	0.117 (0.239)	0.136 (0.276)	0.657* (0.339)	-0.052** (0.027)
2. Stopped an activity	0.308** (0.149)	0.047*** (0.014)	-0.161** (0.067)	0.053 (0.085)	0.069 (0.097)	0.093 (0.061)	-0.098 (0.209)	-0.218 (0.243)	-0.381 (0.315)	-0.003 (0.022)
3. Use of better varieties	0.0007 (0.197)	0.011 (0.017)	-0.102 (0.065)	0.223** (0.109)	0.090 (0.130)	0.028 (0.079)	-0.578** (0.253)	-0.879*** (0.307)	-0.223 (0.373)	0.045 (0.028)
4. Pest management	0.789** (0.337)	-0.102* (0.058)	0.020 (0.121)	-0.112 (0.192)	0.231 (0.197)	-0.007 (0.137)	-0.177 (0.532)	-0.055 (0.611)	0.0727 (0.757)	0.027 (0.041)
5. Soil fertility management	-0.070 (0.185)	0.031* (0.018)	-0.105 (0.088)	-0.007 (0.108)	0.124 (0.112)	0.131* (0.080)	-0.770** (0.313)	-0.513 (0.357)	-1.124** (0.497)	-0.0003 (0.030)
6. Water use and management	0.330* (0.183)	-0.003 (0.020)	-0.147 (0.108)	0.172 (0.107)	-0.133 (0.125)	0.110 (0.080)	-0.163 (0.256)	-0.190 (0.300)	0.006 (0.377)	0.017 (0.025)
7. Land preparation and management	0.022 (0.223)	0.018 (0.017)	0.0460 (0.071)	0.108 (0.120)	-0.111 (0.137)	-0.006 (0.083)	0.455* (0.257)	0.269 (0.300)	0.846** (0.389)	-0.002 (0.029)
8. Crop management	-0.062 (0.178)	0.0219 (0.015)	0.0003 (0.060)	-0.013 (0.097)	0.092 (0.113)	0.074 (0.066)	0.552** (0.227)	0.362 (0.261)	0.383 (0.335)	-0.037 (0.025)
9. Temporal adjustments	0.252 (0.182)	-0.0005 (0.0145)	-0.014 (0.058)	0.136 (0.096)	0.129 (0.123)	0.081 (0.069)	0.211 (0.219)	-0.003 (0.258)	-0.054 (0.308)	0.052** (0.024)

*** p<0.01, ** p<0.05, * p<0.1; Standard errors in parenthesis.

5.5.2 Role of study site location on different innovations.

Table 5.3 below presents the influences of study site locations on innovations. The estimated coefficients are the differences in the latent propensities of households in each country (i.e. *Ethiopia*, *Kenya* and *Tanzania*) to engage in a given innovation relative to households in *Uganda*, ceteris paribus.

Table 5.3 Role of study site location on different innovations (reference category-*Uganda*).

Innovation	*Ethiopia*	*Kenya*	*Tanzania*
1. Introduction and testing of new crops	0.0755 (0.270)	0.677*** (0.236)	1.187*** (0.224)
2. Stopped an activity	0.604*** (0.221)	0.576*** (0.207)	0.567*** (0.203)
3. Use of better varieties	0.489* (0.258)	0.359 (0.260)	0.533** (0.251)
4. Pest management	[6]	-1.988*** (0.587)	-1.326*** (0.431)
5. Soil fertility management	-1.093** (0.529)	0.976*** (0.254)	1.706*** (0.242)
6. Water use and management	-0.021 (0.301)	0.0603 (0.296)	1.275*** (0.239)
7. Land preparation and management	0.701*** (0.258)	1.164*** (0.283)	1.116*** (0.276)
8. Crop management	0.045 (0.237)	0.046 (0.227)	0.706*** (0.234)
9. Temporal adjustments	0.389* (0.224)	1.595*** (0.231)	1.094*** (0.213)

*** p<0.01, ** p<0.05, * p<0.1; Standard errors in parenthesis

[6]In our analysis, the result on the influence of information received by *Ethiopia* on pest management was not provided because the variable was dropped due to perfect collinearity.

Relative to *Uganda*, our results show that for most innovations, *Ethiopia*, *Kenya* and *Tanzania* are more innovative as shown by positive coefficients. The only exceptions are *pest management* in all the three countries, and *soil fertility management* in Ethiopia. Relative to *Uganda*, *Tanzania* is the most innovative in 8 innovations, followed by *Kenya* in 5 innovations and the least is *Ethiopia* with 4 innovations. Uganda is not different from both *Ethiopia* and *Kenya* in *crop* *management* and *water use and management.* Also, *Uganda* is not different from *Ethiopia* in *introduction and testing of new crops* and *Kenya* in *use of better varieties.*

5.5.3 Influence of reasons on different innovations

One of the objectives in this study was to find the important reasons cited by households for different innovations. Table 5.4 above presents these results. The estimated coefficient on each reason variable refers to the influence of each reason on the latent propensities of households to engage in a given innovation, ceteris paribus.

There are a number of innovations for which we do not find significant reasons. For those innovations that have significant reasons, the most common reasons are: *better yields* influencing 5 innovations; *amount and pattern of rainfall* influencing 4 innovations; *market opportunities* influencing 3 innovations; *land productivity and availability* influencing 2 innovations. The least common reasons are *labour availability* and *pests and diseases*. We find that *extension services and policy* is not a reason for any of the innovations.

Table 5.4 Role of reasons on different innovations

Innovation	*Better yields*	*Market Opportunities*	*Amount and pattern of rainfall*	*Land productivity and availability*	*Labour availability*	*Pests and diseases*	*Extension services and policy*
1. Introduction and testing of new crops	0.462*** (0.179)	0.150 (0.201)	-0.353 (0.220)	0.267 (0.210)	0.208 (0.208)	-0.150 (0.186)	0.196 (0.251)
2. Stopped an activity	0.316** (0.157)	0.135 (0.186)	0.560*** (0.183)	0.0318 (0.184)	0.144 (0.193)	0.131 (0.172)	0.024 (0.234)
3. Use of better varieties	1.507*** (0.198)	0.976*** (0.354)	0.575*** (0.208)	-0.101 (0.219)	0.160 (0.237)	0.565** (0.284)	-0.014 (0.359)
4. Pest management	0.437 (0.441)	0.660* (0.400)	0.299 (0.408)	0.346 (0.430)	-0.311 (0.406)	-0.392 (0.341)	0.090 (0.417)
5. Soil fertility management	-0.0790 (0.204)	0.236 (0.229)	0.225 (0.247)	0.273 (0.235)	0.344 (0.224)	-0.058 (0.195)	0.183 (0.273)
6. Water use and management	0.106 (0.211)	-0.099 (0.238)	0.377 (0.234)	-0.040 (0.224)	-0.304 (0.242)	0.0323 (0.211)	0.446 (0.274)
7. Land preparation and management	0.515** (0.201)	0.496* (0.297)	0.634*** (0.206)	0.909*** (0.239)	0.549** (0.279)	0.030 (0.316)	-0.418 (0.415)
8. Crop management	0.362** (0.171)	0.104 (0.224)	0.525*** (0.184)	1.151*** (0.193)	0.303 (0.218)	-0.211 (0.216)	0.100 (0.306)
9. Temporal adjustments	0.116 (0.163)	-0.016 (0.208)	0.231 (0.190)	0.244 (0.194)	-0.190 (0.211)	0.254 (0.218)	0.004 (0.262)

*** p<0.01, ** p<0.05, * p<0.1; Standard errors in parenthesis

5.5.4 Influences of gender differentiated roles on innovations

One of the objectives in this study was to find out how gender differentiated roles influences innovations among farming households. Table 5.5 below presents these results. The estimated coefficient on who does an activity (i.e. *men* or *women*), refers to the differences between the latent propensities of households to engage in an activity given who does an activity and the reference category (*both men and women*), ceteris paribus.

Table 5.5 Influences of gender differentiated roles on innovation (reference category- both men and women responsible)

Innovation	*Men*	*Women*
1. Introduction and testing of new crops	0.085	-0.131
	(0.196)	(0.0943)
2. Stopped an activity	0.187	0.050
	(0.176)	(0.084)
3. Use of better varieties	0.354*	0.071
	(0.212)	(0.107)
4. Pest management	0.249	-0.035
	(0.405)	(0.186)
5. Soil fertility management	-0.334	-0.187*
	(0.243)	(0.104)
6. Water use and management	-0.270	-0.184*
	(0.237)	(0.108)
7. Land preparation and management	-0.339	-0.029
	(0.216)	(0.116)
8. Crop management	-0.034	0.087
	(0.189)	(0.095)
9. Temporal adjustments	0.094	0.121
	(0.188)	(0.099)

*** $p<0.01$, ** $p<0.05$, * $p<0.1$; Standard errors in parenthesis

Results (Table 5.5) indicate that, relative to the reference category (*both men and women*), for most of the innovations, there are no significant differences for *men* or *women*. The exceptions are the positive influence of *men* on *use of better varieties*, and negative influences of women on *soil fertility management* and *water use and management*. These results provide some evidence that suggests that there is a more constrained environment for innovations of women than for men.

5.5.5 Influence of gendered access to forecast information on innovation

One of the objectives in this study was to find out how gendered access to different types of forecast information influences innovations among farming households. Table 5.6 presents these results. The estimated coefficient on each variable refers to the differences in latent propensities of households to engage in an activity given who received the forecast information (information received by: *men*; *women; both men and women*) and the reference category (*none*), ceteris paribus.

Overall, our results show that for different categories of forecast information, most of the innovations for *men, women* and *both men and women* are not different from the reference category. Therefore, forecast information is not influencing a lot of innovations. Recall, that *extension services and policy* was not an important reasons for any innovations conducted. For those coefficients that are significant, our expectation is that for all types of information, relative to the reference category of no information (*none*), the coefficients will be positive. Table 5.6 shows that out of 10 significant variables, 7 are positive.

Table 5.6 Influence of gender differentiated access to different forecast information on innovations (reference category-none)

Innovation	Extreme weather forecast information			Pest and disease forecast information			Weather forecast information		
	men	*women*	*both men and women*	*men*	*women*	*both men and women*	*men*	*women*	*both men and women*
1. Introduction and testing of new crops	-0.339 (0.256)	0.284 (0.315)	-0.342 (0.298)	0.370 (0.304)	0.046 (0.322)	0.556* (0.321)	-0.210 (0.281)	-0.770** (0.335)	-0.198 (0.294)
2. Stopped an activity	-0.233 (0.216)	0.034 (0.278)	0.206 (0.276)	0.225 (0.281)	-0.091 (0.282)	-0.315 (0.301)	0.101 (0.244)	-0.038 (0.287)	0.440 (0.277)
3. Use of better varieties	0.384 (0.240)	0.363 (0.323)	0.522 (0.384)	0.437 (0.378)	0.446 (0.334)	-0.169 (0.395)	0.521* (0.287)	-0.002 (0.330)	0.804** (0.385)
4. Pest management	0.286 (0.766)	0.873 (0.779)	0.475 (0.690)	-0.084 (0.584)	7	0.082 (0.674)	0.201 (0.748)	-0.614 (0.897)	-0.558 (0.693)
5. Soil fertility management	0.339 (0.378)	-0.194 (0.319)	-0.630 (0.359)	0.271 (0.358)	-0.157 (0.320)	0.149 (0.362)	0.201 (0.362)	0.175 (0.347)	0.613* (0.367)
6. Water use and management	0.139 (0.296)	-0.218 (0.351)	-0.216 (0.379)	-0.374 (0.377)	-0.586* (0.349)	-0.616 (0.403)	-0.395 (0.333)	0.267 (0.350)	-0.016 (0.342)
7. Land preparation and management	0.957*** (0.255)	0.0212 (0.383)	-0.424 (0.401)	-0.372 (0.390)	-0.0121 (0.404)	0.501 (0.423)	-0.341 (0.302)	0.102 (0.416)	0.529 (0.384)
8. Crop management	0.079 (0.228)	0.028 (0.302)	0.253 (0.315)	-0.279 (0.322)	-0.635** (0.322)	-0.492 (0.332)	0.320 (0.262)	0.286 (0.317)	0.127 (0.306)
9. Temporal adjustments	0.354* (0.214)	0.530* (0.317)	0.010 (0.304)	-0.225 (0.326)	0.093 (0.342)	0.059 (0.330)	0.366 (0.257)	-0.111 (0.326)	0.342 (0.294)

*** p<0.01, ** p<0.05, * p<0.1; Standard errors in parenthesis.

[7] In our analysis, the result on the influence of information received by women on pest management was not provided because the variable was dropped due to perfect collinearity.

When *men* receive extreme weather forecasts, there are positive coefficients for *land preparation and management* and *temporal adjustments.* When *women* receive extreme weather forecast information, there is only a positive coefficient for *temporal adjustments.* For *both men and women*, when they receive pest and disease forecast information, there is a positive coefficient in *introduction and testing of new crops.* But when *women* receive pest and disease forecast information, there is a decrease in *water use and management* and *crop management.* For weather forecast information, when *men* receive information, there is an increase in *use of better varieties.* Also, when *both men and women* receive weather forecast information there are positive coefficients for *use of better varieties* and *soil fertility management*. But when *women* receive weather forecast information, there is less *introduction and testing of new crops*.

The above result does not match with our expectations since providing information to *women* should not make households less innovative than those households which did not get information. There are possible reasons for this result. 1) Recall, in Chapter 2 we indicated that women in poor households may be more risk averse than men. Therefore, when *women* receive forecast information, they may become more involved in the decision making process and their risk averseness could dampen household level innovation. 2) Or when *women* receive forecast information, they may perceive some innovations as being not worth undertaking. Because of their central role in household management and in welfare enhancing activities such as ensuring food security, health and hygiene, child care and education, *women* could undertake less of these perceived non-worthwhile innovations. Instead, they may use their time to supplement income based on other activities. 3) The information that *women* receive may be correlated with other household characteristics such as unequal ownership and control of resources. In this case, the observed full innovation effect may be a result of those systematic correlations. Therefore, it is important to consider the selection criteria for information dissemination.

5.5.6 Influence of household headship structures on different innovations

Table 5.7 presents results of the influences of household headship structures on different innovations. Recall that the headship structures *(1- 5)* are listed in terms of decreasing influence of males in terms of decision making. The estimated coefficient on each headship variable refers to the differences in latent propensities to engage in an activity between a household headship type and the reference category *(female headed, divorced, single or widowed)*, ceteris paribus.

We find that the significant coefficients are all are positive. Households that are *male headed, with wife present* have positive significant effects in *introduction and testing of new crops* and *crop management.* Also, *female headed, husband away and not active* households, have positive coefficients in *introduction and testing of new crops, stopped an activity,* and *soil fertility management*. There are no significant effects on innovations for households that are *male headed, with no wife* and *female headed, husband away and active* relative to the reference category.

A possible explanation for our result is that, as we go from the reference category (*headship 5*) to *female headed, husband away and not active (headship 4)*, some external gendered constraints are relieved but the internal gendered constraints are increased. In this case it appears as though relaxing the external gendered constraints outweigh the increase in internal gendered constraints resulting in an overall positive effect on innovation. The external and internal gendered constraints then seem to counteract one another resulting in no significant effect on innovation for households that are *male headed, with no wife* and *female headed, husband away and active.* But for a household that is *male headed, with wife present*, we again seem to have few external gendered constraints and more internal gendered constraints resulting in an overall positive effect on innovation.

Table 5.7 Influences of headship structures on innovations.

Innovation	*Household headship structures* 1. Male headed, with wife present	2. Male headed, with no wife	3. Female headed, husband away and active	4. Female headed, husband away and not active
1. Introduction and testing of new crops	0.431** (0.171)	0.043 (0.550)	0.470 (0.484)	0.742* (0.445)
2. Stopped an activity	-0.138 (0.150)	-0.137 (0.456)	-0.283 (0.497)	0.701* (0.424)
3. Use of better varieties	-0.090 (0.188)	-0.374 (0.551)	0.102 (0.521)	0.419 (0.599)
4. Pest management	0.372 (0.354)	0.742 (0.743)	[8]	[9]
5. Soil fertility management	0.256 (0.192)	-0.026 (0.586)	0.686 (0.761)	1.091** (0.555)
6. Water use and management	0.321 (0.197)	0.293 (0.607)	0.467 (0.558)	-0.099 (0.621)
7. Land preparation and management	0.173 (0.199)	-0.078 (0.530)	0.537 (0.510)	-0.238 (0.533)
8. Crop management	0.472*** (0.171)	-0.351 (0.481)	0.390 (0.463)	0.466 (0.467)
9. Temporal adjustments	0.126 (0.170)	-0.319 (0.454)	-0.0205 (0.434)	0.059 (0.457)

1=Male headed, with a wife or wives,
2=Male headed, divorced, single or widowed,
3=Female headed, husband away, husband makes most household/agricultural decisions,
4=Female headed, husband away, wife makes most household/agricultural decisions.
(*Reference category =5. Female headed, divorced, single or widowed*)

*** p<0.01, ** p<0.05, * p<0.1; Standard errors in parenthesis

[8 and 9]In our analysis, the result on the influence of *female headed, husband away and active* and *female headed, husband away and not active* on pest management was not provided because the variable was dropped due to perfect collinearity.

5.6 Summary and conclusion

In order to investigate the gender differentiated innovations in the presence of climate change, we modelled nine innovations as latent variables by a standard probit model. The different categories of explanatory variables included reasons for innovations cited by households, gender of the household head and who makes agricultural and household decisions, gender-specific access to forecast information, gendered roles in activities, and site control variables. Our results show that some of the estimated coefficients are significant with the expected signs. Our probit model as a whole is statistically significant as shown by a likelihood ratio chi-square of 2535.62 with a p-value of 0.0000.

Regarding impact of household characteristics on innovations, we find that the presence of *on farm water* is a complement to a number of innovations. Also, *information assets* positively influence some innovations. Household characteristics such as: *total land*; *social capital*; *income sources*; *primary education*; *post-secondary education; household size* are found to be either complements or substitutes depending on the type of innovation. We also find that *social capital* and *secondary education* each negatively influence a single type of innovation. We do not find any significant influence of *production assets* on innovations.

Regarding the role of study site location on innovations, we find that relative to *Uganda*, farming households in *Tanzania* are more innovative, followed by *Kenya* and *Ethiopia* is the least innovative. Regarding reasons for different innovations, we find that *better yields*; *market opportunities*; *amount and pattern of rainfall*; *land productivity and availability,* are the most common reasons cited by households for innovations. But again, these reasons tend to be significant for only some type of innovation.

Regarding the influence of gender differentiated roles on innovations, our results suggest that, relative to *both men and women*, there are some significant differences between innovations of *men* or *women*. We find *men* to positively influence *use of better varieties*, and *women* to negatively influence *soil fertility management* and *water use and management*. These results provide some evidence that suggest that there is a more constrained environment for innovations of women than for men.

Regarding gender differentiated access to forecast information, our results show that for different categories of forecast information, most of the innovations for *men*, *women* and *both men and women* are not different from the reference category *(none)*. Although forecast information is not influencing a lot of innovations, we do find that when *men* and *both men and women* receive forecast information, generally they are more likely to undertake some innovations relative to *none*. On the other hand, when *women* receive forecast information, we find that there are some types of innovations where the probability of them being undertaken is decreased relative to *none*.

Regarding household headship structures, the reference category is a household headed by a female who is divorced, single or widowed. Relative to the reference category, we find that there are only significant effects for *male headed, wife present* and *female headed, husband away and not active* in some innovations. There are no significant effects on innovations for households that are *male headed, with no wife* and *female headed, husband away and active* relative to the reference category.

Chapter 6: Conclusions

6.1 Introduction

The overall goal of this study was to look at gender-differentiated innovations of farming households in maize production in the context of climate change in four East African countries. In pursuit of this goal, the following research questions were investigated:

i. How do household characteristics influence innovations?
ii. Do farming households in east African countries in the study region differ in their innovations?
iii. How do gender differentiated roles in maize production influence innovations?
iv. What are the major reasons cited by households for their innovations in maize production?
v. How does gender differentiated access to forecast information influence innovations?
vi. How do household headship structures influence innovations in maize production?

We used two approaches to model the gender differentiated innovations in the presence of climate change, a count negative binomial regression model and a probit model. Following is what we found with respect to our research questions using these two approaches.

6.2 Summary of the results and conclusions

Regarding the influence of household characteristics on innovations, with the count model, results show that *information assets* increases the number of innovations. Similarly, the probit model results indicate that *information assets* is a complement to a number of different types of innovations. Results from the count model also show that access to *total land* and *income sources* positively influence innovativeness among farming households. But with the probit model, we find that these variables can either be complements, like in the count model, or substitutes depending on the type of innovation. With the probit model, we find that *social capital* decreases *stopped an activity* and education variables are either complements or substitutes depending on the type of innovation. On the contrary, with the count model, we do not find a significant influence of *social capital* or different educational levels on innovations. Results from the probit model show that *on farm water* is a household characteristic that increases a number of different types of innovations. But, with the count model, we do not find a significant influence of *on farm water* on the number of innovations. Neither model shows a significant influence of *production assets* on innovations.

Regarding site controls, results from the count model showed that being in *Kenya* and *Tanzania* increases the number of innovations compared to *Uganda*, which is the reference category. Similarly, the probit model showed that farmers in *Tanzania* generally are more innovative, followed by those in *Kenya*. The probit model shows that *Ethiopia* has a significant influence on innovations, although it has lower innovations compared to *Kenya* and *Tanzania*. On the contrary, with the count model, we do not find a significant influence of *Ethiopia* on innovations.

Regarding reasons for different innovations, with both the count model and probit models, results show that *better yields, amount and pattern of rainfall, land productivity and availability,* and *pests and diseases* are the most common cited reasons for innovations. Additionally, the probit model finds *market opportunities* and *labour availability* as one of the common reasons cited by households for some innovations. Neither model finds significant influences of *extension services and policy* on innovations.

Regarding the influence of gender differentiated roles on innovations, results from the probit model suggest that, there are significant differences between some types of innovations of *men* or *women* relative to *both men and women*. Specifically, we find *men* to positively influence *use of better varieties*, while *women* negatively influence *soil fertility management* and *water use and management*. With the count model, we do not find significant influences of gender differentiated roles on innovations. Overall, from both models, gender differentiated roles do not seem to have a widespread influence across innovations.

Regarding gender differentiated access to forecast information, with the count model, when *men* or *both men and women* receive forecast information, our results indicate that the number of innovations increase relative to *none*. Similarly, with the probit model, we find that when *men* and *both men and women* receive forecast information, generally they are more likely to undertake some innovations relative to *none*. With the probit model, we find that when *women* receive forecast information, there are some types of innovations where the probability of them being undertaken is decreased relative to *none*. With the count model, we do not find a significant influence of *women* on innovations. Overall, we find from both models that when *men* or *both men and women* receive forecast information, the number of innovations increase relative to *none*. However, when *women* receive forecast information, there is either a decrease in the number of innovations or there is no significant influence on innovations relative to *none*.

Regarding the influence of headship structures on innovations, both models found that a household which is *female headed, husband away and not active* in household/agricultural decisions is likely to be more innovative compared to the reference category which is a household headed by a female who is divorced, single or widowed. In addition, in the probit model we also found that a household which is *male headed, with wife present* does have a positive significant influence on innovations. In both models, there are no significant effects on innovation for households that are *male headed, with no wife* and *female headed, husband away and active* in decision making relative to the reference category.

6.3 Limitations of the study

Our study covers a broad area of four countries in East Africa, and looks at different types of innovations in maize production. Therefore, our results may not be as well identified as could be achieved with more causal focused studies that look at a smaller area and one specific type of innovation. Along these lines, a basic challenge we had in this study was how to measure/model general innovation. We employed the count model and the probit model in investigating factors influencing innovations. Each of these models has limitations in modelling innovations. In the count model, each innovation is treated as having the same weight, even though some innovations may cost more to undertake than others. As a result, a household making for example, 3 innovations is considered less innovative than a household making for instance 5 innovations, despite the fact that undertaking 3 innovations may cost more than carrying out 5 innovations. Therefore, counts of innovations may cloak important differences among them. Unfortunately, we do not have cost information about innovations to attempt to address this problem. In the probit regression, the process of reducing a count of 46 innovations to 9 categories may have caused us to omit important differences between innovations in each category. Our results from the probit model could also have been affected by the specific aggregation choices that were used in defining the categories of innovations. Despite the possible limitations, our study presents a wide range of significant results, many of which hold across different modelling approaches to specifying innovation, which can be viewed as preliminary relationships between gender and innovations to be further explored with more specific studies.

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Appendix: Household level survey

CCAFS Baseline Household Level Questionnaire	Site ID (SITEID)				
	Block ID (BLOCKID)				
	Village ID (VILLID)				
	Household ID (HHID)				

CCAFS Baseline Household Level Questionnaire

Introduction and consent by main respondent

Before the beginning of the interview read out the following paragraph and ensure that the respondent understands before asking for consent.

"Good morning/afternoon. We are coming from (_partner organization's name_)__ with permission from the local government. We are conducting a survey ***looking at farming practices and how they change over time****. We would like to ask you some questions that should take no more than one to one and half hours of your time. We would like to share some of this information widely in order that more people understand how food is grown and used in this region and the issues that you face regarding food production and soil, water and land management.*

Your name will not appear in any data that is made publicly available. The information you provide will be used purely for research purposes; your answers will not affect any benefits or subsidies you may receive now or in the future. Do you consent to be part of this study? You may withdraw from the study at any time and if there are questions that you would prefer not to answer then we respect your right not to answer them.

Has consent been given? *(01=Yes, 00=No)* [__ __] CONSENT

Section 0 – Data Handlers

	Name✍	Code	Date (d/m/y)	Signature
Interviewer	________	[__ _] FLDCODE	__ __ / __ __ / __ __ __ FLDDAY, FLDMTH,FLDYEAR	____________
Supervisor	________	[___] SUPCODE	__ __ / __ __ / __ __ __ SUPDAY,SUPMTH,SUPYEAR	____________
1st Data entry clerk	________	[___]	__ __ / __ __ / __ __ __	____________

	____	DE1CODE	DE1DAY, DE1MTH,DE1YEAR	____
2nd Data entry clerk	____	[____] DE2CODE	__ __ / __ __ / __ __ __ __ DE2DAY, DE2MTH,DE2YEAR	____

GPS coordinates (UTM) N:____________ GPSN

(to be filled in by site supervisor) S: ____________ GPSS

E:____________ GPSE

W:____________ GPSW

Section I: - Household Respondent and Type

Ideal respondent: household head and/or spouse. Most of these questions can be completed without having to question the respondent directly. Be sensitive about the way you gather this information.

1. Name of household head

a. First name (more than 1 if needed) HEADNAM1 ✎____________

b. Last name HEADNAM2 ✎____________

2. Name of Main respondent

a. First name (more than 1 if needed) RESPNAM1 ✎____________

b. Last name RESPNAM2 ✎____________

3. Sex of the respondent *(01=Male, 02=Female)* RESPSEX [__ __]

4. What is the relationship of main respondent to household head RESPREL [__ __]

(00=Head, 01=Spouse, 02=Parent, 03=Child, 04=Grandchild, 05=Nephew/Niece, 06=Son/daughter-in-law, 07=Brother/sister, 96= Other related (specify) 97=Other unrelated (specify)

SPECREL ✎____________

5. Household community/ethnicity/caste *(see code sheet)* HHETHNIC [__ __]

6. Household type	HHTYPE	[__ __]
01=Male headed, with a wife or wives, *02=Male headed, divorced, single or widowed,* *03=Female headed, divorced, single or widowed,* *04=Female headed, husband away, husband makes most household/agricultural decisions,* *05=Female headed, husband away, wife makes most household/agricultural decisions,* *06=Child headed (age 16 or under)/Orphan* *96=Other, specify*	SPECTYPE	____________

Section II: - Demography

1. How many people, including yourself and other adults, are in your household?	HHSIZE	[__ __]
2. How many people in your household are under the age of 5yrs?	HHLT5	[__ __]
3. How many people in your household are over the age of 60yrs?	HHGT60	[__ __]
4. What is the highest level of education obtained by any household member?	HHEDUC	[__ __]

00=No formal education,01=Primary, 02=Secondary, 03=Post Secondary

Section III: - Sources of Livelihood Security

Read the following question as an introduction to the questioning. Once in the table, go row by row.

1. During the last 12 months, which of the following did you produce **from your own farm,** and how were they used? ***Note: This only refers to production and use of products from the farm. If, for example, firewood is collected off-farm and used or sold, then it is not included***

	Any produced / harvested on your own farm?	Who does most of the work?	Any consumed in household or used on farm?	Any sold for cash?

Product		PROD *(01=Yes, 00=No)*	RESP *(01=Man, 02=Woman 03=female child, 04=Male child, 05=Several, 06=Other)*	CONS *(01=Yes, 00=No)*	SOLD *(01=Yes, 00=No)*
Food crop (raw)	CRAW	[__ __]	[__ __]	[__ __]	[__ __]
Food crop (processed – e.g. snack foods)	CPRC	[__ __]	[__ __]	[__ __]	[__ __]
Other/cash crop (tea, coffee, sisal, cotton, jute, sugar cane, etc.)	COTH	[__ __]	[__ __]	[__ __]	[__ __]
Fruit	FRUT	[__ __]	[__ __]	[__ __]	[__ __]
Vegetables	VEGT	[__ __]	[__ __]	[__ __]	[__ __]
Fodder	FODD	[__ __]	[__ __]	[__ __]	[__ __]
Large livestock (cattle, buffalo, camels)	LGLV	[__ __]	[__ __]	[__ __]	[__ __]
Small livestock (sheep, goats, pigs, chickens, donkeys)	SMLV	[__ __]	[__ __]	[__ __]	[__ __]
Livestock products (milk, eggs, etc.)	LVPD	[__ __]	[__ __]	[__ __]	[__ __]
Fish	FISH	[__ __]	[__ __]	[__ __]	[__ __]
Timber	TIMB	[__ __]	[__ __]	[__ __]	[__ __]
Fuel wood	WOOD	[__ __]	[__ __]	[__ __]	[__ __]
Charcoal	CHAR	[__ __]	[__ __]	[__ __]	[__ __]
Honey	HONE	[__ __]	[__ __]	[__ __]	[__ __]
Manure/compost	COMP	[__ __]	[__ __]	[__ __]	[__ __]
Other, specify: (SPECPROD) ✍________________________	OTHE	[__ __]	[__ __]	[__ __]	[__ __]

Read the following question as an introduction to the questioning. Once in the table, go row by row.

2. During the last 12 months, which of the following **did you harvest or collect from outside your farm,** and how were they used?

Note: This only refers to use of products from outside the farm.

		Any harvested or collected from outside your farm? *(01=Yes, 00=No)*	Who does most of the work? *(01=Man, 02=Woman, 03=Female child, 04=Male child, 05=Several, 06=Other)*	Any consumed in household or used on farm? *(01=Yes, 00=No)*	Any sold for cash? *(01=Yes, 00=No)*
Product		PRD2	RSP2	CNS2	SLD2
Food crop	FOCR	[__ __]	[__ __]	[__ __]	[__ __]
Fruit	FRUT	[__ __]	[__ __]	[__ __]	[__ __]
Fodder	FODD	[__ __]	[__ __]	[__ __]	[__ __]
Fish	FISH	[__ __]	[__ __]	[__ __]	[__ __]
Timber	TIMB	[__ __]	[__ __]	[__ __]	[__ __]
Fuel wood	WOOD	[__ __]	[__ __]	[__ __]	[__ __]
Charcoal	CHAR	[__ __]	[__ __]	[__ __]	[__ __]
Honey	HONE	[__ __]	[__ __]	[__ __]	[__ __]
Manure/compost	COMP	[__ __]	[__ __]	[__ __]	[__ __]
Other, specify: ✍____________________	OTHE (SPECPOUT)	[__ __]	[__ __]	[__ __]	[__ __]

Read the following question as an introduction to the questioning. Once in the table, go row by row.

3. During the last 12 months did any cash come to the household through any of the following means?

Note: If answer to 1 is 'yes' then ask 2, otherwise ask 3

Source of cash		1. Any cash income during the last 12 months? **If Yes, go to 2 If No, go to 3** CASH *(01=Yes, 00=No)*	2. If Yes, was this a new source which you did not have previously? THIS *(01=Yes, 00=No, -8=N/A)*	3. If No, did you receive cash from this source at any time in the past? LAST *(01=Yes, 00=No, -8=N/A)*
Employment on someone else's farm	OTFM	[__ __]	[__ __]	[__ __]
Other paid employment (e.g. salary)	PAID	[__ __]	[__ __]	[__ __]
Business (other than farm products)	BSNS	[__ __]	[__ __]	[__ __]
Remittances or gifts	GIFT	[__ __]	[__ __]	[__ __]
Payments for environmental services	ENVS	[__ __]	[__ __]	[__ __]
Other payment from projects/ government including benefits in kind (e.g. pensions, aid, subsidies, etc.)	PRGV	[__ __]	[__ __]	[__ __]
Loan/credit from a bank or other formal institution (microfinance, projects/programs, registered group)	LNBK	[__ __]	[__ __]	[__ __]
Loan/credit from an informal source (moneylender, relative, etc.)	LNIF	[__ __]	[__ __]	[__ __]
Renting out your farm machinery (e.g. tractor, thresher, pump, etc.) or animals for traction	RNTL	[__ __]	[__ __]	[__ __]
Renting out your own land	RENT	[__ __]	[__ __]	[__ __]

Section IV: - Crop, Farm Animals/Fish, Tree and SLM Changes

Read the following question as an introduction to the questioning.

1. I would now like you to tell me what changes you have made in the way you have been managing your land, crops and farm animals over the last 10 years. [If the respondent is obviously too young to have been farming over the last 10 years, ask about what their father did over the last 10 years at this location]

1. Have you or your family been farming or keeping animals or fish in this locality for 10 years or more? *(01=Yes, 00=No)*	FARM10YR	[____]

2. Now I would like to hear about changes you have made in the types of crops you have grown within the last 10 years

Have you ...		**Write the crop codes (use the code sheet)**			
		CRP1	CRP2	CRP3	CRP4
Introduced any new crop?(over some time) *(see crop codes)*	CRIN	[__ __]	[__ __]	[__ __]	[__ __]
Are you testing any new crop (still not sure about) *(see crop codes)*	CRTS	[__ __]	[__ __]	[__ __]	[__ __]
Stopped growing a crop (totally) *(see crop codes)*	SGCT	[__ __]	[__ __]	[__ __]	[__ __]
Stopped growing a crop (in one season) *(see crop codes)*	SGC1	[__ __]	[__ __]	[__ __]	[__ __]

3. What are your three most important crops? By 'main crop' I mean the crops you grow on your farm which are most important to your household's livelihood. *(see crop codes)*	MNCRPNW1	[__ __]
	MNCRPNW2	[__ __]
	MNCRPNW3	[__ __]
4. What were your three most important crops 10 years ago? *(see crop codes)*	MNCRP101	[__ __]
	MNCRP102	[__ __]
	MNCRP103	[__ __]
5. What are your three most important farm animals or fish? By 'main farm animals' I mean the animals you keep on your farm which are most important to your household's livelihood. *(see farm animal and fish codes)*	MNFRMNW1	[__ __]
	MNFRMNW2	[__ __]
	MNFRMNW3	[__ __]
6. What were your three most important farm animals or fish 10 years ago? *(see farm animal and fish codes)*	MNFRM101	[__ __]
	MNFRM102	[__ __]
	MNFRM103	[__ __]

Read the following question as an introduction to the questioning.

7a. Tell me more about **what** changes you have made to the crop varieties you have planted over the last 10 years

Ask the respondent to tell a story and take notes on a separate page, fill in the table after the interview, before you leave the household in case follow up is needed.

Have you/Are you...		Crop code CRP1	Crop code CRP2	Crop code CRP3	Crop code CRP4	Crop code CRP5
Introduced new variety of crops	NWVR	[__ __]	[__ __]	[__ __]	[__ __]	[____]
Planting higher yielding variety	PHYV	[__ __]	[__ __]	[__ __]	[__ __]	[____]
Planting better quality variety	PBYV	[__ __]	[__ __]	[__ __]	[__ __]	[____]
Planting pre-treated/improved seed	PPIS	[__ __]	[__ __]	[__ __]	[__ __]	[____]
Planting shorter cycle variety	SHCY	[__ __]	[__ __]	[__ __]	[__ __]	[____]
Planting longer cycle variety	LGCY	[__ __]	[__ __]	[__ __]	[__ __]	[____]
Planting drought tolerant variety	DRTL	[__ __]	[__ __]	[__ __]	[__ __]	[____]
Planting flood tolerant variety	FDTL	[__ __]	[__ __]	[__ __]	[__ __]	[____]
Planting salinity-tolerant variety	SLTL	[__ __]	[__ __]	[__ __]	[__ __]	[____]
Planting toxicity-tolerant variety	TXTL	[__ __]	[__ __]	[__ __]	[__ __]	[____]
Planting disease-resistant variety	DSTL	[__ __]	[__ __]	[__ __]	[__ __]	[____]
Planting pest-resistant variety	PSRS	[__ __]	[__ __]	[__ __]	[__ __]	[____]
Testing a new variety	NVTS	[__ __]	[__ __]	[__ __]	[__ __]	[____]
Stopped using a variety	STVR	[__ __]	[__ __]	[__ __]	[__ __]	[____]
Other, specify (SPECCHCP) ____________________	OTHE	[__ __]	[__ __]	[__ __]	[__ __]	[____]

7b. Tell me more about **what** changes you have made in the way you manage your land, soil and water and in **how** you have prepared your land over the last 10 years, and which crops these changes affected.

Make sure you prompt for fruit, vegetables, cash crops, fodder and tree crops.

Ask the respondent to tell a story and take notes on a separate page, fill in the table after the interview, before you leave the household in case follow up is needed.

Land Use and management		Crop code CRP1	Crop code CRP2	Crop code CRP3	Crop code CRP4	Crop code CRP5
Expanded area	EXAR	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Reduced area	RDAR	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Started irrigating	STIR	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Stopped irrigating	SPIR	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Stopped burning	SPBR	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Introduced intercropping	INCR	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Introduced crop cover	CRCV	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Introduced micro-catchments	MCCT	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Introduced/built ridges or bunds	BUND	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Introduced mulching	MULC	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Introduced terraces	TERR	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Introduced stone lines	STLN	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Introduced hedges	HEGD	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Introduced contour ploughing	CTPL	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Introduced rotations	ROTA	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Introduced improved irrigation (water efficiency)	INIR	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Introduced improved	INID	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]

Land Use and management		Crop code CRP1	Crop code CRP2	Crop code CRP3	Crop code CRP4	Crop code CRP5
drainage						
Introduced tidal water control management	INWC	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Introduced mechanized farming	INMF	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Earlier land preparation	ELPP	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Earlier planting	ELPT	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Later planting	LTPT	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Started using or using more mineral/chemical fertilisers	MNFT	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Started using manure/compost	MNCP	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Stopped using manure/compost	MNCP	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Started using or using more pesticides/herbicides	UMPH	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Started using integrated pest management	UMIP	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Started using integrated crop management	UMCM	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Other, specify (SPECLAND) ______________	WHOT	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]

Why have you changed your practices?

7c. ***Why*** you have made these changes and again, to which crops were the changes applied to. ***Ask the respondent to tell a story and take notes on a separate page, fill in the table after the interview, before you leave the household in case follow up is needed.***

		Crop CRP1	Crop CRP2	Crop CRP3	Crop CRP4	Crop CRP5	Not crop specific (01=Yes, 00 =No) NCSP
Markets							
Better yields	BTY	[__ __]	[__	[__ __]	[__	[__ __]	[__ __]
Better price	PRC	[__ __]	[__	[__ __]	[__	[__ __]	[__ __]
New opportunity to	OPS	[__ __]	[__	[__ __]	[__	[__ __]	[__ __]
Climate							
More erratic rainfall	ERA	[__ __]	[__	[__ __]	[__	[__ __]	[__ __]
Less overall rainfall	LRA	[__ __]	[__	[__ __]	[__	[__ __]	[__ __]
More overall rainfall	MRA	[__ __]	[__	[__ __]	[__	[__ __]	[__ __]
More frequent	MDR	[__ __]	[__	[__ __]	[__	[__ __]	[__ __]
More frequent	MFL	[__ __]	[__	[__ __]	[__	[__ __]	[__ __]
Strong winds	SWN	[__ __]	[__	[__ __]	[__	[__ __]	[__ __]
Later start of rains	LSO	[__ __]	[__	[__ __]	[__	[__ __]	[__ __]
Earlier start of rains	ESO	[__ __]	[__	[__ __]	[__	[__ __]	[__ __]
More cold spells or	MCS	[__ __]	[__	[__ __]	[__	[__ __]	[__ __]
More frequent	MFC	[__ __]	[__	[__ __]	[__	[__ __]	[__ __]
Higher salinity	HISA	[__ __]	[__	[__ __]	[__	[__ __]	[__ __]
Higher tides (sea	HITI	[__ __]	[__	[__ __]	[__	[__ __]	[__ __]
higher temperatures	HITE	[__ __]	[__	[__ __]	[__	[__ __]	[__ __]
lower groundwater	LGW	[__ __]	[__	[__ __]	[__	[__ __]	[__ __]
Land							
Land is less	LDL	[__ __]	[__	[__ __]	[__	[__ __]	[__ __]
Land is more	LDM	[__ __]	[__	[__ __]	[__	[__ __]	[__ __]
Less land	LLN	[__ __]	[__	[__ __]	[__	[__ __]	[__ __]
More land	MLN	[__ __]	[__	[__ __]	[__	[__ __]	[__ __]
Labour							
Insufficient labour	ISLB	[__ __]	[__	[__ __]	[__	[__ __]	[__ __]
Sufficient labour	SFLB	[__ __]	[__	[__ __]	[__	[__ __]	[__ __]
Able to hire labour	HRL	[__ __]	[__	[__ __]	[__	[__ __]	[__ __]
Unable to hire	EXL	[__ __]	[__	[__ __]	[__	[__ __]	[__ __]
Unable to hire	AVL	[__ __]	[__	[__ __]	[__	[__ __]	[__ __]
Pests & diseases							
More resistant to	PDR	[__ __]	[__	[__ __]	[__	[__ __]	[__ __]
New pests/diseases	NWP	[__ __]	[__	[__ __]	[__	[__ __]	[__ __]
Projects etc.							

		Crop CRP1	Crop CRP2	Crop CRP3	Crop CRP4	Crop CRP5	Not crop specific (01=Yes, 00 =No) NCSP
Markets							
Government/ project	GVT	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Government/ project	GVS	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Policy changes	PLC	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Other kinds of changes not listed above, specify (SPECPRAC)______________	OTPD	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]

7d. Tell me more about **what** changes you have made with respect to farm animal and/or fish keeping over the last 10 years and what animal types these changes apply to.

Ask the respondent to tell a story and take notes on a separate page, fill in the table after the interview, before you leave the household in case follow up is needed

CHANGES IN Farm Animals/Fish		Farm animal and fish codes *(see farm animal and fish codes)*				
		FRM1	FRM2	FRM3	FRM4	FRM5
New farm animal or fish types introduced	NANI	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
New farm animals or fish types being tested	NANT	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Stopped keeping one or more types of farm animals or fish	SKFA	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
New breed introduced	NBRD	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Reduction in herd size	RDHS	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Increase in herd size	INHS	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Change in herd composition	CHHC	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Stall keeping introduced	STKP	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Fencing introduced	FENC	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Cut and carry introduced	CCIN	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Growing fodder crops	GFDC	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Improved pastures	IMPS	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
Fodder storage (e.g. hay, silage)	FDST	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
OTHER kinds of changes not listed above	OTLS	[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
(SPECLIVE)_________						

7e. ***Why*** have you made these changes to your animal keeping and again, to which farm animals were the changes applied to.

Ask the respondent to tell a story and take notes on a separate page, fill in the table after the interview, before you leave the household in case follow up is needed.

		Animal code *(see farm animal codes)*					Not animal specific (01=Yes, 00=No)
		FRM1	FRM2	FRM3	FRM4	FRM5	NASP
Better price	PRCE	[__ __]	[___]	[__ __]	[__ __]	[__ __]	[__ __]
New opportunity to sell	OPSL	[__ __]	[___]	[__ __]	[__ __]	[__ __]	[__ __]
More productive	MOPR	[__ __]	[___]	[__ __]	[__ __]	[__ __]	[__ __]
More frequent droughts	MDRT	[__ __]	[___]	[__ __]	[__ __]	[__ __]	[__ __]
More frequent floods	MFLD	[__ __]	[___]	[__ __]	[__ __]	[__ __]	[__ __]
Higher tides	HYTD	[__ __]	[___]	[__ __]	[__ __]	[__ __]	[__ __]
Frequent cyclones	FRCY	[__ __]	[___]	[__ __]	[__ __]	[__ __]	[__ __]
More salinization	MOSZ	[__ __]	[__]	[__ __]	[__ __]	[__ __]	[__ __]
Insufficient labour	ISLB	[__ __]	[___]	[__ __]	[__ __]	[__ __]	[__ __]
Able to hire labour	HRLB	[__ __]	[___]	[__ __]	[__ __]	[__ __]	[__ __]
More resistant to diseases	PDRS	[__ __]	[___]	[__ __]	[__ __]	[__ __]	[__ __]
New diseases are occurring	NWPD	[__ __]	[___]	[__ __]	[__ __]	[__ __]	[__ __]
Governmen t/ project told us to	GVTD	[__ __]	[___]	[__ __]	[__ __]	[__ __]	[__ __]

		Animal code *(see farm animal codes)*					Not animal specific (01=Yes, 00=No)
		FRM1	FRM2	FRM3	FRM4	FRM5	NASP
Government/ project showed us how	GVSW	[__ __]	[___]	[__ __]	[__ __]	[__ __]	[__ __]
Policy changes	PLCY	[__ __]	[___]	[__ __]	[__ __]	[__ __]	[__ __]
Other, specify (SPECCHAN)______	OTPD	[__ __]	[___]	[__ __]	[__ __]	[__ __]	[__ __]

Section V: - Food Security

I would now like to ask you to describe a **typical food year** for your household. For each month say whether the food you consume is mainly from your own farm or from other sources. In addition, which months if any you tend to find you do not have enough food to eat for your family?

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1. Source of food	[ ]	[_]	[_]	[_]	[_]	[_]	[_]	[_]	[_]	[_]	[_]	[ ]
FDSC	*Codes for Q1: 1=Mainly from own farm, 2=Mainly from off farm (purchase/aid/other)*											
2. Shortage / struggle to feed the family	[ ]	[_]	[_]	[_]	[_]	[_]	[_]	[_]	[_]	[_]	[_]	[ ]
HUNG	*Codes for Q2: 1=Shortage, 0=No shortage*											

Section VI: - Land and Water

Water for agriculture

1. Do you have the following on your farm? *(01=Yes, 00=No)*

Irrigation	WADRIP	[__ __]
Tanks/infrastructure for water harvesting	WATANKS	[__ __]
Dams or water ponds	WADAMS	[__ __]
Boreholes	WABORE	[__ __]
Solar water pumps	WASOWP	[__ __]
Wind water pumps	WAWIWP	[__ __]
Water pumps (other type)	WAWPOT	[__ __]
Inlet/water gate	WAINWG	[__ __]

Land use

For the next questions, I would like you to separate land owned by you or someone in your household, land rented by you or someone in your household and communal land to which you have access.

2. What is the locally relevant land unit?	LANDUNIT	✍__________________
3. Supervisor to include here the equivalent of that unit area in hectares	HAEQUIV	[__ __ __.__ __]

4. For the past 12 months…:

		Owned	Rented In	Did you use communal land?
		OWND	RENT	COMM *(01=Yes, 00=No)*
How much land did your household have access to?	LAND	[___ __ . ___]	[____ __]	[__ __]
How much is dedicated to food crops?	FOOD	[__ __ __ __]	[____ __]	[__ __]
How much is dedicated to grazing?	GRZE	[__ __ __ .__]	[__ _ __]	[__ __]
How much is under tree cover?	TREE	[__ __ __ .__]	[__ ___ __]	[__ __]
How much is under aquaculture?	AQUA	[__ __ ____]	[__ __ __]	[__ __]
What area of your land is degraded or unproductive?	DGRD	[__ __ __ __]	[_ ____ __]	[__ __]

5. How many trees have you planted on your farm over the last 12 months? *(00=none, 01=less than 10, 02=11 to 50, 03=51 to 100, 04=more than 100)*	TREEPLNT	[__ __]
6. How many trees have you deliberately protected on your farm over the last 12 months? *(00=none, 01=less than 10, 02=11 to 50, 03=51 to 100, 04=more than 100)*	TREEPROT	[__ __]
7. In the last 12 months did you produce any tree seedlings? *(01=Yes, 00=No)*	PRODTREE	[__ __]
8. In the last 12 months did you purchase any tree seedlings? *(01=Yes, 00=No)*	BUYTREE	[__ __]
9. Do you sometimes hire in an animal-drawn plough? *(01=Yes, 00=No)*	HIREANPL	[__ __]
10. Do you sometimes hire in a tractor or other farm machinery? *(01=Yes, 00=No)*	HIRETRAC	[__ __]
11. Do you sometimes hire in farm labour? *(01=Yes, 00=No)*	HIREFMLB	[__ __]

Section VII: - Input and Credit

1. In the last 12 months did you use any purchased, certified/improved seed? *(01=Yes, 00=No)* CERTSEED [__ __]

2. In the last 12 months did you use any purchased, inorganic/mineral fertiliser? BUYFERT [__ __]
(01=Yes, 00=No) *[If no, skip to question 3]*

2.1 If yes, please list the type of fertiliser used and crops you applied fertiliser to.

(01=Urea, 02=NPK, 03=DAP, 04=CAN, 05=Rock Phosphate, 06=Local mixture, 07=Several types)

Type of fertiliser applied	Crop Codes			
(FERTTYPE)	(FERTCRP1)	(FERTCRP2)	(FERTCRP3)	(FERTCRP4)
[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
[__ __]	[__ __]	[__ __]	[__ __]	[__ __]
[__ __]	[__ __]	[__ __]	[__ __]	[__ __]

3. In the last 12 months did you purchase any pesticides/herbicides? BUYPEST [__ __]
(01=Yes, 00=No)

4. In the last 12 months did you purchase any veterinary medicines? BUYVTMD [__ __]
(01=Yes, 00=No)

5. In the last 12 months did you get any credit for agricultural activities? *(01=Yes, 00=No)* CRDAGACT [__ __]

6a. In the last 12 months did you purchase any crop or livestock insurance? *(01=Yes, 00=No)* BUYINS [__ __]

6b. If yes, was it weather-based insurance? (01=Yes, 00=No) WBIN [__ __]

Section VIII: - Climate and Weather Information

1. We know that weather is important to farming and would now like to ask you whether you have received any weather information during the last 12 months and what form this takes.

		1. Did you receive any information?	2.From whom or how did you receive the information?	3. Who received the information in the household?	4. Did it include advice on how to use the information in your farming?	5. Were you able to use the advice?	6. What aspects of farming did you change as a result of this information?
Type of information		*(01=Yes, 00=No)* **If No, go to next row.**	*(List up to three* **See code sheet**	*01=Men, 02=Women, 03=Both*	*(01=Yes, 00=No* **If No, go to next row.**	*(01=Yes, 00=No)* **If No, go to next row**	*(you can choose up to 3)*
		RECE	MSN1, MSN2, MSN3	WHO	INAD	USAD	ASP1, ASP2, ASP3
Forecast of drought, flood, frost, cyclone, tidal surge or other extreme event	RKEX	[__ __]	[__ __] [__ __] [__ __]	[__ __]	[__ __]	[__ __]	[__ __] [__ __] [__ __]
Forecast of pest or disease outbreak	RKPD	[__ __]	[__ __] [__ __] [__ __]	[__ __]	[__ __]	[__ __]	[__ __] [__ __] [__ __]
Forecast of the start of the rains	FCRN	[__ __]	[__ __] [__ __] [__ __]	[__ __]	[__ __]	[__ __]	[__ __] [__ __] [__ __]
Forecast of the weather for the following 2-3 months	FCMN	[__ __]	[__ __] [__ __] [__ __]	[__ __]	[__ __]	[__ __]	[__ __] [__ __] [__ __]
Forecast of the weather for today, 24 hours and/or next 2-3 days	FCDY	[__ __]	[__ __] [__ __] [__ __]	[__ __]	[__ __]	[__ __]	[__ __] [__ __] [__ __]

Section IX: - Community Groups

1. Do you, or any other household member, belong to a group or groups doing the following activities? *(answer 01=Yes or 00=No for each activity)*

a.	Tree nursery/tree planting	GRPTREE	[__ __]
b.	Fish/shrimp ponds	GRPFISH	[__ __]
c.	Fishing	GRPFING	[__ __]
d.	Forest product collection	GRPFORET	[__ __]
e.	Water catchment management	GRPWATER	[__ __]
f.	Soil improvement activities	GRPSOIL	[__ __]
g.	Crop introduction/substitution	GRPCROP	[__ __]
h.	Irrigation	GRPIRRIG	[__ __]
i.	Savings and/or credit	GRPCRED	[__ __]
j.	Marketing agricultural products (i.e. livestock,	GRPMARK	[__ __]
k.	Productivity enhancement (i.e. livestock, crops,	GRPPROD	[__ __]
l.	Seed production	GRPSDPRD	[__ __]
m.	Vegetable production	GRPVGPRD	[__ __]
n.	Others **<u>not mentioned above</u>** related to soil, land or water management	GRPOTHE	[__ __]

(please specify) SPECGRP ✍ ________________________

Let's talk about climate related crises specifically.

2. Have you faced a climate related crisis (eg. Flood, drought, frost, tidal surge) in the last 5 years? FLD5YRS [__ __]
(01=Yes, 00=No) ***[If No, skip to next section]***

3. When this occurred, did you receive some assistance? FLDHELP [__ __]
(01=Yes, 00=No) ***[If No, skip to next section]***

4. If Yes, from which of the following did you receive assistance?
(Answer 01=Yes or 00=No for each of the following)

a.	Friends, relatives, neighbours	HELPFRDS	[__ __]
b.	Government agencies	HELPGOV	[__ __]
c.	Politicians, e.g. MPs	HELPMPS	[__ __]
d.	NGOs/CBOs	HELPNGO	[__ __]
e.	Religious organisations	HELPCHCH	[__ __]
f.	A local community group that you are a member of	HELPGRP	[__ __]

(If Yes, please answer question 5)

g. Other		HELPOTHE	[__ __]
please, specify	SPECHELP	✍ ______________________	

5. If you received help from a group, which of the following group activities helped with your problem?

(Answer 01=Yes or 00=No for each of the following activities)

a.	Tree nursery	HLPTREE	[__ __]
b.	Fish ponds	HLPFISH	[__ __]
c.	Fishing	HLPFING	[__ __]
d.	Forest product collection	HLPFORET	[__ __]
e.	Water catchment management	HLPWATER	[__ __]
f.	Soil improvement activities	HLPSOIL	[__ __]
g.	Crop introduction/substitution	HLPCROP	[__ __]
h.	Irrigation	HLPIRRIG	[__ __]
i.	Savings and/or credit	HLPCRED	[__ __]
j.	Marketing agricultural products (i.e. livestock, crops, trees or fish)	HLPMARK	[__ __]
k.	Productivity enhancement (i.e. livestock, crops, trees or fish)	HLPPROD	[__ __]
l.	Seed production	HLPSDPRD	[__ __]
m.	Vegetable production	HLPVGPRD	[__ __]
n.	Others related to soil, land or water management	HLPOTHE	[__ __]
	please specify SPECGPHP	✍ ______________	

Section X: - Assets

1. Which of the following items does your household own at the present time? *(01=Yes, 00=No)*

a.	Radio	ASRADIO	[__ __]
b.	Television	ASTV	[__ __]
c.	Cell phone	ASCELLPH	[__ __]
d.	Bicycle	ASBIKE	[__ __]
e.	Motorcycle	ASMTBIKE	[__ __]
f.	Car or truck	ASCAR	[__ __]
g.	Computer	ASCOMP	[__ __]
h.	Solar panel	ASSOLAR	[__ __]
i.	Tractor	ASTRACT	[__ __]

1. Which of the following items does your household own at the present time? *(01=Yes, 00=No)*

j.	Mechanical plough	ASMECHPL	[__ __]
k.	Mill (e.g. for grinding cereals or oilseeds)	ASMILL	[__ __]
l.	Improved stove	ASSTOVE	[__ __]
m.	Generator (electric or diesel)	ASMOTOR	[__ __]
n.	Battery (large, e.g. car battery for power)	ASBATT	[__ __]
o.	Water pump/Treadle pump	ASTRPUMP	[__ __]
p.	Biogas digester	ASBGDIGS	[__ __]
q.	Refrigerator	ASFRIDGE	[__ __]
r.	Air conditioning	ASAIRCON	[__ __]
s.	Electrical fan	ASELCFAN	[__ __]
t.	Thresher	ASTHRESH	[__ __]
u.	LPG	ASLPG	[__ __]
v.	Internet access	ASINTNET	[__ __]
w.	boat	ASBOAT	[__ __]
x.	fishing nets	ASFSHNET	[__ __]
y.	bank account	ASBNKACC	[__ __]
z.		ASSETZ	[__ __]
aa.		ASSETAA	[__ __]

2. Which of the following structures/utilities does your household have? *(01=Yes, 00=No)*

a.	Improved storage facility for crops (food or feed)	STSTCRPS	[__ __]
b.	Water storage tank (for domestic water, > 500 litres)	STWTANK	[__ __]
c.	Well/borehole (for household water)	STWELL	[__ __]
d.	Running/tap water in the dwelling	STTAP	[__ __]
e.	Electricity from a grid	STELEC	[__ __]
f.	Improved housing (e.g. concrete, bricks, etc.)	STIMPHS	[__ __]
g.	Improved roofing (e.g. tin, tiles, etc.)	STIMPRF	[__ __]
h.	Separate housing for farm animals	STHSANIM	[__ __]
i.		STRUCTI	[__ __]
j.		STRUCTJ	[__ __]

Is there anything you would like to add to what you have shared with us today in relation to the topic we discussed?

Thank you for taking the time to answer our questions. You have given us very important information that will allow us to better understand farming challenges and food production issues in your area that can be shared with different people that are interested in what investments and changes can help improve livelihoods.

Were answers discussed with other family member? *(to be answered by enumerator at end of survey) (1=Yes, 0=No)*	ANSDISC	[__ __]

For enumerator:

Please note what, if anything, went differently from the plan in this particular interview (concerns, observations). Please note any points that you want to highlight as important for this interview – include also specific household characteristics that seem worth mentioning.

Write up of the story for CROPS

Write up of the story for Livestock