GENDER PERSPECTIVES IN ECONOMIC ASSESSMENT OF EAST COAST FEVER VACCINATION ON HOUSEHOLD WELFARE AMONG SMALLHOLDER DAIRY CATTLE FARMERS IN UASIN GISHU COUNTY, KENYA

HUMPHREY JUMBA

A Thesis submitted to the Graduate School in partial fulfillment for the requirement of the award of a Master of Science Degree in Agricultural Economics of Egerton University

EGERTON UNIVERSITY

JUNE, 2019

COPYRIGHT

DEDICATION

I dedicate this thesis to my loving and caring mother, Mary Kivailu; whose advice and support has given me great inspiration in life, and to my sister Beatrice Vehinda Kivailu for underlying love and moral support.

ACKNOWLEDGEMENT

First and foremost, I take this chance to praise and thank the Almighty God for the love, care, and good health He has bestowed upon me throughout the research work. I extend my appreciation to Egerton University for giving me a chance to undertake a Master of Science degree in Agricultural Economics. I express my most sincere gratitude and appreciation to my research supervisors Prof. George Owuor and Dr. Henry Kiara for their unwavering support and guidance during the entire research work. I am grateful to the International Livestock Research Institute (ILRI), through Policies, Institutions, and Livelihoods program for the financial support during entire fieldwork. I thank ILRI scientists, in particular, Dr. Nils Teufel and Dr. Isabelle Baltenweck for their useful advice.

I am equally indebted to the course lecturers for their valuable insights, advice and constructive criticisms during the proposal stage and write up of this thesis. I am immensely grateful to my relatives for their moral and financial support during this period of study. I acknowledge my colleagues for their useful ideas during the whole period of my research. I thank the management of Ziwa and Tarakwa dairies and cattle keepers for their enthusiasm and collaboration during the entire period of fieldwork. Finally, I am grateful to the enumerators who assisted in data collection and cleaning.

ABSTRACT

East Coast fever (ECF) is a current threat to smallholder cattle keepers in the eastern, central, and southern Africa regions; as it causes substantial economic losses. Infection and Treatment Method (ITM) is considered to be the best method for ECF control. ITM has potential benefits of improving the livelihood of cattle keepers; through improving cattle productivity and reducing cost of production. However, since its commercialization in 2010, not all the cattle keepers in the targeted population have adopted it, and its effect on household welfare remains unclear. The study aimed at determining the perception, adoption, and impact of ITM on household welfare among smallholder male-headed (MHHs) and female-headed (FHHs) cattle keepers. The study used a multistage sampling technique to identify 448 (298 MHHs and 150 FHHs) households in Uasin Gishu County, Kenya. Descriptive statistics were used to analyze farmers' perception on ITM effectiveness. Average Treatment Effect (ATE) framework was used to estimate actual and potential adoption rates and determinants of adoption. Finally, Propensity Score Matching (PSM) was used to evaluate the effect of ITM adoption on household cattle income. Data were managed using STATA computer program. Results reveal a positive perception in both MHHs and FHHs, regarding reduction in mortality rate, reduction in the cost of acaricide use, increase in milk yield and boosting of animals immune system, and cattle growth among other benefits. However, the package and availability of the vaccinators were raised to be key adoption concerns. Inadequate ITM awareness among the targeted population caused significant ($p \leq 0.1$) adoption gaps of 20% and 12% among MHHs and FHHs, respectively. The ATE-probit results indicated that education level, herd-size, group membership, access to extension services, and credit access had a positive and significant effect on ITM uptake in both MHHs and FHHs. Land size and household size had significant and positive influence in FHHs only. The results further point out that uptake of ITM results in household welfare improvement; as the household annual income shifts by approximate (28% and 30%) for MHHs, and (29% to 32%) for FHHs. Therefore for livestock stakeholder to enhance livelihoods of smallholder cattle keepers through the adoption of ITM, they should make use of gender-responsive innovation platforms like social-groups where farmers can easily access extension service, credit and even gain knowledge from each other regarding ITM. Besides, the relevant stakeholders should re-package the ITM vaccine into smaller batches that are appropriate for smallholder farmers and train more vaccinators to enable smallholder cattle keepers to easily access them.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS AND ACRONYMS

ATE	Average Treatment Effect
ATT	Average Treatment Effect on the Treated
ATU	Average Treatment Effect on the Untreated
BMGF	Bill and Melinda Gates Foundation
CIA	Conditional Independence Assumption
CTTBD	Centre for Ticks and Tick-borne Diseases
DVS	Direct Veterinary Services
EAVRO	East African Veterinary Research Organization
ECF	East Coast fever
FAO	Food and Agriculture Organization
FGDs	Focus Group Discussions
FHHs	Female-Headed Households
GALVmed	Global Alliance for Livestock Veterinary Medicines
GDP	Agricultural Gross Domestic Product
ICT	Information and Communications Technology
IFAD	International Fund for Agricultural Development
ILRI	International Livestock Research Institute
ITM	Infection and Treatment Method
IV	Instrumental Variable
JEA	Joint Exposure and Awareness
KBM	Kernel Based Matching
KDFF	Kenya Dairy Farmers Federation
KNBS	Kenya National Bureau of Statistics
LS	Least Squares
MHHs	Male-Headed Households
MLE	Maximum Likelihood Estimation
NGO	Non-governmental Organization
NNM	Nearest Neighbor Matching
PSB	Population Selection Bias

PSM	Propensity Score Matching
RM	Radius Matching
SDG	Sustainable Development Goal
TBD	Tick-Borne Disease
UNDP	United Nations Development Programme
VIF	Variance Inflation Factor

CHAPTER ONE

INTRODUCTION

This chapter provides background information on East Coast fever (ECF), Infection and Treatment Method (ITM) and critical gender gaps the study intends to fill. Besides, this chapter presents the statement of problems and specific research questions that were tackled in the study. The importance of the research to policymakers and its contribution to the current body of knowledge are discussed in the justification section. Finally, the chapter presents the scope of the study and operational definitions of the key terms used in the study.

1.1 Background Information

East Coast fever (ECF) is a virulent cattle disease caused by a single cell parasite *Theileria parva,* and it is transmitted by the brown ear tick *(Rhipicephalus appendiculatus)* as the primary vector - as it feeds on susceptible cattle (Di Giulio *et al.*, 2009). The ECF diseases is by far economically the most dangerous Tick-Borne Disease (TBD) in smallholder agro-pastoral and pastoral livestock production systems, as it is regarded as one of the most severe constraints to increasing cattle productivity in these systems (Minjauw *et al.*, 2003). In eastern, central and southern Africa regions; ECF disease is reported to affect eleven countries in total, Kenya being among them (Mbassa *et al.*, 2009).

According to Di Giulio *et al.* (2003), ECF is a major cause of cattle deaths among East-African indigenous cattle, with reported mortality rates ranging from 40-80% in untreated immature cattle in Maasai pastoralists' herds. The disease is not only responsible for cattle deaths but also results in stunting of calves, reduction in animal traction power and a decrease in milk production in animals that survive (ILRI, 2014). Milk production is of particular concern because it has been reported to be the primary staple food and a primary source of nutrition for smallholder livestock keepers (Randolph *et al.*, 2012). In this regard, Marsh *et al.* (2016) observed that the occurrence of ECF has led to a negative impact on the well-being of smallholder households that keep cattle as their primary source of income. Indeed, reported economic losses due to ECF are significant; recent estimates put the figure at $300 million annually (ILRI, 2014). Besides, previous studies on ECF reported that nearly 60% (75 million) of the region's cattle are at risk of contracting ECF disease (GALVmed, 2015).

Selection of resistant herds for breeding, treating of sick animals, and use of acaricide for ECF vector control are the primary conventional ways of ECF control. Acaricide use has become less attractive for a variety of reasons; including the high cost of acaricide treatments and inadequate access to functional dipping facilities. Environmental and sustainability issues of acaricide use also arise, including toxic residue, contamination of the environment and ECF-vector resistance (Mugisha *et al.,* 2005; Di Giulio *et al.,* 2009). In addition to vector control methods, the infected cattle are treated using curative drugs. However, these drugs are costly to acquire and to administer to infected cattle (Homewood *at al*., 2006). Furthermore, chemotherapy technique has been reported to be ineffective since it leads to negative consequences, as the animals that recover from ECF may suffer from; weight loss, produce less milk, provide less draft power and could suffer from reduced fertility and delays in reaching maturity. Similarly, in endemic areas, cattle that recover from ECF tend to become carriers of this disease (Taracha and Taylor, 2005). The traditional methods like use of herbs, bush burning (vector breeding sites), hand-picking, and birds picking are no-longer in use since they are deemed not to be effective in controlling this disease.

Owing to the limitations of the above methods, immunization of cattle by Infection and Treatment Method (ITM) has been recommended by scientist to offer a valuable alternative for ECF control (Oura *et al.,* 2004; Homewood *et al.,* 2006; Kivaria, 2007; Walker, 2007). ITM involves infection of healthy cattle with live parasites and simultaneous treatment with a single dose of a long-acting formulation of *oxytetracycline* to curtail the infection. The result is a mild reaction leading to lifelong immunity to similar or related parasites.

GalvMed (2010) found that use of ITM reduced mortality rate in calves from 80% to less than 2%; thus enabling pastoral-communities to stabilize/build-up larger herds, and led to increased livestock and milk sales. Besides, pastoralists were able to reduce the amount of acaricide they use to control ticks and other tick-borne diseases, providing additional economic and environmental benefits. Following report by GalvMed (2009) mature cattle that have been vaccinated, with the distinctive ECF vaccination ear-tags, make up to 50% higher market prices as compared to those that are unvaccinated.

However, despite vaccination of cattle against ECF being reported to lead to stable yields under different environmental conditions and its introduction considered as a step towards stabilization and sustainable intensification of livestock sector in agro-pastoral and transhumance livestock keepers, its uptake is still low. In Kenya uptake of ITM has been undermined on account of several unknown reasons which constraints male and female livestock producers differently. According to existing literature, women who are reported to be dominants in smallholder agricultural production in developing nations are seen to lag behind in uptake of new technologies and improved management systems or benefit equally from their introduction as compared to men (Doss and Morris, 2001). The low adoption and benefits from agricultural innovations by women is reported to be due to unequal access to productive resources as well as opportunities within the household, where most are noted to be dominated by men (World Bank, 2007 and FAO, 2011).

The gender inequality in various agricultural sectors and many developing countries imposes real costs on society regarding untapped potential in achieving food security and economic growth. Besides, intensification and increased market orientation of agricultural production have been shown to lead to the higher dominance of the production process by men, hence benefiting men more at women's expense (Dahal *et al.*, 2009). While technologies are intended to be productivity enhancing, value-adding, and labor or cost-saving, not all innovations are beneficial and responsive to the needs of poor women and men or their expected users. According to literature, some agricultural interventions harm the targeted beneficiaries; as some benefits men more at the expense of women (Rao, 2002; Venter and Mashiri, 2007; World Bank *et al.*, 2009).

In Kenya, ITM was commercialized in 2010, and Uasin Gishu County was among the first targeted regions. Since then adoption of ITM remains partial among the areas targeted. To further enhance the uptake process of ITM and improve cattle productivity, ILRI and GALVmed have adopted several development initiatives, some of which include collaboration with national government through Kenya Dairy Farmers Federation (KDFF) and private organization through SIDAI Africa to create awareness and deliver this technology to cattle keepers. Some of the initiatives used include; subsidized campaigns, field trials, extension visits, agricultural shows and use of mass media.

1.2 Statement of Problem

Adoption of ITM has the potential to improve livelihoods of smallholder dairy cattle keepers through control of ECF. Uptake of ITM is anticipated to improve dairy cattle producers' welfare through a reduction in mortality rate due to ECF, increase milk output, improve cattle market value, and decrease the cost of acaricide use among other benefits. In Kenya, ITM was commercialized in the year 2010 with Uasin Gishu County being the target region. However, despite its perceived multiple advantages; ITM uptake has been disappointing on account of several reasons among them gender-related constraints and inadequate awareness among smallholder dairy cattle keepers. Besides, the effects of ITM adoption on household wellbeing are not yet apparent. It is on the preceding that this study aimed at filling these knowledge gaps.

1.3 Objectives

1.3.1 General Objective

The general objective of the study was to contribute toward the improvement of the smallholder dairy cattle keepers' welfare through enhancing uptake of ITM in control of ECF in Uasin Gishu County, Kenya.

1.3.2 Specific Objectives

i) To determine gender disaggregated perception on ITM among smallholder dairy cattle keepers.

ii) To determine the actual and potential uptake rates of ITM among male-headed and female-headed dairy cattle keeping households

iii) To determine gender disaggregated effect of ITM uptake on household income among smallholder dairy cattle keepers.

1.4 Research Questions

i) How do men and women dairy cattle keepers perceive ITM in control of ECF?

ii) What are the actual and potential uptake rates of ITM among smallholder male-headed and female-headed dairy farming households?

iii) What is the effect of ITM adoption on male-headed and female-headed household's income among smallholder dairy cattle keepers?

1.5 Justification of the Study

Livestock is primary sources of food (milk and meat), cash income, manure and serve as a store of wealth and hedge against inflation among smallholder farmers (Gezie and Kidoido, 2014). Furthermore, livestock keeping is considered to be a major source of employment for a significant portion of the rural population (Berhanu *et al.*, 2009). Therefore, helping smallholder farmers to keep their cattle healthy and free from contagious diseases like ECF is considered as a positive measure of improving their livelihoods. This aim is in line with sustainable development goal (SDG) number one (end hunger, achieve food security and adequate nutrition for all, and promote sustainable agriculture). Thus, this kind of studies can assist policymakers and researchers to put in place proper interventions which can enhance uptake of agricultural innovations.

The inclusion of gender lens in the study helps to understand gender dynamism and constraints concerning uptake of agricultural technologies. The gender aspects boost development of gender mainstreaming strategies approaches and policies which promote gender equity in both dissemination of knowledge and sharing of benefits accruing from the uptake of given agricultural interventions. This outcome will not only lead to the empowerment of rural women and men, but it is also vital for economic development as a whole. Uptake of agricultural technologies comes with social gains which contribute positively to the enhancement of SDG number five (attains gender equity, empower women and girls everywhere). Finally, findings from this study will add positively to pioneer literature by filling some of the knowledge gaps, and it will create more gaps for further research.

1.6 Scope and Limitation of the Study

This study focused on smallholder dairy cattle keepers located within Uasin Gishu County. The data collected were limited to a period of twelve months; January 2015 to December 2015. Due to language barrier, enumerators from the study area were relied upon in data collection. The ability to recall determined the accuracy and validity of the data collected, as the majority of the smallholder farmers did not keep farm records. To improve on reliability and validity of the data primarily for the income and cost of production, recent short term financial transactions, quarterly information, were used to project the annual income from cattle or costs of production. The enumerators were encouraged to probe to determine if there were any variation in the daily activities during the production period and its effect on the projection for the annual income or costs.

1.7 Operational Definition of Terms

Actual adoption: The estimated rate of smallholder dairy cattle keepers who had vaccinated their cattle against ECF by the time the survey was conducted.

Household cattle income: This includes sales of: milk (milk sold plus milk consumed by the household), livestock, manure, hired animal power, and bull services-if any- in Kenyan shillings in the January 2015 to December 2015 production period.

The ITM exposed/aware population: Smallholder dairy cattle keepers who had knowledge about vaccination against ECF by the time the survey of conducted.

Female-headed household: A household headed by a woman who is either a widow, separated, divorced or unmarried (*de jure household female-headed households*).

Full ITM adopters: Smallholder dairy cattle keepers who had vaccinated their whole cattle herds against ECF by the time the survey was conducted.

Household size: A group of people living together, cooking and eating from the same pot for a period of not less than six months by the time the survey was conducted.

Adopters of ITM: Smallholder dairy cattle keepers who had vaccinated their cattle herds against ECF (either partially or fully) by the time the survey was conducted.

Male-headed household: A household headed by a man as the key decision maker.

Partial ITM adopters: Smallholder dairy cattle keepers who had vaccinated only part of their cattle herds against ECF by the time the survey was conducted.

Potential adoption: The estimated rate of smallholder dairy cattle keepers who had the ability to vaccinate their cattle against ECF by the time of the survey, but they were constrained due to lack of awareness.

Smallholder dairy cattle keepers: Dairy farmers keeping less than five heads of cattle per acre of land.

CHAPTER TWO

LITERATURE REVIEW

This chapter starts by presenting an overview of smallholder dairy farming in Kenya; followed by a literature review on the description of East Coast fever disease. Besides, a brief discussion on the development and dissemination of the Infection and Treatment Method (ITM) is presented. This section further provides literature on gender gaps in adoption of agricultural technologies where key drivers affecting the uptake of agricultural innovations are discussed with gender lens into perspective. Due to inadequate literature that mainly focuses on gender and livestock-related technologies, a general literature review on crop and livestock related innovations was conducted. Finally, the theoretical and conceptual framework supporting the study is discussed.

2.1 Smallholder Dairy Sector in Kenya

Cattle are highly valued assets in sub-Saharan Africa, as a majority of the rural population depends directly or indirectly on livestock as their source of livelihoods. Economically, livestock keeping employ approximately 80 % of the rural population in the eastern, central, and southern regions of Africa (FAO, 2009). According to IFAD (2006), an estimated one million smallholder farmers in these regions depend on dairy cattle as a source of income. In Kenya, the smallholder dairy sector contributing immensely to the livelihoods of the rural poor, and the national economic developing, as 56 % of the total milk produced in Kenya comes from smallholder dairy sector. According to Staal *et al.* (2003), smallholder dairy farming is the largest contributor to the livestock income, which accounts for almost 33 % of the agricultural gross domestic product (GDP) in Kenya.

In Kenya, dairy sector is dominated by smallholder cattle keepers, with current estimates of 4.3 million heads of cattle (Odero, 2017); representing approximately 85 % of the dairy cattle in eastern Africa region (ILRI, 2000). The sector is considered as the largest and rapidly expanding dairy sector in sub-Saharan Africa (IFAD 2006). In most parts of Kenya, smallholder dairy production is conducted on small farms with herd size ranging from one to five heads of cattle (Bebe *et al.*, 2003). The production is based on the close integration of both livestock and crops. The major types of animals kept are pure breed, cross-breeds and

indigenous (zebu) cows, which provide milk for communities in the drier parts of the country (ILRI, 2000).
The main exotic cattle breeds kept by smallholder dairy farmers in Kenya include; Ayrshire, Friesian, Guernsey, Jersey, and their crosses (ILRI, 2000). In Kenya, cross-bred cattle constitute the largest proportion of the total population of dairy cattle kept by smallholder farmers, with Ayrshire and Friesian being the dominate breeds (ILRI, 2000). Zebu cattle, which constitute about 70 % of the total population of livestock in Kenya, are widely distributed in all agro-ecological zones of the country due to their high adaptation to diverse climatic zones.

A majority of smallholder dairy farmers in Kenya uses intensive, semi-intensive, and extensive farming systems to manage their cattle (Auma *et al.,* 2017). The indigenous zebu cattle are kept under traditional extensive farming systems in vast areas of Kenya (Auma *et al.,* 2017). The method used in cattle management depends on a variety of factors, which include climatic conditions- agro-ecological zones and human population density (Staal *et al.*, 2003). The intensive dairy production system is mainly practiced in the Kenyan highlands; primarily due to high human population densities, which results in fragmentation of land into smaller pieces. This system involves zero-grazing farming practices where animals are fed on crop residues and planted fodder supplemented with concentrate feeds (Njarui *et al.,* 2016). Intensive cattle farming system is mainly practiced in the Central, Central Rift-valley, and parts of the Coastal regions.

A semi-intensive cattle production system is characterized by cattle grazing freely on pastures and stalls feeding where animals are confined; in most cases, the animals are given supplement feeds during milking. According to Njarui *et al.* (2016), the main dairy animals kept under this system are cross-breed. However, milk production in this system is lower as compared to purely zero-grazing systems (Auma *et al.,* 2017). This system is mainly practiced in the Rift valley, Central and Coastal parts of Kenya.

The extensive dairy cattle keeping systems is practiced among indigenous zebu cattle, primarily in the Western, Coastal, Eastern, and parts of Rift Valley regions of Kenya. Cattle feeds used in these regions include grass, fodder (mainly Napier grass), crop residues, weeds, and compounded forages. In areas where farms are small, farmers confine their cattle and feed them through a cut-and-carry system (Njarui *et al.,* 2016).

In Kenya, although smallholder dairy farming is considered a feasible economic enterprise, the enterprise is constrained by poor market access, poor access to breeding services, low quantity and quality of feeds, weak institutions and rural infrastructure development, poor technical skills on animal husbandry practices, and animal diseases (IFAD 2006; FAO, 2009; Auma *et al.,* 2017). Scarcity of farming land has forced smallholder dairy farmers to move towards less productive regions where cattle grazing dominate, and there are high risks of cattle diseases; especially tick-borne diseases with ECF being of great economic importance (Gachohi *et al.,* 2012; Perry, 2016).

2.2 Origin and Symptoms of East Coast fever

East Coast fever (ECF) was introduced into Southern Africa from Eastern Africa at the beginning of the twentieth century (Sibeko *et al.,* 2010). The disease was reported first in Zimbabwe - then Southern Rhodesia- in 1902 (Lawrence et al., 1992). The introduction of ECF in Zimbabwe was through a consignment of cattle brought in from the Coastal region of Eastern Africa, and that is why it was named East Coast fever (Norval *et al.,* 1992). The reasons for importation were twofold; first was to replace cattle herds that had been decimated by the *rinderpest* pandemic, and second to boost natural recovery of cattle population which had been destroyed during Anglo-Boer war of 1899-1902, as most of them were killed due to the high demand for beef and transport oxen (Norval *et al.,* 1992).

ECF is endemic in eleven countries in eastern, central, and southern parts of Africa, these countries include: Kenya, South Sudan, Tanzania, Uganda, Rwanda, Democratic Republic of Congo (DRC), Mozambique, Burundi, Malawi, Zimbabwe and Zambia (Lawrence *et al.,* 1992; Malak *et al.,* 2012). According to the current reports, there is a continuous spread of ECF disease to new regions; between 2003 and 2004 the disease was reported in Comoros Island, making it the 12th ECF endemic country with source pointing to the importation of cattle from Tanzania (De Deken *et al.,* 2007).

According to Theiler (1912), ECF is caused by a parasite known as *Theileria parva* that is spread by a vector known as *Rhipicephalus appendiculatus* (commonly known as brown ear tick). ECF is characterized by the *lymphoid hyperplasia*, which is usually accompanied by *leucopenia* and exhaustion of the *lymphoid* tissue (Irvin and Mwamachi, 1983). Fever, dullness, enlarged *lymph* nodes near the tick bites are common clinical signs in ECF infected cattle (Mbassa *et al.,* 2006). Irvin and Mwamachi (1983) noted that in advance stage ECF clinical signs include *lacrimation* which is accompanied by *photophobia,* development of *anorexia,* cessation of rumination, corneal opacity, frothy nasal, and eye discharges and *terminal dyspnea*. Besides, diarrhea, *leukopenia, pulmonary edema,* and *anemia* are common signs in ECF infected cattle (Norval *et al.*, 1992). In cases of pregnant cows, abortion is common, especially in the *'pyrexic'* stage of the disease.

The ECF clinical symptoms are reported to be more severe in exotic breeds compared to native cattle (Norval *et al.* 1992), as local breeds are mostly resistant to the parasite causing ECF, however with mild symptoms. The mortality rate in fully susceptible herds can be as high as 100 percent (Mbassa *et al.* 2006), with death occurring within 18-30 days after infestation and infection of susceptible cattle by *Theileria parva* (Lizundia *et al.,* 2005). This time-lapse is mainly due to the initial incubation period of the parasite, which is reported to be within 10-25 days before the *Theileria parva* parasite spreads to the animal's body organs (Eygelaar *et al.,* 2015).

2.3 Control Methods of East Coast fever

Cattle keepers use different methods to control ECF. Control of ECF vector (brown ear tick) through use of acaricide is the most widely used methods by smallholder cattle keepers in ECF endemic regions (Kivaria, 2007; Walker, 2007). This method entails the use of dipping baths/tanks, spray-races, pour-on/spot-on, hand-spray or hand-dressing to apply pesticides (acaricide) on cattle skin with the main aim of killing ECF vectors (Gachohi *et al.,* 2012). However, this method has turned out to be unsustainable mainly due to development of resistance by vectors and the cost of buying acaricide (Homewood *et al.,* 2006). Previous estimates put the cost between US$6 to US$36 per adult animal in Kenya, Uganda and Tanzania (Minjauw and McLeod 2003); currently, the cost might be higher mainly due to inflation and other economic factors. In some instance, farmers have inadequate knowledge on how to mix the acaricide as stipulated in the instruction guide, hence rendering it ineffective or poisonous (George *et al.*, 2004).

Farmers employee control breeding where they inter-breed exotic cattle with native ones to have cross-bred with stronger immune systems to fight the parasite causing ECF (Minjauw and de Castro, 1999); as cattle local/native cattle breeds are more resistance to ticks and TBD compared to exotic cattle breeds. However, this method is not very effective since indigenous cattle are also susceptible to ECF, although the reaction is less severe compared to exotic animals (Samish, 2004).

In some instance, cattle keepers' hand-pick the tick vectors as a biological means of controlling the disease (Samish, 2004). This technique is mainly practiced in the pastoral livestock production systems. Alternating grazing field with crops is practiced in some parts as it helps in controlling ECF vectors through reduction vector population, as grasses are termed to be the breeding sites for ECF vectors (Minjauw and McLeod 2003). However, these techniques have been termed to be ineffective in control of ECF.

For cattle already infected with ECF, treatment method 'chemotherapy technique' is used to cure the animals. According to Gachohi *et al.* (2012), initially veterinary officers used *tetracycline* antibiotic to treat ECF; however, its effect was only effective when administered during early stages of the ECF infection. Currently, more effective ECF therapeutic drugs '*parvaquone* and *buparvaquone*' are now being used to treat ECF infected cattle. However, these drugs are unsustainable due to high cost for smallholder farmers to manage (Lawrence *et al.*, 1992). Besides, some of the animals that recover tend to become carriers of ECF parasite as sometimes the cattle improves to varying degrees, in extreme cases death is common due to blocked capillaries and parasites infecting the central nervous system.

2.4 Development and Dissemination of Infection and Treatment Method (ITM)

The 'Muguga cocktail' ITM vaccine has evolved over several decades, a process that started in South Africa (Perry, 2016). The first batch of ITM was developed and refined at the former East African Veterinary Research Organization (EAVRO) at Muguga, Kenya, between 1967 and 1977 (ILRI, 2014). Work on ITM was undertaken as part of a regional project funded by the United Nations Development Programme (UNDP) and executed by the Food and Agricultural Organization (FAO) of the United Nations. Since then, various versions of the ITM vaccine have been developed each differing in the strains of *Theilerial* parasites that are used in administering of this technology. The most widely used version in Kenya is known as the 'Muguga cocktail ITM vaccine*'* (Nene *et al.,* 2016).

In collaboration with the not-for-profit Global Alliance for Livestock Veterinary Medicines (GALVmed), ILRI has registered the vaccine in Kenya, Malawi, and Tanzania (Nene *et al.,* 2016). To date, the ILRI-produced vaccine has been used to immunize over one million cattle against ECF in Kenya, Malawi, and Tanzania (ILRI, 2014). In Kenya, Kenya's Director of Veterinary Services (DVS) with support from ILRI has tested and confirmed the safety and effectiveness of the 'Muguga cocktail ITM vaccine'; which was commercialized in 2010 (Nene *et al.,* 2016).

Production of the ECF vaccine is a complicated, time-consuming and costly process (ILRI, 2014, Patel, *et al.* 2018). Production one million doses of vaccine require approximate 130 heads of cattle that have not previously been exposed to the disease, 500 rabbits, and at least 600,000 ticks. Besides, it takes approximate 18 months to produce a batch of *'Muguga cocktail'* ITM vaccine. The ITM vaccine requires a cold chain and careful handling to deliver and have it administered by trained veterinarians, as ITM can be lethal if it is not administered with the required dose of antibiotic cover (Nene *et al.,* 2016).

The commercial production of the '*Muguga cocktail*' ITM vaccine has now been taken up by the Centre for Ticks and Tick-borne Diseases (CTTBD), in Malawi, facilitated by GALVmed and the Bill and Melinda Gates Foundation (BMGF) which supports its commercialization (GALVmed, 2014). To make the process successful, ILRI is supporting the establishment of the ECF vaccine production processes in Malawi through the transfer of ticks, parasite seed *stabilates,* and technical backstopping (ILRI, 2014). In East Africa region, ITM is being delivered through registered and approved private and public veterinary services providers (Perry, 2016).

2.5 Determinants of Gender Gaps in the Uptake of Agricultural Technologies

Studies have shown that despite the ability of agricultural technologies to improve the livelihood of the rural poor, their adoption remains low, with women lagging in most of the cases (Doss and Morris, 2001; Njuki *et al.,* 2014; Galie *et al.,* 2015). Uptake of agricultural technologies takes three phases approach; awareness stage, tryout stage, and continuous adoption (Nchinda *et al.,* 2010; Lambrecht *et al.,* 2014; Theis *et al.,* 2018). In line with this, an individual farmer needs to be aware of agricultural innovation before trying and fully embracing it (Diagne and Demont, 2007; Simtowe *et al.*, 2016). However, in most cases, each phase has been shown to have a different effect on men and women farmers; with women farmers being mostly disadvantaged in all three stages (Theis *et al.,* 2018).

An empirical review of previous adoption studies considers factors related to characteristics of producers, perception on the effectiveness of the agricultural innovations and institutional set-up as the key drivers affecting farmers' engagement in the three agricultural technologies adoption phases (Pretty *et al.,* 2011). Studies attribute low adoption of agricultural innovations to social, cultural, economic, and institutional factors which influence men and women differently (Bageant and Barret, 2015; Njuki and Sanginga, 2013). However, in most of the studies, it is not well illustrated on how the factors influence different genders of the household head, as a majority of the studies analyses the data with little or no focus on gender issues.

According to literature, awareness stage is considered as a major constraint to adoption of agricultural technologies in most of developing nations (Ani *et al.,* 2004; Conley *et al.,* 2001); with effects of inadequate awareness of uptake agricultural technologies being more severe among women farmers (Theis *et al.,* 2018). The level of knowledge regarding agricultural technology enhances the acceptance, adoption, and extent of adoption of agricultural technology. Targeted farmers who are aware of farming innovations are in a better position to gather more information concerning technologies' attributes an act that guides them in deciding on whether to uptake it or not (Simtowe *et al.*, 2016).

According to Ragasa *et al.* (2014), inadequate awareness of agricultural technologies among women is attributed to limited mobility which hinders them from accessing extension service or attending training programs regarding farming innovations that are being promoted to improve their livelihoods. In most African setup, men are shown to dominate training opportunities that are introduced in their locality to better their welfare with; women are sidelined mostly due to cultural barriers (Njuguna *et al.,* 2011). In some cases, women are shown to have great challenges in accessing digital information which can be used in training or alerting them on new agricultural technologies, as most of them, especially from FHHs lack access to digital assets like phones, radio and televisions (Ragasa *et al.,* 2014).

According to literature, the age of the household head might influence the adoption of agricultural technologies either negatively or positively. According to Doss (2011), elderly framers were seen to have more control over agricultural resources; hence, it was easy for them to pay for agricultural technologies as compared to young farmers. Besides, age of the farmers contributes positively or negatively to getting information about agricultural technology, as in some cases most of the elderly farmers have well-built networks from which they can access agricultural information (Deere and Doss, 2006). Older farmers are considered to have better access to productive resources as compared to young farmers, hence have a higher likelihood of paying for and adopting agricultural technologies (Tanellari *et al.,* 2010).

Low levels of literacy among men and women farmers contribute to the low adoption of agricultural technologies. Several adoption studies have shown that less educated household heads lag in adoption of agricultural-related innovations that are introduced to better their livelihoods (Wanyama *et al.,* 2013). Most of the studies attribute this to limited capability experienced by the less educated household decision maker face in interpreting the information given to them during training or once they obtain from visual and print media platforms (Shiferaw *et al.,* 2009). According to Deere and Doss (2006), this is mainly due to their inability to read and understand the training manual or listen to adverts in digital platforms like phones or radios. In some cases, less educated farmers experience great challenges in attending agricultural shows or training where they can gain information concerning new agricultural innovations.

Studies consider the level of experience of the household head to affect the adoption of agricultural technologies, as more experience farmers are shown to have a better understanding of the farming challenges and the importance of the innovations (Tanellari *et al.,* 2010). Lack of social group participation has been documented to be one of the key factors contributing to the low level of awareness and uptake of agricultural technologies among smallholder farmers. Active participation in social group activities has been documented to assist both men and women acquire knowledge from extension service providers and even sharing information among themselves (Doss, 2009). In some cases, the social group plays a crucial role in overcoming resource constraints, especially for women who are constrained in controlling household resources. Through groups, women mobilize agricultural resource among themselves and pay for agricultural innovations thus overcoming social inequities that surround them due to cultural and social norms (Doss *et al.,* 2003, Meinzen-Dick *et al.,* 2011, Ragasa *et al.,* 2014)

Poor infrastructure contributes negatively to the adoption of agricultural technologies among men and women, especially for those who are far from the extension offices, as it hinders extension workers from reaching farmers. This situation might be more hurting for women who are unable to walk for long distance to visit extension offices; as they are constrained by domestic chores and cultural barriers which curtail their movement (Njuguna *et al.* 2011); although the gender dynamics surrounding this aspect is not well articulated in the literature. Simtowe (2016) noted that distance to the nearest extension service provider influences the adoption of agricultural technologies as farmers who are near the extension service provider are likely to be reached and be trained on the available agricultural innovations.

Besides, lack of proper institution and proper policies in place put smallholder farmers in a disadvantaged position as they are unable to access credit and other government support, in most cases smallholder farmers are forced to have collateral to access credit. The situation is more difficult for women compared to men, as most of the household resources which can be used as collateral are within men's control (Ross *et al.,* 2004; Phiri, 2007; Njuki *et al.,* 2014; Ragasa *et al.,* 2014). Hence when it comes to try-out or fully adoption of agricultural technologies that need payment or productive resources, mostly men dominate, in some cases, women from the male-headed household are supported by their male counterparts (Deere and Doss, 2006; Doss, 2009).

Household size has been documented in most literature to be one of the factors contributing positively to the adoption of agricultural technologies. In some cases, the members of the household might provide labour required to cater for the increased labor resulting from new technologies. Household with more working force might generate cash used to pay for the agricultural technologies (Kafle, 2011); although it is not clear in the literature on how household size affects the adoption of agricultural technologies in different household headship.

Access to both physical and financial resources is considered vital in the adoption studies, as farmers use it to pay for the innovation expenses. However, in sub-Saharan Africa, it is noted that men dominate control over most of the household resources, an act that disadvantages women when it comes to the uptake of innovations. Some studies argue that women in MHHs can still use the resource to adopt, but in case of different ownership of assets that are being targeted by the technology this aspect might not work (Meinzen-Dick, 2011).

2.6 Theoretical and Conceptual Framework

2.6.1 Theoretical Framework

This study is built on the random utility theory. Following this, individual smallholder cattle farmers are assumed to decide by choosing options that will maximize their perceived utility gains. They are expected to rationally reveal their preference in line with the objective of improving their household welfare regarding increased income gains. The utility function can represent this preference, and the decision problem can, therefore, be modeled as utility maximization problem, in which the utility of each alternative is a linear function of observed individual characteristics plus an additive error term (Gardebroek, 2002). Therefore, total utility is the sum of observable and unobservable components, with appropriate distributional assumptions on the error terms.

Following this, letting choice of adopting ITM or otherwise be represented by k, where $k=1$ if the farmer is willing to adopt ITM and $k = 0$ otherwise. The resource endowment of farm household is given by z and vector x represents factors influencing the choice of that control method which includes: institutional characteristics, farm and farmer characteristics, and attributes of the technology that gives the individual confidence to prefer that particular technology.

This can be modeled as shown below;

$$U_1 = U(1, Z, X) = Y(1, Z, X) + \varepsilon_1 \quad (1)$$

If he/she does not have preference for the control method utility will be;

$$U_0 = U(0, Z, X) = Y(0, Z, X) + \varepsilon_0 \quad (2)$$

Where u is utility from intervention program and y is the determinist part of the utility and the random component ε representing the component of the utility known to the farmer but cannot be observed by the researcher, it is assumed to be independently and identically distributed (Green, 2003). An individual will prefer to adopt ITM *iff*

$$U_1 > U_0 \text{ for all } U_1 \neq U_0 \quad (3)$$

The presence of a random component permits to make probabilistic statements about decision maker's behavior; for example if the farmers prefer the intervention the probability of distribution is given by the formula below;

$$\begin{aligned} p_i &= pr(y_i^* = 1) = pr(U_{ij} > U_{0i}) = pr[\gamma_1 D_1(z_{ri}, f_{ri}) + e_{1i} > y_0 D_1(Z_{ri} F_{ri})) + e_{0i} = \\ & pr[e_{1i} - e_{0i} > D_i(Z_{ri}, F_{ri})(y_0 - y_i)] = p_r[\varepsilon_i > D_i(z_{ri}, F_{ri}) = D(x_i^1 \beta) \end{aligned} \quad (4)$$

Where p_i= the probability of i^{th} individual up-taking ITM technology; $\varepsilon_1 = e_{1i} - e_{0i}$ is a random disturbance term which is specific to producer utility preference and $D(x_i^1 \beta)$ is the cumulative distribution functions for ε_i evaluated at $X_i^1 \beta$. Farmer is therefore expected to uptake ITM technology only if he/she expected to get a higher utility as compared to other available control methods.

2.6.2 Conceptual Framework

Figure 1 represents a conceptual framework for ITM uptake. The context illustrates the adoption process of agricultural innovations, in this case ITM technology. According to the framework, adoption process begins with potential adopters getting exposed to /aware of the agricultural innovations. Thus, cattle keepers in the study area will only adopt ITM once they are aware of its existence. In a farm setting, this process is influenced by institutional factors and socio-economic characteristics of the targeted individual/farmer. The difference in socio-economic characteristics (gender of the household head, education level, age, household size, land size, cattle herd size, and major occupation) tangled with institutional factors (group membership, access to extension services, access to credit and ownership of information and communications technology (ICT) equipment) are assumed to influences the ability of individual farmer to get exposure to, and adopt ITM technology with a view of maximizing their net returns.

In addition to awareness, perception (positive or negative) of the potential adopters will determine their ability to either adopt ITM or not. This will depend on how an individual farmer perceives the efficacy and accessibility of the intervention in equation (ITM). According to literature, some of the anticipated benefits resulting from ITM adoption include; reduced cattle death rate, increase market price, continuous milk production, a high market price for vaccinated cattle against ECF and reduced frequency of spraying using acaricide which leads to increase in household net income from cattle and other cattle-related products.

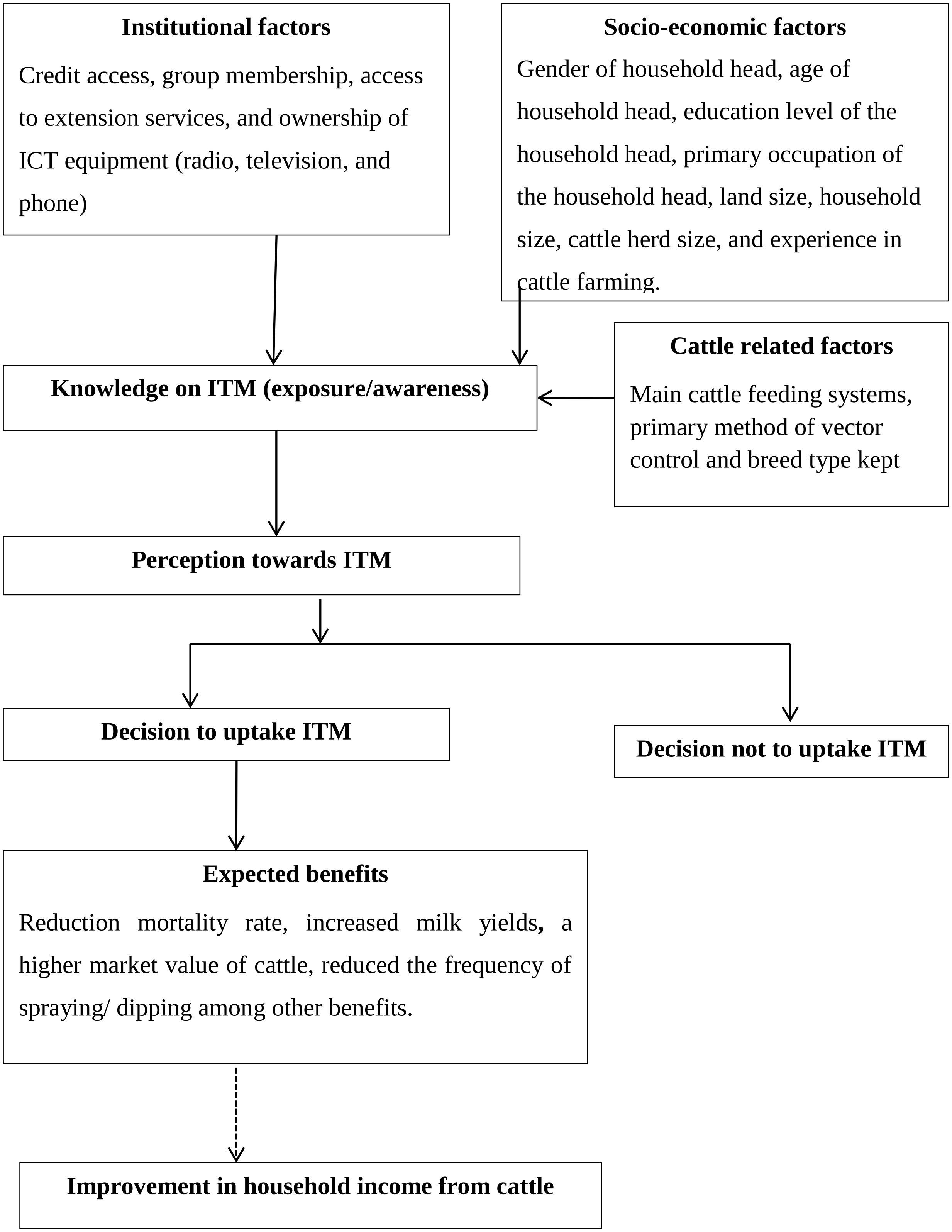

Figure 1: Conceptual Framework

Source: Author conceptualization

CHAPTER THREE

METHODOLOGY

This chapter presents information on the study area, and the study design, where sample size and sampling procedure used in primary data collection are discussed. The section further presents analytical techniques used in data analysis for the three research questions. Finally, the variables used in econometric analysis are presented.

3.1 Study Area

This study is based on a survey conducted in Uasin Gishu County. This region was selected due to the high prevalence of ECF, and also being one of the ITM project target areas in Kenya. Besides, dairy cattle farming contribute significantly to the livelihood of the majority of the rural population. Uasin Gishu County lies between longitude 34^o 50’ East and 35^o 37’ West and latitudes 0^o 03’ South and 0^o 55’ North. The county is bordered by Trans-Nzoia County to the North, Elogeyo-Marakwet County to the East, Baringo County to the South-east, Kericho County to the South, Nandi County to the South-west and Kakamega County to the North-West. The county covers an approximate area of about 3,327 square kilometres (Km^2).

Uasin-Gishu County is divided into six sub-counties namely; Soy, Turbo, Kapseret, Kesses, Ainabkoi, and Moiben (Figure 2). Ecologically, the county is located in the high agricultural potential and low potential agro-ecological zones. The county experiences mean annual rainfall of about <500mm to >1,000 mm in low potential zones and <1,200 mm to >1,800 mm in high potential zones, with a temperature range of about 8.4^oc to 26.2^o c. Demographically, Uasin Gishu County has a population of 894,179 people, representing 50.2% male and 49.8% female with annual population growth rate of 2.9% (KNBS, 2009).

Agriculture is the primary economic activity in this county, as approximately 75% of the land-holding is under farming. Mixed farming is a common practice in the region as a majority of the farmers depend on livestock keeping and crop production as their primary source of livelihood. The main livestock kept include; dairy cattle, goats, sheep, and poultry, while crop produced includes; maize, wheat, beans and passion fruits.

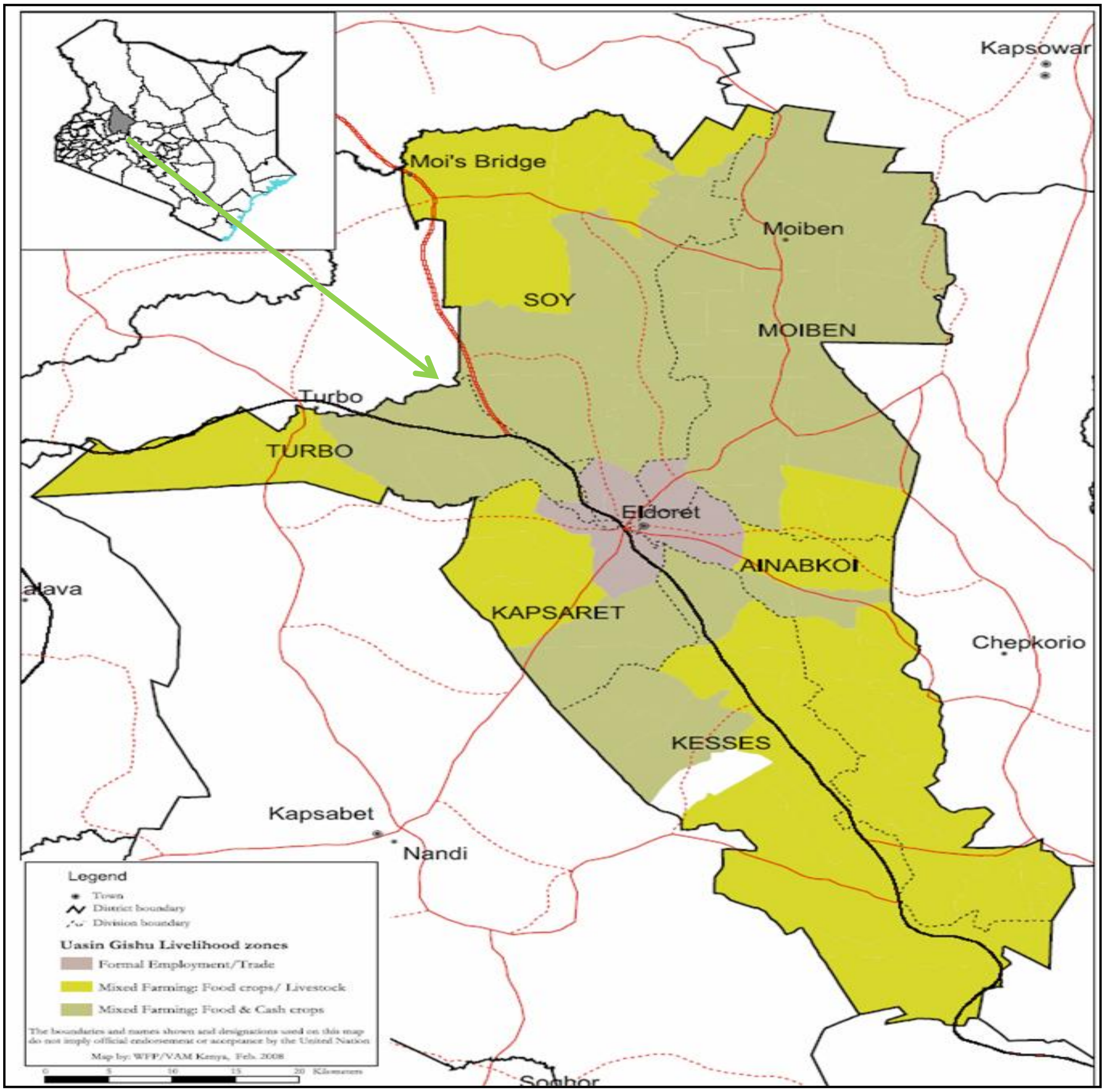

Figure 2: Map of the Uasin Gishu County, the selected study site.

Source: World Resource Center, 2016.

3.2 Sampling Design

Multi-stage sampling technique was used in selecting households for the survey. The first stage involved a purposive selection of Uasin Gishu County because it was one of the ITM project target region in Kenya. Besides, there is high prevalence of ECF disease. The second stage involved purposive selection of two sub-counties where dairy cattle keeping was considered as main economic activity. Upon discussion with experts from Kenya Dairy

Farmers Federation (KDFF) and local dairy hubs located in the regions, it led to the purposive selection of Kesses and Soy sub-counties. In the third stage, purposive identification and selection of ITM exposed and non-exposed villages from the two sub-counties were done with the help of experts from the local dairy hubs, and this led to the selection of 56 villages. In the fourth and final stage, a sampling frame was developed with the help of experts on the ground where lists of both MHHs and FHHs were developed. A simple random sampling technique - by proportional to size - was employed to select MHHs from the villages of interest, while all female-headed households were considered for the survey because they were fewer in number. This generated a total of 298 MHHs and 150 FHHs who were successfully sampled and surveyed. The overall distribution of the respondents by region and gender of the respondent is as shown in Table 1.

Table 1: Distribution of the respondent by sub-county and gender of the household head

Sub-county	FHHs		MHHs	
	Number of respondent	percentage	Number of respondent	percentage
Kesses	84	56.00	147	49.33
Soy	66	44.00	151	50.67
TOTAL	150	100.00	298	100.00

Source: Author computation

3.3 Sample Size Determination

The required sample-size was determined by probability proportionate to size sampling methodology (Kothari, 2004).

$$n = \frac{pqz^2}{\varepsilon^2} \quad (5)$$

Where, $n =$ minimum sample size $p =$ proportion of cattle keepers in the study area. Q= weighting variable computed as $(q = 1 - p)$, $Z =$ confidence level at 95%. ε =allowable error term. Since the proportion of the population was not known with certainty $p = 0.5$ with allowable error term of 0.05. The calculation using the formula above resulted in a sample size of 384 households which was adjusted to 400 households. However, during the preparation of sample frame, the population of women in the sample-frame was found to be too small; hence all of them were included in the sampling. This process resulted in an increase in sample-size to 448 households.

3.4. Data Collection Method and Data Analysis

This study uses a cross-sectional data set collected from smallholder dairy cattle keepers in Uasin-Gishu County based on 2015 production period. The data were collected through administration of a pre-tested semi-structured questionnaire to 448 respondents. The questionnaires were administered by a team of trained enumerators mostly who could speak and understand the local (Kalenjin) language. The data were analyzed using STATA 12, a quantitative data analysis computer program.

3.5 Analytical Techniques

Objective one: A five-point Likert scale was used to measure the perception of smallholder dairy cattle keepers on ITM as a potential technology for ECF control. The study considered an odd number (5) Likert scale to provide a room for a neutral response for farmers who had no opinion about the attribute in the equation. This approach had an advantage over an even number of Likert scale where an individual could be forced to score on either positive or negative sides of the statements. As forcing an individual farmer to score on a Likert scale of an even number might skew the overall results of the survey mainly due to the difficulties individual farmers with neutral opinion might face in scoring on the attributes under consideration (Kulas *et al.,* 2009; Fern *et al.,* 2016).

The smallholder dairy cattle keepers' perceptions towards ITM were operationalized as extents of their agreement with a set of ten selected attributes regarding ITM which were obtained from the previous qualitative study done in the same region of study (Jumba *et al.,* 2016). The perceptions were measured on a Likert scale ranging from strongly agree, agree, undecided, disagree, and strongly disagree. Understanding of farmers' opinions on the efficacy of ITM was captured by focusing on the ability of ITM to increase milk yield, reduce acaricide use, improve the market value of the cattle and boost animal's immunity against other diseases. Besides, the study focused on smallholder dairy cattle keepers' perception of constraints that might be preventing them from adopting the ITM technology. It included opinion: on the price of ITM services, accessibility to the ITM service provider and the package of the vaccine.

Percentages and coefficient of variations were used to summarize the data collected on respondents' perceptions of the effectiveness of ITM in management of ECF. Portions were used mainly because unlike means; they are considered to be a good measure of central tendency for ordinal data like for the case of a Likert scale (Harpe, 2015). The main aim of understating farmers' perception towards ITM was to enable policymakers and researchers to come up with better attributes of ITM that will be in line with farmers' needs

Objective two: Since the commercialization of ITM in Uasin Gishu, not all the individuals in the targeted population are aware of the technology. In the initial stages, ITM-distributors/vaccinators used field trials through subsidized campaigns to create more awareness regarding ITM. These strategies might have been done under prejudice where farmers with a higher likelihood of adopting ITM were given priority with the aim of acting as model farmers where other cattle keepers could easily learn from them. Besides, those farmers who are aware of ITM self-selected themselves whether to uptake it or otherwise based on their ability to interpret the promotions and adverts from newspapers, agricultural shows, and media. Therefore, due to inconsistency in ITM awareness, it is difficult to estimate its adoption rates and barriers to its uptake using classical approaches like Probit, Logit or Tobit models even when the sample size is collected randomly from the population (Dimara and Skura, 2003 and Dontsop-Nguezet *et al.*, 2010).

Thus, the study used average treatment effect (ATE) framework model to determine the adoption rates and factors influencing adoption as used by (Diagne and Demont, 2007; Dontsop-Nguezet *et al.*, 2010; Simtowe and Muange, 2013; Simtowe, 2016). The ATE framework was relevant in the study because it helped in control of both non-awareness and selection bias from the facilitators of ITM and the farmer respectively which could result in biased (underestimation or overestimate of correct population adoption rate) estimates (Diagne, 2006). The ATE framework model adopts average treatment effects (ATE) to measure the actual population adoption rate of a particular intervention. According to literature, this is commonly used to measure the effect/impact of a "treatment" on a person randomly selected in the population (Wooldridge, 2002). In line with impact evaluation approach, every individual in the targeted population has two choices (dummy whether to adopt or not) based on condition that he/she should be aware of the innovation.

To theorize the ATE framework, let y_i be the potential uptake outcome of a farmer when aware of ITM and y_0 be the potential uptake outcome when not aware. The potential uptake outcome can be either uptake status or not. However, in reality a farmer would only uptake a technology when he/she is exposed to it (Diagne and Demont, 2007). As a result, ($y_0 = 0$) for all farmers who are not aware of vaccination against ECF (ITM technology). Hence, the uptake outcome of the farmer i is given by y_{1i} and the average uptake outcome is denoted as $ATE = Ey_i$. In this study, it is assumed that the binary variable k to be an indicator for exposure to ITM $k = 1$ to represent exposure to the ITM and $k = 0$ otherwise). The estimation of adoption rates and its determinants were based on the observed random vectors from a random sample of the population as shown in the equation six:

$$(y_i, w_i, x_i, z_i) \quad i = 1,2.........n \qquad (6)$$

Where x_i is the vector of covariates that determines potential adoption outcome (e.g. the value of y_i) and z_i is the value of covariates that determine exposure (the value of w_i) with possibility of x_i and z_i having common elements (Dibba *et al.*, 2012; Simtowe *et al.*, 2016).

The ATE parameter is estimation of the potential demand of a technology by the target population under full exposure. The difference between the population mean potential adoption outcome and the population actual adoption outcome is the non- exposure bias, also known as adoption gap, which exist because of inadequate awareness of the technology in the whole population. The difference between the populations mean adoption outcome (ATE) and the mean adoption outcome among the exposed (ATT) is referred to as the population selection bias (PSB). The details of the estimation procedures of the ATE parameters in the adoption context are as illustrated.

Due to the problem of missing data, where there is the inability to observe both an outcome and its counterfactual make it impossible in general to observe the outcome variable of interest for the targeted individuals had they not been exposed to the ITM, hence, it is impossible to estimate the expected value of y_i by the sample average of a randomly drawn sample, since some of the y_i in the sample will be missing.

According to Imbens (2004) the ATE methodology provides the appropriate framework for the identification and consistent estimation of population adoption rate $E(y_1)$ and that of the determinants of adoption $E(y_1|x)$, which in this framework corresponds to the conditional ATE denoted usually as $ATE(x)$. The parametric estimation procedure of ATE is based on the following equation that identifies $ATE(x)$, which holds under the conditional independence assumption (CIA) (Wooldridge, 2002) as shown in equation seven.

$$ATE(x) = E(y_i|x) = E(Y|X, K=1) \tag{7}$$

The parametric estimation proceeds by specifying a parametric model for the conditional expectation of the observed adoption status y given the vector of covariates x restricted to the subsample of the individuals who are aware $(k=1)$ of the technology.

$$E(y|X, k=1) = g(X, \hat{\beta}) \tag{8}$$

Where g is a known (possibly non-linear) function of the vector of covariates X and the unknown parameter vector β, which is to be estimated using standard Least Squares (LS) or Maximum Likelihood Estimation (MLE) procedures using the observations (y_i, x_i) from the sub-sample of exposed farmers $(k=1)$ only, treating y as the dependent variable and x the vector of explanatory variables. Treating $\hat{\beta}$ as estimated parameter, the predicted values $g(xi, \overline{\beta})$ can be calculated for all the observations i in the sample (including the observations in the non-exposed subsample). The ATE, ATT and ATU are estimated - across the full sample (for ATE) and respective sub-sample (ATT for exposed population and ATU non-exposed population) as shown in equations 9, 10 and 11.

$$A\hat{T}E = \frac{1}{n}\sum_{i}^{n} = 1g(x_{i1,}\hat{\beta}) \quad (9)$$

$$A\hat{T}T = \frac{1}{n_e}\sum_{i=1}^{n} w_i g(x_i \hat{\beta}) \quad (10)$$

$$A\hat{T}U = \frac{1}{n - n_e}\sum_{i=1}^{n} (1 - w_i) g(x_i \hat{\beta}) \quad (11)$$

The effects of the determinants of adoption as measured by the k marginal effects of the k dimensional vector of covariates x at a given point $\bar{x}$ are estimated as:

$$\frac{\partial E(y_1 | \bar{x})}{\partial x_k} = \frac{\partial g(\hat{x}, \hat{\beta})}{\partial x_k} \quad (12)$$

Where k= 1…….n

Where; x_k is the k^{th} component of x; the above formula was used in calculating the population adoption gap (GAP=JEA-ATE) and the population selection bias (PSB=ATT-ATE). ATE- probit adoption model was used in determining joint exposure and adoption as illustrated in equation thirteen.

$$p(y = 1 | x') = \Phi(x'\theta) \quad (13)$$

Where, $x' = (z, x)$ is the vector of covariates determining both exposure k and uptake y_i and θ is the parameter vector to be estimated. All the estimations were done in STATA using the STATA add-on adoption command. The variables used in ATE model and their expected effects on likelihood of ITM adoption are as shown in Table 2.

Objective three: estimation of effects of ITM adoption on household income is constrained by the fact that the livelihood indicators of the treated group (ITM adopters) were not well documented as from the launch of the project. Consequently, it was not possible to observe the welfare shift due to ECF vaccination when restricted to adopters only. Thus, measuring the effects of ITM adoption using before and after scenario could not be applicable in this study. This implies that there is a problem of missing data because it is not possible to measure the impact on the same individuals at the same time, as we cannot observe the outcome variable of interest for the targeted individuals had they not participated (Wooldridge, 2002). According to Greene (2003), this can be achieved by evaluating the welfare shift using treated and control group from the sample population. Whereby we assume the control group can reflect the position of the treated group before uptake of ITM.

In the study, ITM was not randomly distributed to potential adopters, as individuals within the targeted population made their own decision on whether to vaccinate or not to vaccinate their cattle against ECF. This was mainly based on the expected utility gain from vaccination as compared to other conventional methods of ECF vector control. However, this decision could have been affected by other unobservable characteristics within the individuals that gave them an upper hand in ITM adoption. Rosenbaum and Rubin (1983) noted that self-selectivity among target population might lead to endogeneity problem, which failure to address could lead to overstatement or understatement of the welfare effects of any intervention; as adopters could be better off even without embracing the intervention.

To correct this bias that might be caused by the self-selectivity problem, instrumental variables (IV) approaches could be used. The IV technique embraces the use of an additional variable, known as the 'instrument,' in the next stage that introduces an element of randomness into the assignment. However, this approach still might yield bias estimates as it is difficult to get good matches between the adopters and non-adopters of a given intervention. Besides, it might be difficult for one to identify an excellent instrument to use in the regression. For this reasons, propensity score matching (PSM) was used in this study to estimate the welfare effect of ITM on household income.

The basic idea of the PSM method is to estimate the welfare effect of a given intervention by matching those individuals who have adopted (treated) against those who are yet to adopt (non-treated). However, the main weakness of PSM is that unobservable attributes of an individual that may affect both the outcome variables and choice of a given intervention are not accounted for directly, as it assumes selection is based on observable variables (Dehejia and Wahba, 2002; Smith and Todd, 2005).

The PSM is a two-step procedure. In the first stage, a probability model for adoption is estimated with the aim of calculating the probability (propensity scores) of ITM adoption for an individual based on observable characteristics. In the second stage, each treated individual is matched to a non-treated with similar propensity score from the control group, with the aim of estimating the average treatment effect for the treated (ATT). According to existing literature, several matching methods have been developed to match adopters with non-adopters of similar propensity scores; it is assumed that all matching methods should yield the same results. However, in reality, there are trade-offs regarding bias and effectiveness with each technique (Caliendo and Kopeinig, 2008). In this study, the use of nearest neighbor matching, kernel-based matching, radius matching, stratification matching and weighting matching were employed.

Letting k_i be a dummy variable equal to one if the individual i is a treated individual (household that has vaccinated against ECF) zero if otherwise. In addition assuming that y_i^1 and y_i^0 are the outcome variables describing household income patterns for individual (household) i conditional on the presence and absence of being in a treatment regime or not, respectively. Then the impact of the innovation/intervention on the i^{th} household, usually called treatment effect is as shown in the equation fourteen:

$$\Delta = y_i^1 - y_i^0 \tag{14}$$

However, in estimation of treatment effects only $y = k_i y_i^1 + (1 - k_i) y_i^0$ is observed rather than y_i^1 and y_i^0 for the same individual at the same time. Thus it is not possible to compute treatment effects for every unit at the same time. The primary treatment effect of interest that can be estimated is therefore the average treatment effect (ATT) given by;

$$ATT = E(y_i^1 - y_i^0 | k_i = 1) = E(y_i^1 | k_i = 1) - E(y_i^0 | k_i = 1) \tag{15}$$

Which answers the following question, how much did household participating in the program benefit compared to what they would have experienced without participating in the program? Data on $(y_i^1 | k = 1)$ is available among adopters. Evaluator's classic problem is to find the missing data $E(y_i^0 | k_i = 0)$ which is the main problem of causal inference (Heckman *et al.*, 1999).

Following the solution advanced by Rosenbaum and Rubin (1983), based on the assumption that given a set of observable covariates X , potential (non-treatment) outcomes are independent of participation status (conditional independence assumption-CIA): ($y_i^0 \perp k_i | X$). Hence after adjusting for observable differences, the mean of the potential outcome is same for $k_i = 1$ and $k_i = 0$, as clarified by the equation sixteen:

$$(E(y_i^0 | k_i = 1, X) = E(y_i^0 | k_i = 0, X)) \tag{16}$$

This condition allows the use of matching technique to measure how group of participating household would have performed, had they not participated; it is possible to condition participation on the propensity score denoted by p(x) rather than on observed characteristics X , as indicated by Rosenbaum and Rubin (1983). The propensity score represents the probability of treatment conditional on the vector of observable characteristic and may be interpreted as the one-dimensional summary of the set of observed variables. Thus the technological effect (ATT) for household with "similar" propensity score is as shown in equation seventeen:

$$\Delta y_i = E(y_i^1 | k_i = 1, p(x_i) - E(y_i^0 | k_i = 0, p(x_i) \tag{17}$$

Where y_i^1 denotes the income when i^{th} household is vaccinating its cattle using ITM, y_i^0 is the income of i^{th} household who does not participate in vaccinating cattle using ITM, and k_i denotes the ITM participation, 1=participate, 0=otherwise. The mean difference between observable and control is given by:

$$ATT = \varepsilon = k_i = E(y_i^1 | k_i = 1) - E(y_i^0 | k_i = 0 \tag{18}$$

Where ε is the bias; given by:

$$\varepsilon = E(y_i^0 | k_i = 1) - E(y_i^0 | k_i = 0) \tag{19}$$

In regression framework the treatment effects model is given by equation below:

$$y = \alpha + \beta_1 k_i + \beta_2 x_i + e_i \tag{20}$$

Where k_i is a dummy variable that takes the value 1 if farmer i has vaccinated his/her cattle using ITM and takes the value 0 otherwise, x_i is a vector of control variables such as farmer characteristics; β measures the effect of vaccination on household mean returns. Under the assumption of homogenous treatment effects, β identifies the average treatment effect as well as the treatment effect on the treated. Table 2 presents variables used in estimation of *pscore* used in PSM modeling.

3.6 Statistical and Specification Tests

Before performing regressions analysis, all hypothesized independent variables to be used in modeling were checked for the existence of multicollinearity problems. Multicollinearity arises due to a linear relationship between explanatory variables. The issue of multicollinearity might cause the estimated regression coefficients to have wrong signs and high *R*-square value. Besides, it creates considerable variance and standard error with a wide confidence interval, hence becoming challenging to estimate the effect of each variable (Gujarati, 2004 and Woodridge, 2002). Different approaches can be used to identify the presence of multicollinearity problem between the model regressors. The variance inflating factor (VIF) technique is commonly used in an array of literature (Gujarati, 2004). The VIF method was also preferred in this study. According to Gujarati (2004), the VIF is described as how the presence of multicollinearity inflates the variance of an estimator. According to Maddala (2001), VIF for an individual explanatory variable x_i is computed as:

$$VIF(x_i) = \frac{1}{1 - R_i^2} \tag{21}$$

Where: $R_i^2 =$ the coefficient of correlation among explanatory variables.

Larger values of VIF indicate stronger association among one or more model explanatory variables. As a rule of thumb, to avoid serious problem of multicollinearity, it is quite essential to exclude the variables with the VIF value exceeds a value of ten (Gujarati, 2004). Alternatively, the inverse of VIF (1/VIF), called tolerance, can be executed to detect multicollinearity. The closer the TOL of an explanatory variable is close to zero, the higher the degree of association of that variable with the other regressors. For the case of discrete independent variables, contingency coefficient test method was used to detect the problem of multicollinearity. The discrete variables are said to be collinear if the value of contingency coefficient test is higher than 0.75. Mathematically, it is computed:

$$C = \sqrt{\frac{x^2}{N + x^2}} \tag{22}$$

Where: $C =$ Coefficient of contingency

x^2 = *Chi-square* random variable

$N =$ Total sample size.

The values of contingency coefficient range from 0 - 1, with zero indicating no association between the variables and values close to 1 indicating high degree of association.

Table 2: Description of variables to be used in the ATE-framework and propensity score matching models

Variable	Description	Units of measurement	Prior Expectation
AGEHH	Age of the respondent	Number of years	+,-
EDUL	Highest level of education attained by the respondent	Number of years	+
GEND	Gender of respondent	Dummy : 1= male, 0=female	+,-
GRPM	Household head active member of either formal/informal self-help group	Dummy : 1= yes, 0= no	+
CRDT	Household head access to credit in the last 12 month	Dummy : 1= yes, 0=no	+
NEXT	Number of contact with extension officers in the last 12 month	Numbers of visit	+
DITMP	Distance to the nearest ITM/extension service provider	Walking time in minutes	-

HSZ	The size of the household	Numbers of individual	+,-
LNDSZ	Land size owned by the household	Number of acres	+.-
EXP	Years of experience in cattle keeping	Number of years	+,-
ICT	Ownership of ICT facilities (either phone, television or radio)	Dummy: 1=yes; 0=No	+
HRDSZ	Number of cattle own by the household	Cattle head count	+
FDSYM	The main cattle feeding system practiced by the farmer	Dummy:1 = zero grazing; 0 = others	+,-
BTYP	Type of cattle breed kept by the household	Dummy:1=exotic/cross-breeds, 0=indigenous breeds	+
DSTW	Distance from the household to the nearest water source	Distance in minutes – walking	+
KNITM	Knowledge on ITM technology	Dummy (1=yes, 0=otherwise)	+
INCML	Income from sell of milk and milk products	Total sum in Ksh.	+
INCMC	Income from sell of cattle and other cattle related services	Total sum in Ksh.	+
OCP	Household head main occupation	Dummy : 1 = farming 0 = off-farm income	+,-
MVCTR	Main method of vector control	Dummy:1=spraying; 0=others	+,-

CHAPTER FOUR

RESULTS AND DISCUSSION

This chapter presents the descriptive and econometric results of the study. The first sub-section presents descriptive results on the sampled households' demographic, institutional and cattle related characteristics separated by adoption status and the gender of the household head. The second sub-section presents results on the gendered perception of ITM: regarding efficacy and challenges to its adoption. In the third sub-section, econometrics results on the ITM adoption rates and factors influencing adoption are presented with the gender of the household head into consideration. Finally, the last sub-section presents the findings on the effect of ITM adoption on household cattle income among MHHs and FHHs.

4.1 Descriptive Results of the Sampled Households

This sub-section report result for the descriptive statistics on the farmer, farm, and institutional characteristics of the sampled households, disaggregated by gender and adoption status. In total, the study uses data from 448 respondents, 298 from MHHs and 150 from FHHs. In MHHs, 57.04% of the total respondents had acquired information about ITM. Besides, 41.28% of the total respondents were ITM adopters, and 58.72% were non-adopters. In FHHs, 46.01% of the total respondents were aware of ITM, and only 19.33% of the total respondents were considered as ITM adopters.

4.1.1 Farmer Characteristics

Descriptive results on mean: age, education level, and household size are presented Table 3. The mean age by adoption status of the sampled smallholder dairy cattle keepers was significantly different at 5% and 1% level, for MHHs and FHHs respectively. In MHHs, ITM adopters had the lowest mean age of 43.41 years as compared to mean age of 46.47 years for non-adopters. Younger farmers are more open to new ideas and are more likely to adopt new agricultural interventions as compared to elderly farmers. Thus, young farmers were ready to adopt ITM in control of virulent ECF. Old farmers are considered to be more reluctant to embrace new agricultural interventions as they tend to remain conservative to their traditional ways (Rao and Qaim, 2011; Asiedu-Darko, 2014). Conversely, this was different for the case of FHHs, where ITM adopters had the largest mean age of 50.32 years as compared to a mean of 43.07 years for the non-adopters. Elderly farmers in FHHs may be more empowered as they could have more access to information, land, and other agricultural resources, which younger women may lack due to cultural barriers. According to Doss (2011), older women are reported to have higher mobility and more access to resources as compared to younger women, which increases their ability to become aware of, and adopt new agricultural interventions as compared to younger ones.

The results revealed that years of formal education of household head were statistically different at 1% significance level in both MHHs and FHHs. In MHHs, ITM adopter had a higher mean of 12.05 years of schooling as compared to 10.15 years of education for the case of non-adopters. On the other hand, ITM adopters in FHHS had a higher mean of 10.01 years of schooling as compared to 7.03 years of education for non-adopters. The higher education levels among ITM adopters in both MHHs and FHHs suggest that farmers with higher levels of formal education were in a better position of gaining access to, and adopting new agricultural interventions. They could easily get trained and acquire inputs (ITM-vaccine) for the new agricultural interventions that aimed at improving their livelihoods. Formal education has been reported to enhance the capability of the household head acquiring knowledge and adopting new agricultural interventions (Kassie *et al.*, 2011; Simtowe *et al.*, 2011).

Regarding household size, there was a significant difference between adopters and non-adopters at 1% and 5% level of significance in MHHs and FHHs, respectively. Adopters of ITM in MHHs had an average of 4.38 household members as compared to an average of 4.10 household members for non-adopters. Concerning FHHs, ITM adopters had an average of 4.66 household members as compared to 3.75 household members for non-adopters. Higher ITM adoption among larger households could be possibly attributed to an increased need for the household food and other expenditures. Thus, there is a need to increase milk and milk income, as both are essential commodities in the study area. Furthermore, this may be due to the anticipated increase in labour size due to the increasing herd size, because of reduced mortality due to ECF. Gezie and Kidoido (2014) noted that larger household size increased the probability of adapting agricultural technology because large family size is usually associated with a higher labour endowment.

Table 3: Differences in mean age, education level and household size by ITM adoption and gender of the household head

Variables	MHHs			FHHs		
	Non-adopter	Adopter	t-stat	Non-adopter	Adopter	t-stat
Age	46.44	43.58	3.10**	44.93	48.17	-2.72**
Education level	10.15	12.05	-5.94***	9.64	11.26	-3.50**
Household size	4.10	4.38	-1.85*	3.75	4.66	-3.84**

Note: *, **, *** = Significant at 10%, 5% and 1% level, respectively

Farming was the primary occupation in the majority of the ITM adopters in MHHs as about 65.85% of the adopters engaged in farming as compared to 52.57% of non-adopters (Table 4). Similarly, in FHHs about 80% of the ITM adopter household head involved in farming as compared to 20% of their counterparts. The difference was statically significant at 5% level of significance in both MHHs and FHHs. Farmers who exclusively depend on agriculture may have high experience in farming, hence aware of risk and uncertainties associated with ECF. Besides, partaking farming as the primary occupation increase the farmer's ability to interact with extension service providers in the region. The more interaction with extension agents makes them acquire more knowledge on the importance of vaccination against ECF; thus they are ready to adopt ITM with the aim of reducing the cost of production and other associated losses due to ECF. Simtowe *et al.* (2016), argues that participation in off-farm income generating activities lowers the ability of the farmers to interact with extension service providers, which makes them less knowledgeable on the intended interventions.

Table 4: Differences in primary occupation of the household head by adoption status and household-headship

Variable	Description	MHHs			FHHs		
		Non-adopters	adopters	χ^2 stat	Non-adopter	adopter	χ^2 stat
primary occupation	Farming	52.57	65.85	5.23 **	36.67	80.00	3.03**
	Off-farm	47.43	34.15		63.33	20.00	

Note: *, **, *** = Significant at 10%, 5% and 1% level, respectively.

4.1.2 Farm Characteristics

Descriptive results (Table 5) reveal that herd size by adoption status was statistically different at 5% level of significance in both MHHs and FHHs. In MHHs, the mean herd size of those who adopted ITM was largest at 5.06 heads of cattle per household as compared to 4.56 heads of cattle for non-adopters. The mean herd size of ITM adopters in FHHs was largest at 5.27 heads of cattle per household as compared to 4.13 herds of cattle for non-adopters. The difference in herd size may probably mean that cattle keepers with larger herd size were more open to new ideas and were more risk takers than their counterparts. Smallholder dairy cattle keepers with a larger herd size were ready to vaccinate their cattle against ECF with the aim of reducing the risk of losing them to ECF. Furthermore, they could sell some of their animals and channel the returns to vaccinating the rest of the herd. Asset ownership has been linked to the ability to adopt innovations; as some of them can be sold and be used to pay for the technological expenses (Meinzen-Dick *et al.,* 2011).

In FHHs ITM adopters had a larger land size of 4.92 acres as compared to 3.15 acres for non-adopters. There was a significant difference in mean of land size by adoption status among FHHs at 5 % significance level. The larger land size among adopters in FHHs is a sign of wealth and empowerment as this could explain the ability of the women to use the returns from other agricultural sources to supplement the adoption of new agricultural innovations. They could sell some of the other farm produce and use the returns to pay for the new agricultural technologies. Galie *et al*. (2015) argued that ownership and control over agricultural resources by women increases their capability of participating in agricultural interventions.

Table 5: Difference in mean cattle herd-size and land-size, by adoption status and household head-ship

	MHHs			FHHs		
Variables	**Non-adopter**	**Adopter**	**t-stat**	**Non-adopter**	**Adopter**	**t-stat**
Cattle herd size	4.56	5.06	-2.65**	4.13	5.13	-3.57**
Land-size	3.36	3.70	-1.57	2.74	3.88	-4.45***

Note: **, *** = Significant at 5% and 1% level, respectively.

Results on breed type, cattle keeping system and method of tick control are presented in Table 6. There was a significant relationship between method of vector control and adoption of ITM at 5% and 10% significance level in MHHs and FHHs, respectively. In MHHs, 56.14% of the household heads among ITM adopters used spraying as the primary method of vector control as compared 42.39% for the non-adopters. Regarding FHHs, 58.79% of ITM adopters used spraying method in vector control as compared to 39.32 for non-adopters. Spraying as the primary method of vector control was indicative of a relatively well-off farmer, implied by the ability to purchase equipment and acaricide, and employ labour required for spraying at the farm level. The differences could be due to knowledge difference regarding the ability of ITM to cut on the costs of vector control through reduction in spraying.

Table 6: Characterization of cattle feeding system, breed-type kept and primary method of vector control, by adoption status and household head-ship

Variable	Description	MHHs			FHHs		
		Non-adopters	adopters	χ^2 stat	Non-adopters	adopters	χ^2 stat
Feeding-systems	Zero-grazing	41.14	47.98	1.37	38.76	41.43	2.53
	Others	58.86	52.03		61.24	58.57	
Breed- type	improved-breeds	95.43	98.37	8.65	93.83	96.67	0.04
	Others	4.57	1.63		6.17	3.33	
method of vector control	Spraying	42.39	56.14	35.82**	39.32	58.79	21.22*
	Others	57.61	43.86		60.68	41.21	

Note: *, **, ***=significant at 10%, 5% and 1% level, respectively.

4.1.3 Institutional Characteristics

Regarding institutional characteristics; the results indicate that there was a significant difference in the average distance of responded from home to the nearest extension/ITM service providers at 1% significant level in both MHHs and FHHs as shown in Table 7. Considering working-time in minutes, ITM adopters in MHHs covered an average 20.77 minutes while non-adopters covered an average of 28.08 minutes to reach the nearest extension/ITM service. In FHHs, adopters of ITM covered a shorter distance, a mean of 12.80 walking time in minutes to reach extension offices as compared to 20.45 walking time in minutes for non-adopters. Distance from the household to the nearest extension service offices provides a good proxy for measuring the ease of access to information and production inputs. Location of the ITM service providers plays a more significant role in access to ITM information and even reduces the transaction cost in acquiring ITM inputs. Wollni and Andersson, (2014) noted that distance from the farm gate to the nearest extension service providers act as a critical hindrance to the adoption of new agricultural technologies, as it influences transaction costs and access to agricultural related information.

Table 7: Differences in mean of distance to the nearest ITM service providers, distance to the nearest water source and number of extension visit, by adoption status and household head-ship

Variable	MHHs			FHHs		
	Non-adopter	adopter	t-test	Non-adopter	adopter	t-test
Distance to nearest ITM /extension service provider	28.09	20.77	4.93***	20.45	12.80	4.51***
Distance to the nearest water source	2.67	3.01	-1.51	3.06	3.00	0.11
Number of contact with extension agents	1.41	2.43	-10.91***	1.42	2.23	-6.15***

Note: *** = significant at 1% level.

Concerning the number of contacts with extension service providers in the last production period, adopters of ITM had more contact than their counterparts, and there was a significant difference at 1 % and 5% significance level among MHHs and FHHs, respectively. Adopters of ITM in MHHs had the highest number of contact with extension service provider at 2.43 times within the last production period of 12 months as compared to non-adopters at 1.41 times. Similarly, adopters of ITM in FHHs had the highest contact with extension service provider at 3 times within the last production period as compared to 1.5 times for non-adopters. The ability to adopt ITM can be enhanced by individual farmer awareness on cattle health and other vector/ disease management practices. Access to extension services positively influences adoption of new agricultural technologies as it helps in awareness creation. Dolisca *et al*. (2006), argued that a total number of contacts with extension service provider act as a reliable proxy for awareness creation and subsequent adoption of the innovation.

Table 8 presents results of group membership and credit access. Regarding group membership, there was a significant relationship between active membership in community-based self-help groups and ITM adoption at 1% significance level for both MHHs and FHHs. In MHHs, about 85.37% of ITM adopters participated in self-help groups activities as compared 66.86% of the non-adopters. Regarding FHHs, 93.33% of those who adopted ITM belonged to self-help groups compared to 25% for non-adopters. Livestock keepers are using existing self-help group to mobilize cattle for vaccination, which is an easier way of raising the required 40 heads of cattle per batch of the vaccine. Furthermore, self-help group supports the uptake of new agricultural interventions through initial resource mobilization and spread of information to the targeted population. Shiferaw *et al.* (2006) argued that farmer-groups influence small-holder farmers' ability to adopt agricultural innovations, as they act as essential channels through which farmers can gain access to information regarding new agricultural interventions and even gain access to financial support.

Table 8: Characterization of group membership, credit access and ownership of ICT facilities, by adoption status and household-headship

Variable	Description	MHHs			FHHs		
		Non-adopters	adopters	χ^2 stat	Non-adopters	adopters	χ^2 stat
Group membership	Yes	66.86	85.37	13.02***	25.00	93.33	10.03***
	No	33.14	14.63		75.00	6.67	
Credit access	Yes	43.39	73.98	27.37***	44.17	68.42	14.87***
	No	56.61	26.02		55.83	31.58	
Ownership of ICT facilities	yes	88.00	82.11	2.026	80.99	72.41	1.049
	No	12.00	17.89		19.01	27.59	

Note: **, ***=significant at 5% and 1% level, respectively.

Concerning credit access, the ability of the household head to access credit (either in cash or in-kind) from either formal or informal sector in the last one year was statistically significant at 1% level of significance in both MHHs and FHHs. In MHHs, the proportion of household head that accessed credit was highest amongst ITM adopters, about 73.98 % obtained loans as compared to 43.39 % of non-adopters. In FHHSs, 68.42% of those who adopted ITM accessed credit compared to 44.17 % for non-adopters. These findings imply that farmers who have access to credit have higher chances of adopting ITM; this might be due to a possibility of using the credit-cash to pay for the ITM services. Credit programs may aid farmers to purchase inputs or procure physical capital needed for technology adoption (Mohamed and Temu, 2008).

4.2 Gendered Perception of ITM Technology among Smallholder Cattle Keepers

The study used a five-point Likert scale (strongly disagree=1, disagree=2, neutral=3, agree=4, and strongly agree=5) to rate and understand cattle keepers perception toward ITM. In total ten statements were used to capture farmers perceptions in both MHHs and FHHs. The statement captured issues on the effectiveness of ITM in control of ECF, and barriers to its adoption. This aimed at identifying the specific attributes that might help researchers and policymakers to design a technology that will meet specific needs of farmers. These statements were obtained from a qualitative study (FGDs) done in the same region before the quantitative one. The responses were based only on the cattle keepers who knew and either wholly or partially (vaccinated part of their cattle herds against ECF) adopted ITM.

The descriptive analysis (Table 9) show that a majority of respondents from MHHs and FHHs agreed that ITM is the appropriate method for ECF control as depicted by positive scores on statements concerning ITM performance. According to the results, reduction in mortality rate due to ECF was the best most perceived benefits from ITM adoption by respondents from both MHHs and FHHs. In MHHs, ITM adopters had a strong perception regarding reduction in mortality rate due to ECF; with 77.05% of respondent scoring on strongly agree. These results were similar for the case of FHHs, where a majority the respondent strongly agreed with the comment regarding reduction in mortality rate due to ECF with 62.02% of the respondent scoring on 'strongly-agree.' These results suggest that adoption of ITM is a better intervention in reducing mortality rate due to ECF. This finding conforms with previous studies, where ECF vaccination is reported to lower mortality rate from more than 80% to less than 2% among the vaccinated herds (Toye and Ballantyne, 2015).

Regarding the reduction in the use of acaricide in ECF vector control, findings shows that about 68.03% and 51.72% of MHHs and FHHs, respectively, 'agree' with this attribute. These findings suggest that vaccination against ECF has a significant effect on the cost of ECF vector control. These findings are in line with those found by Jumba *et al.* (2016) where vaccination against ECF led to drastic reduction in the use of acaricide as farmers who had vaccinated their cattle reduce the amount of spraying by almost a half the original times (twice a month instead of weekly). A majority of the respondents had a positive perception concerning an increase in milk productivity/yield per annum due to ECF vaccination, as 60.66% and 51.72% of the respondent in MHHs and FHHs, respectively, agreed with the statement. A possible reason for the positive opinion could be due to the larger lactating herd size among ITM adopters as compared to the non-adopters. Besides, this could be due to the low level of ECF and other diseases among lactating cows which could interfere with the milk yields, and keeping animals of pure-breeds with higher milk producing capacity (Jumba *et al.*, 2016).

The statement on a boost of the cattle's immune system regarding fighting other disease or responding to treatment received a definite "agree" perception by a majority (52.46%) of MHHs but a neutral attitude by a majority (55.17%) of the FHHs. These findings suggest that women in FHHs had less knowledge regarding cattle treatment as compared to men. The minimal involvement of women in cattle treatment activities could explain why they have little experience regarding cattle treatment (Njuki *et al.,* 2013). There was a positive perception regarding an increase in live cattle market value for the case of respondents from MHHs where 63.11% of the respondent 'agree' with this attribute, however, this statement received a neutral score from a majority (68.97%) of the respondents from FHHs. The possible explanation could be due to lack of knowledge on the importance of ECF vaccination-especially regarding reduction in risk of losing the animals to ECF.

Table 9: Respondents' perceptions of ECF vaccination by gender of the household head

Attributes	St-D = 1	D = 2	N = 3	A = 4	St-A= 5	CV
Perception of household heads from MHHs (n=123)						
Vaccination against ECF leads to drastic reduction in cattle mortality rate	0.000%	0.000%	0.820%	22.130%	77.050%	0.094
Vaccination against ECF leads to reduction in acaricide use	1.640%	4.920 %	10.660 %	68.030%	14.750%	0.198
Vaccination against ECF boost milk yield per lactation period	0.820 %	2.460%	19.670%	60.660%	16.390%	0.186
Vaccination against ECF boost cattle's immune system	2.460%	0.820%	27.870%	52.460%	16.390%	0.214
Vaccination against ECF boost calves growth rate	0.000%	4.07%	36.890%	53.280%	5.740%	0.184
Vaccination against ECF improves cattle market value	0.000%	4.920%	16.390%	63.110%	15.570%	0.183
Vaccination against ECF improves cattle's traction power	1.640%	0.000%	90.160%	6.560%	1.640%	0.144
Perception of household heads from FHHs (n=29)						
Vaccination against ECF leads to drastic reduction in cattle mortality rate	0.000%	0.000%	3.450%	34.480%	62.020%	0.124
Vaccination against ECF leads to reduction in acaricide use	0.000%	0.000%	17.240%	51.720%	31.030%	0.167
Vaccination against ECF boost milk yield per lactation period	0.000%	3.450%	24.14%	51.720%	20.690%	0.198
Vaccination against ECF boost cattle's immune system	0.000%	0.000%	55.170%	44.830%	0.000%	0.147
Vaccination against ECF boost calves growth rate	0.000%	0.000%	37.930%	55.170%	6.900%	0.164
Vaccination against ECF improves cattle market value	3.450%	3.450%	68.970%	24.140%	0.000%	0.204
Vaccination against ECF improves cattle's traction power	13.790%	3.450%	79.310%	3.450%	0.000%	0.275

Key: 5 = Strongly Agree, 4 = Agree, 3 = Neutral, 2 = Disagree, 1 = Strongly Disagree; CV=Coefficient of Variation.

The statement concerning the link between ECF vaccination and improvement in cattle growth rate received a positive score from both men and women. A majority of the respondents, 53.28% and 55.17% for the case of FHHs and MHHs agreed with this statement. The possible reason for this could be due to avoidance of stunting associated with infection with ECF in young calves. Thus, maintenance of better health in calves might boost calves growth rate. Finally, mean scores regarding the improvement in traction power in cattle due to ECF vaccination showed that respondents from both MHHs and FHHs had poor perception towards it. Results show that 90.16% and 79.31% of respondent in MHHs and FHHs, respectively, scored "neutral" on this attribute. Lack of involvement of cattle in ploughing in the region as the cows mainly kept for dairying could give a clear explanation for the neutral scores by both men and women.

The study went further and looked at the challenges cattle keepers face in adopting ITM (Table 10). In both cases, all the respondents in MHHs and FHHs perceived the package of the vaccine as the main constraints to its adoption. Respondents from MHHs and FHHs had negative perception on attribute regarding the package of ITM vaccine in the batch of 40 doses. According to the results a majority (62.30%) of respondents in MHHs strongly disagreed with this statement, similar to FHHs where a majority (44.83%) of the respondents scored on "disagree". The negative perception is explained by the fact that it is time demanding to assemble the required 40 heads for vaccination for both men and women. Consequently, it is not easy for all the farmers who want to vaccinate against ECF to have the required cash at the same time, hence posing a real challenge to their desire to vaccinate against ECF (Jumba *et al.,* 2016).

Findings show that both respondents had negative perception on the availability of ITM service providers in their region. A majority of the respondent 62.30% and 51.72% from MHHs and FHHs respectively disagreed with this statement. This could be due to the few authorized ITM vaccinators in the region hence possessing a great challenge for farmers to vaccinate their animals. Results show that majority respondents 54.92% and 44.83% from MHHs and FHHs, respectively, agreed that the price of the vaccine was costly for them to afford. This could be attributed to the initial cost required to pay for the ITM services by the smallholder cattle keepers. Jumba *et al.* (2016) noted that although smallholder cattle keepers perceive ITM to be a best method of controlling ECF, the initial cost which ranges from Kenya shillings 850 to 1200 purposes a great challenge to its adoption.

Table 10: Perceived challenges of ITM uptake among exposed cattle keepers in MHHs and FHHs

Attributes	St-D = 1	D = 2	N = 3	A = 4	St-A= 5	CV
Perception of household heads from MHHs (n=123)						
Farmers are comfortable with the package of the vaccine in batches of 40 doses	62.300%	28.690%	1.640%	6.560%	0.820%	0.570
The providers of ITM service are readily available	11.480%	62.300%	5.740%	18.850%	1.640%	0.410
Farmers are comfortable with the price of the ITM services	13.110%	54.920%	9.020%	22.130%	0.820%	0.414
Perception of household heads from FHHs (n=29)						
Farmers are comfortable with the package of the vaccine in batches of 40 doses	41.380%	44.830%	3.450%	10.340%	0.000%	0.508
The providers of ITM service are readily available	34.480%	51.720%	0.000%	13.790%	0.000%	0.498
Farmers are comfortable with the price of the ITM services	20.690%	44.830%	10.340%	24.140%	0.000%	0.455

Key: 5 = Strongly Agree, 4 = Agree, 3 = Neutral, 2 = Disagree, 1 = Strongly Disagree

CV = Coefficient of Variation.

4.3 Preliminary Diagnostics of the Variables Used In the Econometric Analysis

Before conducting the regression analysis, all the selected independent variables to be used were checked for the existence of multicollinearity problem. The variance inflating factors (VIFs) were used to test the association between continuous explanatory variables while a contingency coefficient test (CC) method was used for the case of discrete explanatory variables. Besides, the white test was used to check for heteroskedasticity.

4.3.1 Test for Multicollinearity

The VIFs results show that the data had no serious problem of multicollinearity (Table 11). The VIFs result showed that for all continuous exogenous variables in both MHHs and FHHs, the values of VIF were less than ten. Besides, tolerance values were far away from zero. These findings imply that there was no substantial association between the continuous regressors.

Table 11: Variance Inflation Factor test results for continuous explanatory variables for MHHs and FHHs

Variable	MHHs		FHHs	
	VIF	1/VIF	VIF	1/VIF
Age of the respondent	1.280	0.782	1.181	0.847
Education level of the respondent	1.250	0.800	1.041	0.961
Household size	1.050	0.953	1.083	0.923
Land-size	1.100	0.912	1.110	0.901
Cattle herd size	1.110	0.905	1.012	0.988
Distance to ITM service provider	1.120	0.895	1.382	0.724
Number of contact with extension agents	1.030	0.970	1.351	0.740
Distance to the nearest water source	1.050	0.957	1.120	0.893
Mean VIF	1.120		1.180	

For the categorical variable, contingent coefficients were calculated and results presented in Table 12 and 13, for MHHs and FHHs respectively. Results show that there was no serious association among the categorical variables, as all the contingent coefficients were less than 0.75 in all the cases. Thus all the discrete explanatory variables tested were used in modeling.

Table 12: Contingency coefficient test results for categorical explanatory variables in MHHs

	Main-occupation	Breed-type	Group-membership	Credit access	Feeding-systems	Vector-control
Main-occupation	1.000					
Breed-type	0.044	1.000				
Group-membership	0.080	0.120	1.000			
Credit-access	-0.109	0.006	-0.146	1.000		
Feeding system	0.040	0.211	0.270	-0.087	1.000	
Vector-control	-0.057	-0.105	-0.106	0.101	-0.158	1.000

Table 13: Contingency coefficient test results for categorical explanatory variables in FHHs

	Main-occupation	Breed-type	Group-membership	Credit access	Feeding-system	Vector-control
Main-occupation	1.000					
Breed-type	0.000	1.000				
Group-membership	0.038	0.067	1.000			
Credit-access	0.067	0.021	-0.070	1.000		
Feeding system	0.047	0.048	0.022	0.131	1.000	
Vector-control	0.080	0.104	0.022	0.143	0.043	1.000

4.3.2 Test for Heteroskedasticity

The *white test* was used to check if there was a problem of heteroskedasticity among hypothesized explanatory variables before econometrics analysis, as presented in Table 14. The test result detected the presence of heteroskedasticity problem in both cases as chi^2 of 161.920 and 177.730 for MHHs and FHHs, respectively were significantly different from zero at 5% levels. As a remedy to these problems, the study used robust standard errors in the subsequent analyses. Robust standard errors help to reduce biasness of the coefficient under the case of heteroskedasticity (Gujarati, 2004).

Table 14: Test for Heteroskedasticity for MHHs and FHHs

Source	**MHHs**			**FHHs**		
	chi²	**df**	**p**	***chi²***	**df**	**p**
Heteroskedasticity	161.920	121.000	0.008	177.730	129.000	0.003
Skewness	26.530	15.000	0.033	33.450	15.000	0.004
Kurtosis	4.080	1.000	0.043	0.990	1.000	0.319
Total	192.540	137.000	0.001	212.170	145.000	0.000
Chi^2 (121) = 161.920				Chi^2 (129) = 177.730		
Prob > chi^2 = 0.007				Prob > chi^2 = 0.003		

4.4 Estimates of ITM Adoption Rates and Gaps among MHHs and FHHs-ATE Framework

This section presents results on estimates of ITM adoption among the targeted population and also gives more insight on factors influencing its adoption with the gender of the household head into consideration. Table 15 presents the results on the potential (ATE) and actual (JEA) adoption rates of the ITM, and the adoption gaps generated by the incomplete diffusion of information regarding ITM among the targeted population. Results show that in the year 2016 only 57% and 46% of the sampled household were aware of ITM for the case of MHHs and FHHs, respectively. The incomplete awareness of ITM among the targeted population restricted the actual adoption rates (JEA) of ITM to 41.10% and 19.40% for the MHHs and FHHs, respectively. These JEA estimate rates were significantly different from zero at 1% level.

The potential adoption rates (ATE) of ITM if all the farmers in MHHs and FHHs were aware of ECF vaccination was estimated at 61.60% and 31.40%, respectively. However, the incomplete awareness of the ITM resulted in adoption gaps of 20.50% and 12.00% for MHHs and FHHs, respectively which were significantly different from zero at 1% level. These findings indicate that there is potential for increasing ITM adoption by more than 20% and 12% for the case of FHHs and MHHs if better awareness programs that will target both men and women are put in place by disseminators. The initial dissemination programs that entail the use of subsidized campaigns, field trials and extension visits that were guided by the prejudice of targeting particular farmers with a higher likelihood of adopting seem to be ineffective.

The potential adoption rates among presently ITM aware sub-population (ATE1) was 72% and 42% for the case of MHHs and FHHs, respectively; while, the potential adoption rates among the non-aware sub-population (ATE0) was 47% and 22% for the case of MHHs and FHHs, respectively. These estimates (ATE1 and ATE0) indicate that there is a higher demand for ITM in the already targeted sub-population as compared to the non-aware sub-population. The estimated population selection biases (PBS) were 10.30% and 10.70% for MHHs and FHHs, respectively, and were significantly different from zero at 1% level. The results of PSBs suggests that probability of ITM adoption by a farmer randomly selected from non-exposed sub-population is significantly different from that of a farmer chosen randomly from exposed sub-population.

Table 15: Estimates of ITM adoption rates and adoption gaps among MHHs and FHHs in the year 2016-ATE framework

Adoption estimator	**MHHs**		**FHHs**	
	Parameters	**S.E**	**Parameters**	**S.E**
Potential adoption rates in the whole population of interest (ATE) :	0.616***	0.032	0.314***	0.044
Potential adoption rates among exposed population (ATE1):	0.720***	0. 026	0.422***	0.031
Potential adoption rates among non-exposed population (ATE0):	0.478***	0. 042	0.223***	0.064
Actual joint exposure and adoption rates (JEA):	0.411***	0.015	0.194***	0.014
Adoption gap (GAP): GAP=ATE-JEA	-0.205***	0.018	-0.120***	0.034
Population Selection Bias (PSB):	0.103***	0.010	0.107***	0.029
Total number of observations	298		150	
Number of household heads aware of ITM	170		69	
Number of household heads adopted ITM	123		29	

Key: *** = significant at 1% level

S.E: = Robust Standard Errors

4.4.1 Determinants of ITM Adoption among MHHs and FHHs-ATE Probit

Table 16 presents results of ATE-probit models on factors influencing adoption of ITM for the case of MHHs and FHHs. Cattle keepers who had vaccinated at least part of their cattle herds against ECF over a period of two and a half years by the time the survey was conducted were classified as ITM adopters. The log likelihoods of 78.84 and 97.96 for MHHs and FHHs, respectively and the pseudo-R-square of 0.325 and 0.638 for MHHs and FHHs, respectively were significant at 1% level. These findings imply that the two models (for MHHs and FHHs) are well fitted, and the explanatory variables used in the models were collectively able to explain over 39% and 43% of variation the farmers' decision regarding the adoption of ITM for the case of MHHs and FHHs, respectively. Marginal effects were further calculated with the aim of providing additional insight on the extent of the influence of each variable on ITM adoption.

Findings reveal that most of the variables in the model had the hypothesized sign and were significant at different levels in explaining the factors influencing ITM adoption. In MHHs, results show that education level, primary occupation, cattle herd size, group membership, access to credit and number of contact with extension agent had a positive and significant relationship with ITM adoption; while age and distance to ITM service provider/extension service offices had a negative and significant sign indicating its negative relation with ITM adoption decision. For the case of FHHs, findings show that age of the household head, education level, household size, primary occupation, access to credit, group membership and the number of contact with extension agents had a positive and significant relationship with ITM adoption. Distance to the nearest ITM service provider/extension offices had a negative and significant sign implying a negative relationship with ITM uptake.

The coefficients of the education level of the household heads were positive and significant at 1% level for both MHHs and FHHs, suggesting that household heads with a higher level of formal education have a higher probability of getting exposed to and adopting ITM than those with less formal education. Increase in one year of schooling of the household head will result in 3.10% increase in the probability of adopting ITM for MHHs, and 2.20% for the case of FHHs when all other factors are held constant. The positive relationship between the education level of the household head and ITM adoption could be attributed to the fact that a higher level of formal education increases the farmer's knowledge regarding ITM which translates to positive perception, therefore, increasing the probability of vaccinating their cattle against ECF. This result conforms with the findings of Khonje *et al*. (2015), where a higher level of formal education increased the likelihood of smallholder maize farmers adopting improved maize varieties, mainly due to more awareness of its availability and the expected benefits.

In MHHs, results show that the coefficient for the age of the head of household is negative and significant at 10% significance level, suggesting that the probability of adopting ITM diminishes with old age. The marginal effects further indicate that one year increase in the age of the household head in MHHs, will results in 0.6% decrease the likelihood of ITM adoption when other factors are held constant. The possible explaination to this finding could be because older farmers may incur higher information search costs regarding agricultural innovations as compared to younger farmers. Hence lack of information on agricultural innovations lowers their ability to embrace them. This finding is in line with that of Simtowe *et al.* (2016) where older farmers lagged behind in uptake of improved pigeon varieties due to lack of awareness regarding improved varieties. Besides, this could be because older farmers tend to remain conservative to their old ways of doing things; hence, the tendency to adopt an innovation always becomes difficult. This may be because they are less receptive to new ideas and are less willing to take risks associated with innovations as compared to the younger farmers. Besides, over the years, older farmers through trial and error might have found better ways of controlling ECF hence they have no incentive to pay for innovations targeting ECF control.

However, for the case of FHHs, the coefficient of age was positive and statistically significant at 5% level. The marginal effects suggest that one year increase in age of the household head, will results in an increase in the probability of ITM adopting by 0.3% when other factors are held constant. The result implies that age of the farmers in FHHs influenced adoption of ITM positively, where older farmers were more likely to adopt as compared to younger ones. This could be due to a higher resource endowment and level of empowerment among older women which enabled them to pay for ITM services with minimal difficulties. Besides, older women have higher mobility as compared to younger ones which might increase their chances of getting information about agricultural innovations (Doss, 2011).

In FHHs, household size had a positive and significant coefficient at 5% level, indicating that larger household size increased the likelihood of adopting ITM. Marginal effects suggest that increase in household size by one unit; will increase the probability of adopting ITM by 0.7% when all other factors are held constant. The reason behind this finding could be due to the available labour that can be channeled into other agricultural enterprises that provide additional income which can be used to pay for the innovations. Besides, this might be due to the value the women with larger household size attaches on their animals, as they are in high demand of milk and other income benefits to provide for their families, thus the need to reduce risk by protecting them from the deadly ECF through vaccination.

The primary occupation of the household head returned a positive and significant coefficient at 5% and 10% level of significance for MHHs and FHHs, respectively. The household head that considered farming as the primary occupation were more likely to adopt ITM as compared to those who engaged in off-farm income generating activities. The marginal effects show that the impact of having farming as a primary activity was inelastic to the probability of ITM adoption, as an increase in time allocation to farming activities by one percent increased the likelihood of adopting ITM by 5.4% and 4.4% for the case of MHHs and FHHs, respectively. Practicing farming as the primary activity might improve the chance of household head interacting with extension services providers, an act which raises their access to information regarding new agricultural innovations. This finding differs from those of Obisesan (2014), who noted that participation in off-farm income generating activities increased chances of adopting agricultural innovations, as the farmers took advantage of the extra cash from off-farm businesses to pay for the innovations inputs or services.

Table 16: Determinant of ITM adoption among MHHs and FHHs-ATE probit model estimates

Variables	MHHs		FHHs	
Dependent variable: Dummy for ITM adoption (1=Yes)				
Independent Variables	**Coef. (S.E)**	**dy/dx**	**Coef. (S.E)**	**dy/dx**
Household characteristics				
Age of the respondent	-0.021 (0.012)	-0.006*	0.010 (0.061)	0. 003**
Education level of the respondent	0.104 (0.037)	0.031***	0.069 (0.010)	0.022***
Household size	0.036 (0.069)	0.011	0.024 (0.028)	0. 007*
Main occupation of the HH (1=farming)	0.181 (0.189)	0.054**	0.138 (0.146)	0.044*
Household wealth and farm characteristics				
Land-size	0.013 (0.049)	0.004	0.039 (0.093)	0.012**
Cattle herd size	0.088 (0.058)	0.026**	0.073 (0.038)	0.023**
Breed- type (1=exotic)	0.034 (0.341)	0.010	0.177 (0.097)	0.055
Feeding- systems (1=zero grazing)	- 0.252 (0.182)	-0.075	-0.203 (0.013)	-0.064
Main method of vector control (1=spraying)	0.231 (0.049)	0.070	0.274 (0.143)	0.086
Institutional and access related characteristics				
Group membership	0.320 (0.036)	0.097**	0.604 (0.075)	0.196***
Credit access	0.417 (0.029)	0.115**	0.424 (0.080)	0.136**
Distance to ITM/extension service providers	-0.034 (0.061)	0.008**	-0.044 (0.172)	0.029***
Number of contact with extension agents	0.588 (0.011)	0.177***	0. 473 (0.087)	0.154**
Ownership of ICT facilities (1=own either radio, phone or television)	0.037 (0.038)	0.024	0.068 (0.073)	0.041
Distance to the nearest water source (walking time in minutes)	0.017 (0.082)	0.005	0. 049 (0.234)	0. 015
Constant	-3.776 (1.531)		-5.218 (1.276)	
Number of observations	168		69	
Pseudo R^2	0.393		0.430	
Prob> Chi ^{2}	0.000		0.000	
LR Chi ^{2}	78.840		97.960	

Note: *, **, *** = Significant at 10%, 5% and 1% level, respectively S.E. = Robust Standard Errors

The coefficient of farm size owned by the household for the case of FHHs was found to be positive and significant at 5% level, suggesting that cattle keepers - in FHHs - with more substantial land holdings are more likely to vaccinate against ECF. Marginal effect further indicates that an increase in household's farm size by one unit; will lead to an increase in the probability of ITM adoption by 1.2% when other factors are held constant. The land is perhaps the most critical resource for women in FHHs, as larger land size could provide an opportunity for farm enterprise diversification for stable income generation which they can use to pay for the ITM services. Awotide *et al.* (2012) noted that diversification of farming enterprise generated more revenue which could be used to pay for expenses required in adopting innovations.

Cattle herd size returned a positive and significant coefficient at 5% level for both MHHs and FHHS, suggesting that households with more heads of cattle have a higher propensity to adopt ITM than those with fewer cattle heads. These findings indicate that an increase in household herd size by one unit increases the probability of vaccinating against ECF by 2.6% and 2.3% for the case of MHHs and FHHs, respectively. Larger herds of cattle are indicators of the wealth of the household, suggesting that slightly wealthier families have a higher probability of adopting ITM as they face fewer difficulties in paying for agricultural innovations. The findings resonate well with those of Simtowe *et al.* (2016), where economically well-off farmers - regarding the number of livestock owned - were able to acquire complementary inputs required to adopt improved pigeon peas for the case of Tanzania.

The dummy whether a farmer was an active member of any social group returned a positive and expected sign, and it was significant at 1% level for both MHHs and FHHs, suggesting that being a member of any social group increased the likelihood of adopting ITM. Furthermore, marginal effects indicate that being an active member of any community-based farmers' group increased the probability of ITM adoption by 9.7% and 19.6% for the case of MHHs and FHHs when other factors are held constant. The reason to these results could be due to the social capital gained by being an active member of social groups which fosters technology uptake by enhancing information sharing through group learning and also facilitating credit access to the members. Besides, most of the smallholder farmers managed to vaccinate their cattle against ECF using social groups, as it was easier to mobilize cattle for ECF vaccination and even pay for ITM service through these groups. Rogers (2003) argued that active participation in social groupings is one way of enhancing social capital/networking where an individual can quickly get access to information regarding agricultural innovations and even get convinced to adopt.

The annual number of contact with extension service providers had a positive and significant influence on the probability of adopting ITM at 1% and 10% level of significance for MHHs and FHHs, respectively; suggesting that the likelihood of adopting ITM increases with increase in access to extension services. Specifically, marginal effects indicate that an increase in the frequency of contact with extension agents by one unit; it will lead to increase in the likelihood of adopting ITM by 17.7% and 15.4% for the case of MHHs and FHHs, respectively, when other factors remain constant. Cattle keepers who were regularly visited by extension agents and those who attend field days or host demonstration/trials were likely to adopt ITM; this was due to their increased awareness of the benefits of adopting ITM. These findings highlight the considerable role of extension agents in creating awareness about agricultural innovations as it is expected that regular contacts with extension agents enhance farmers' knowledge and equips them with new techniques of managing agricultural production. Mugisha *et al.* (2005) found out that the number of access to agricultural extension services positively influenced the adoption of improved groundnut technologies.

Credit access returned an expected positive and significant coefficient at 5% significance level for both MHHs and FHHs, suggesting that agricultural credit have a considerable impact in facilitating the adoption of ITM. The marginal effects suggests that having access to credit increases the probability of ITM adoption by 11.5% and 13.6% for the case of MHHs and FHHs, respectively other factors remaining equal. This is attributed to the fact that credit relaxes the financial constraint cattle keepers' face in purchasing the ITM vaccines and paying for its services. Studies have shown that, as a liquidity factor, the more farmers have access to finance sources, the more likely they can pay for inputs and expenses incurred during the adoption of innovations (Mendola, 2007; Qaim, 2013 and Simtowe *et al.,* 2016).

Distance to the nearest ITM service provider or extension officers returned negative and significant coefficient at 1% and 5% significance level for FHHs and MHHs, respectively. These results imply that distance to the nearest vaccinator or extension offices negatively impacted the possibility of adopting ITM in both household headships. The result of marginal effects further demonstrates that increase in the distance to the nearest extension service by one unit results in a decrease in the probability of ITM adoption by 17.2% and 6.1% for the case of FHHs and MHHs, respectively. Distance from the household to the nearest extension service offices or ITM service providers in the study area provides a good proxy for measuring the ease of access to information and production inputs by the cattle keepers. Location of the ITM service providers plays a more significant role in access to ITM information and even reduces the transaction cost in acquiring ITM inputs. Since ITM is a delicate vaccine and needs to be transported in cold chain (Gachohi *et al.* 2012), it is easier for vaccinators to reach farmers who are near them as compared to those who are far away. According to literature, distance from the farm gate to the nearest extension service offices act as a critical hindrance to the adoption of agricultural innovations, as it influences transaction costs and access to agricultural related information (Wollni and Andersson, 2014).

4.5 Effect of ITM Adoption on MHHs and FHHs Smallholder Cattle Producers' welfare

This sub-section gives more information on the factors influencing adoption of ITM among smallholder dairy cattle keepers and also estimates the welfare gains (regarding net income from cattle) that accrue due to ITM adoption. Propensity score matching model was used to estimate the effects of ITM adoption on household net income from cattle. This model was chosen with the main aim of overcoming the effects of self-selectivity which might have affected the final estimates. The income from cattle considered in the survey consisted of; milk income, returns from the sale of live cattle and any revenue generated from cattle related activities or products less the variable cost of production (cost of feeds, costs of hired labour, cost of disease control and cost of minerals salts and concentrates).

4.5.1 Estimation of propensity scores for both MHHs and FHHs

Before estimation of propensity scores, all explanatory variables used in the propensity score model were checked for the existence of multicollinearity and heteroskedasticity problem with appropriate technique as indicated in the earlier section Table (11, 12 and 13), and 14, respectively. In PSM application, probit regression models were used to estimate the propensity scores of adopter and non-adopter of ITM in both MHHs and FHHs. The dependent variable took the value of one if the farmer/household head adopts ITM and 0 otherwise. Then balancing properties of the propensity scores were checked, these were done by using different specifications of the probit models. The results reported in Table 17 are the specifications that gave more robust results which satisfied the balancing tests. According to the findings, the estimated model appears to perform well for the intended matching exercises. The models have McFadden pseudo-R-square value of 0.325 for MHHs and 0.382 for FHHs and log likelihood value of 131.29 for MHHs and 93.91 for FHHs.

The models further provide information on factors influencing adoption of ITM for the case of MHHs and FHHs. The results show that the coefficients of most of the variables hypothesized to affect adoption have the expected signs and are significant at different levels. These factors had been discussed in the earlier section (objective two). For the case of MHHs, the age of the household head, education level of the household head, the primary occupation of the household head, cattle herd size, group membership, credit access and the number of contact with extension agents influence ITM adoption. In FHHs, the age of the household head, education level of the household head, household size, primary occupation of the household head, land size, cattle herd size, group membership, and the number of contact with extension agents and access to credit influenced adoption of ITM. The only difference between the results in this section and the previous section is on the magnitude of the coefficients between the classical probit used here, and the ATE-probit applied in objective two above.

Table 17: Determinates of ITM adoption among MHHs and FHHs- probit estimation

Variables	**MHHs**		**FHHs**	
Dependent variable: dummy for ITM adoption (1=yes)				
Independent variable	**Coef.**	**S.E**	**Coef.**	**S.E**
Household characteristics				
Age of the respondent	-0.033*	0.014	0.066 **	0.040**
Education level of the respondent	0.142***	0.039	0.360***	0.012***
Household size	0.105	0.071	0.716**	0.023**
Main occupation of the HH (1=farming)	0.758***	0.020	0.606*	0.047*
Household wealth and farm characteristics				
Land-size	0.065	0.049	0.412*	0.167*
Cattle herd size	0.206**	0.061	0.295**	0.152**
Breed- type (1=exotic)	0.565	0.084	0.303	0.152
Feeding- systems (1=zero grazing)	-0.007	0.185	-0.212	0.166
Main method of vector control (1=spraying)	0.335	0.191	1.026	0.072
Institutional and access related characteristics				
Group membership	0.862**	0.022	1.961***	0.193***
Credit access in the last 12 month	0.754***	0.019	0.223**	0.064**
Number of contact with extension agent	0.421***	0.031	0.152 **	0.049**
Ownership of ICT facilities (1=own either radio, phone or television)	0.047	0.172	0.132	0.092
Distance to ITM service	-0.030 ***	0.008	-0.054	0.029
Distance to the nearest water source	0.037	0.051	0.152	0.076
Constant	-3.397	0.472	-14.725	3.817
Number of observations	298		150	
Pseudo R2	0.325		0.382	
Prob> Chi ^{2}	0.000		0.000	
LR Chi 2	131.290		93.910	

Note: *, **, *** = Significant at 10%, 5% and 1% level, respectively;

S.E. = Robust Standard Errors

4.5.2 Verification of the Common Support Condition

Confirmation of the common support/overlap condition is an essential step in PSM matching as it helps to investigate the validity of the final estimates. This assumption helps to identify if the treated individual (ITM adopters) will get a proper match from the control group (non-adopters) available in the dataset. According to Black and Smith (2005), the probability of participation in any intervention conditional on observed characteristics of an individual it is presumed to lie between 0 and 1. Thus for the rule of thumb, only observations within the common support region should be used in matching. The test was done using the '*psgragh*' test as shown in figure 4 and 5 for the case of MHHs and FHHs, respectively. In both cases, the estimates of the distribution of propensity score demonstrated that the overlap condition holds as there are similarities between the control and treatment group. Thus, it was easier to get treated individuals with identical '*pscores'* in the control group.

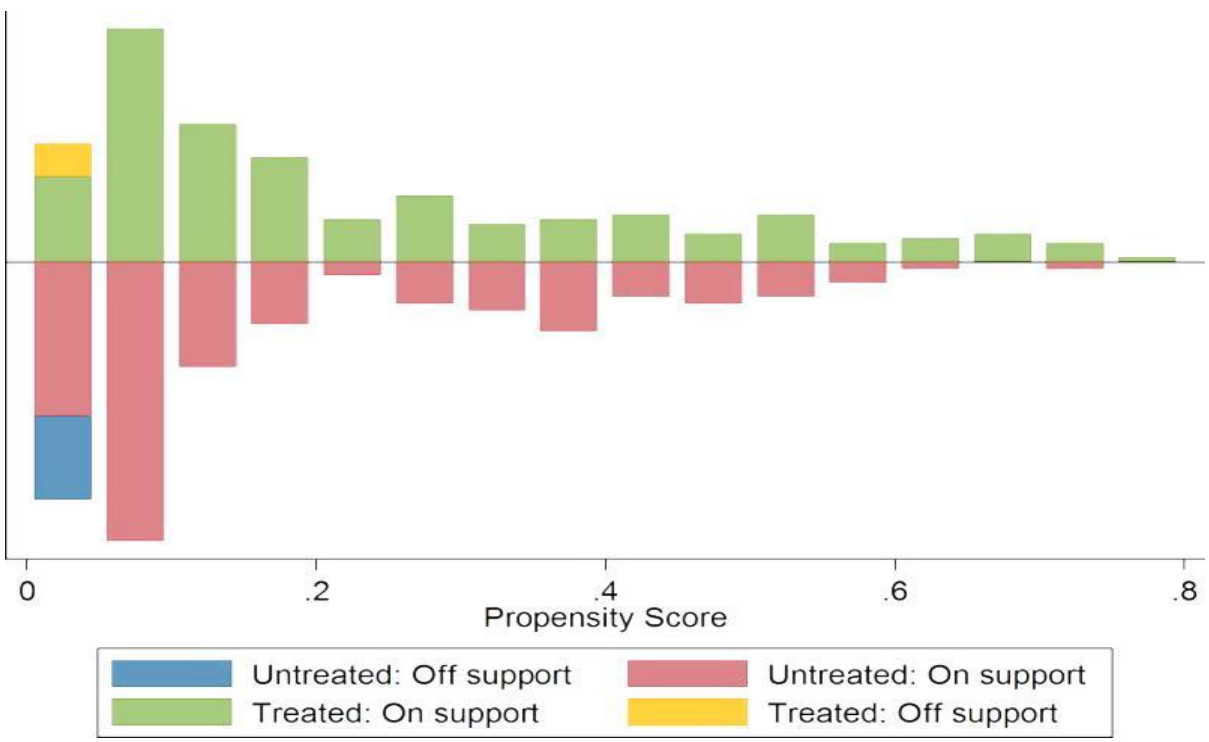

Figure 3: Distribution of propensity score for MHHs

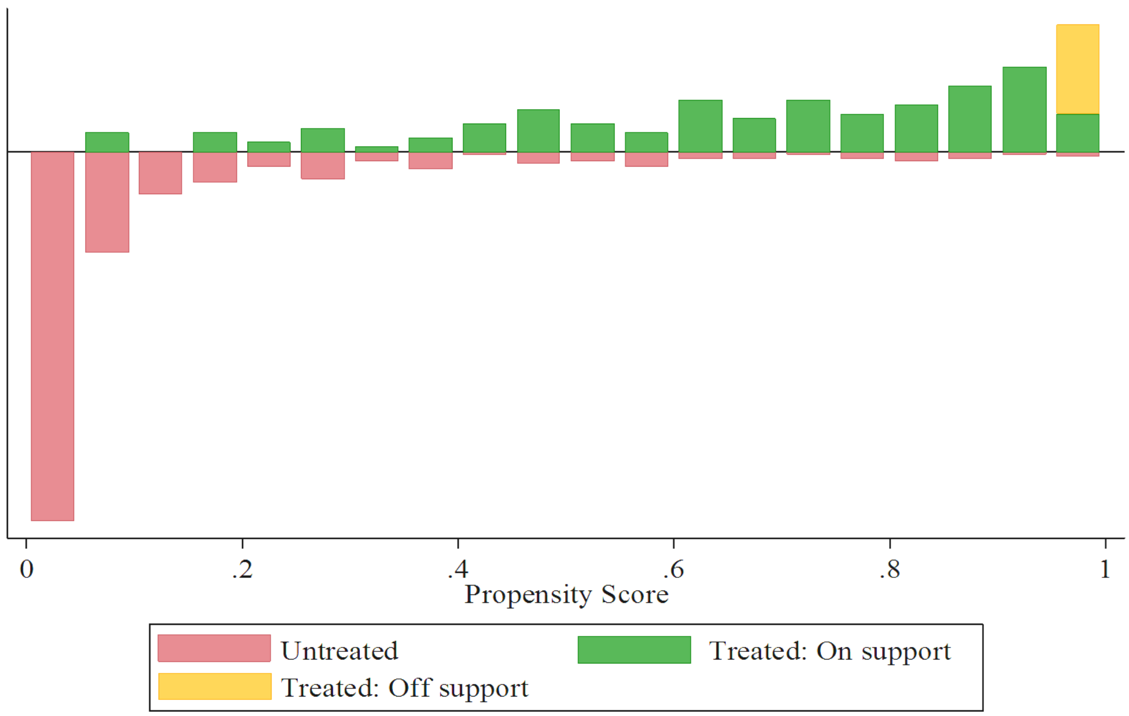

Figure 4: Distribution of propensity score for FHHs

4.5.3 Choice of Matching Algorithm

Estimation of the propensity scores was then followed by matching with the aim of finding out the average treatment effect on the treated (ATT) for intended outcome variables. As discussed in chapter three, there are several matching algorithms. These include nearest neighbor with or without replacement, radius, stratification, kernel, and local linear matching algorithms. This means that a suitable matching algorithm has to be selected. Therefore, different matching estimators were employed in identifying the excellent match between the treatment group and control groups which fall within the common support regions- basing on the predicted propensity scores. The primary test used to check the quality of matching results was to compare the sample before and after matching with the aim of identifying if there were any differences between groups (the matched treated and the control). The choice of the best matching estimator was determined by taking into consideration the reduction in pseudo-R^2 (that is comparing pseudo-R^2 before matching and after matching), the overall decrease in percent mean bias, and checking the number of matched sample size.

The results in Table 18 indicate that in MHHs, kernel matching with a bandwidth of 0.5 resulted in relatively lower overall pseudo-R^2 and had a more significant reduction in mean percentage bias for overall covariates used to estimate the propensity score after matching as compared to other matching algorithms. Besides, the estimate had a larger matched sample size with an overall p-value (for all explanatory variables) being insignificant. However, in FHHs, nearest neighbor matching five (5), resulted in a lower overall pseudo-R^2 after matching and had a more significant reduction in mean percentage bias as compared to other algorithms (see Table 19). These results imply that after matching there was a considerable reduction in systematic differences in the distribution of covariates between adopters and non-adopters in both MHHs and FHHs.

Kernel matching estimate with a bandwidth of five (5) and nearest neighbor matching five (5) were selected as the best estimates for MHHs and FHHs, respectively. As Rosenbaum and Rubin (1983) point out although before matching differences are expected in the covariates, afterward the covariates should be balanced in both groups, and no differences should be found. Dehejia and Wahba (2002) also noted that a matching estimator which reduces the difference between the control and treated groups and the one that bears a lower pseudo-R^2 after matching and results in a larger matched sample size should be considered as the best matching algorism.

Table 18: Matching quality indicators before and after matching for MHHs

Matching Algorithms	Pseudo *R2*		$p>chi^2$		Mean standardized bias		Matched sample size
	before matching	after matching	Before matching	After matching	before matching	after matching	
Near neighbor matching (NNM)							
NNM 1	0.325	0.034	0.000	0.760	44.800	8.900	284
NNM 2	0.325	0.040	0.000	0.599	44.800	11.000	284
NNM 3	0.325	0.046	0.000	0.467	44.800	11.000	284
NNM 4	0.325	0.036	0.000	0.691	44.800	8.800	284
NNM 5	0.325	0.041	0.000	0.595	44.800	10.000	286
Radius matching (RM)							
Caliper 0.01	0.325	0.025	0.000	0.978	44.800	7.500	278
Caliper 0.25	0.325	0.032	0.000	0.588	44.800	8.300	283
Caliper 0.50	0.325	0.026	0.000	0.001	44.800	17.300	285
Kernel matching (KM)							
Band width 0.01	0.325	0.026	0.000	0.975	44.800	7.200	275
Band width 0.25	0.325	0.023	0.000	0.698	44.800	7.800	284
Band width 0.5	0.325	0.014	0.000	0.178	44.800	6.300	284

Table 19: Matching quality indicators before and after matching for FHHs

Matching algorithms	Pseudo *R2*		$p>chi^2$		Mean standardized bias		Matched sample size
	before matching	after matching	Before matching	After matching	before matching	after matching	
Near neighbor matching (NNM)							
NNM 1	0.382	0.063	0.000	0.170	47.800	13.800	140
NNM 2	0.382	0.024	0.000	0.823	47.800	6.300	144
NNM 3	0.382	0.021	0.000	0.879	47.800	6.000	144
NNM 4	0.382	0.018	0.000	0.990	47.800	5.600	147
NNM 5	0.382	0.016	0.000	0.961	47.800	4.900	147
Radius matching (RM)							
Caliper 0.01	0.382	0.147	0.000	0.000	47.800	21.100	142
Caliper 0.25	0.382	0.053	0.000	0.071	47.800	8.300	144
Caliper 0.50	0.382	0.147	0.000	0.000	47.800	17.300	142
Kernel matching (KM)							
Band width 0.01	0.382	0.069	0.000	0.031	47.800	12.800	147
Band width 0.25	0.382	0.021	0.000	0.036	47.800	6.200	147
Band width 0.5	0.382	0.019	0.000	0.031	47.800	11.600	147

4.5.4 Checking For Balance in the Covariates

After choosing the best performing matching algorithm, the next task was to check the balance of covariates after matching process. The mean standardized bias test was used to determine the reduction in bias in covariates after matching method, using the selected matching algorithm. The analysis presents the difference in means of covariates in before and after matching and with their t-test results, and also the percentage reduction in bias for each covariate (see Table 20 and 21 for MHHs and FHHs, respectively). The mean standardized biases before and after matching are shown in the fifth columns while the total bias reductions are reported in the sixth columns. In MHHs, this was done using the kernel matching with a bandwidth 0.5, as it was considered to be the best matching estimates, while for FHHs, it was done using near neighbor matching five (5) as it was the best fit matching algorithm.

Results show that after matching, there was no difference in the sample means of the 13 covariates, a majority of them were insignificant both for the case of MHHs and FHHs. However, before matching there was a difference in the most of the means of covariates used in modeling. This implies that propensity score matching adequately served the role of reducing imbalances between the covariates for both groups in MHHs and FHHs, thus making the control group a plausible counterfactual. Hence, the process of matching created a high degree of covariate balance between the treatment and control samples that were ready to be used in the estimation procedure. Thus the matching results can give a reliable result for ATT estimates in evaluating the effects of ITM on household net income among the smallholder farmers. Hence, results obtained are suitable for formulation policy that can help in scaling up of the ITM innovation among livestock keepers.

Table 20: Testing of covariates balance for adopters and non-adopters for MHHs

Variable	Unmatched matched	Mean Treated	Mean Control	% bias	% reduction bias	t-test T	p>|t|	V(T)/ V(C)
Age	U	43.580	46.442	-37.601		-3.101	**0.002**	0.721
	M	43.381	43.960	-7.704	79.601	-0.710	0.478	1.466
Education level	U	12.050	10.153	70.621		5.942	**0.000**	0.801
	M	11.960	11.651	11.641	83.607	0.834	0.406	1.175
Household size	U	4.386	4.120	21.601		1.851	0.165	1.182
	M	4.330	4.203	10.705	50.703	0.810	0.418	1.311
Main occupation	U	0.660	0.537	27.202		2.300	**0.022**	0.903
	M	0.621	0.701	-14.601	46.200	-1.071	0.286	1.117
Land size	U	3.700	3.360	18.308		1.573	0.117	1.213
	M	3.494	3.832	-19.305	-5.312	-1.436	0.154	1.302
Hard size	U	5.030	4.490	36.512		3.082	**0.002**	0.811
	M	4.910	4.564	23.445	36.003	1.763	0.122	0.984
Breed type	U	0.980	0.903	37.012		2.971	0.113	0.173*
	M	0.981	0.981	0.501	98.641	0.068	0.952	0.945*
Method vector control	U	0.670	0.667	3.704		0.322	0.752	0.986
	M	0.645	0.590	12.013	-22.800	0.834	0.409	0.953
Group membership	U	0.850	0.672	44.301		3.685	**0.000**	0.572*
	M	0.831	0.831	-1.507	96.705	-0.122	0.907	1.032
Credit access	U	0.740	0.434	65.102		5.477	**0.000**	0.790
	M	0.720	0.733	-1.703	97.431	-0.131	0.898	1.022
Distance ITM services provider	U	20.771	28.101	-59.301		-4.930	**0.000**	0.601*
	M	22.403	22.641	-1.902	96.804	-0.132	0.895	0.586*
Distance water source	U	3.024	2.479	31.801		2.758	0.116	1.532*
	M	2.990	2.572	24.608	22.503	1.682	0.195	1.261
Contact extension agents	U	2.441	1.411	129.023		10.911	**0.000**	1.423
	M	2.233	2.390	-20.701	84.001	-1.310	0.192	0.567*

Note: The bolded figures of p values indicates significant covariates

Table 21: Testing of covariates balance for adopters and non-adopters for FHHs

Variable	Unmatched matched	Mean Treated	Control	% bias	% reduction bias	t-test T	p>|t|	V(T)/ V(C)
Age	U	50.901	45.980	88.403		4.211	**0.000**	0.911
	M	49.054	46.062	53.805	39.102	1.674	0.104	0.632
Education	U	11.312	9.654	81.301		3.555	**0.001**	0.460*
	M	10.951	9.610	65.303	19.712	1.927	0.163	0.432
Household size	U	4.750	3.745	89.206		4.282	**0.000**	0.957
	M	4.652	3.742	79.902	10.512	2.323	0.127	0.823
Occupation	U	0.794	0.636	34.912		1.614	0.109	0.732
	M	0.752	0.641	25.001	28.221	0.716	0.484	0.801
Land size	U	3.841	2.752	77.421		4.142	**0.000**	1.822
	M	3.682	2.793	63.003	18.500	1.787	0.144	1.315
Hard size	U	5.177	4.101	81.101		3.682	**0.000**	0.643
	M	4.901	4.090	60.811	25.001	1.745	**0.092**	0.691
Breed type	U	0.972	0.981	-11.313		-0.623	0.538	2.101
	M	0.954	0.990	-25.910	-13.514	-0.681	0.502	5.470*
Method vector control	U	0.837	0.642	43.822		1.986	**0.049**	0.632
	M	0.751	0.647	25.701	41.402	0.712	0.484	0.801
Group membership	U	0.930	0.452	113.314		4.691	**0.000**	0.263*
	M	0.902	0.494	102.552	9.500	2.933	0.907	0.357*
Credit	U	0.662	0.354	64.101		3.117	**0.002**	1.023
	M	0.651	0.342	65.312	-1.913	1.901	0.198	1.001
Distance ITM service provider	U	13.240	20.731	-81.553		-3.472	**0.001**	0.373*
	M	14.051	20.460	-69.716	14.417	-2.051	0.895	0.372*
Distance water source	U	3.457	2.801	49.401		2.259	0.126	0.663
	M	3.502	2.803	53.303	-7.902	1.591	0.120	0.591
Contact with extension agents	U	2.243	1.431	119.322		6.082	**0.000**	1.423
	M	2.153	1.423	106.601	10.621	3.271	0.182	1.101

Note: The bolded figures of p values indicates significant covariates

4.5.5 Estimation of Average Treatment Effect of ITM on Household Income by Household Headship

In this section, the effects of ITM adoption on household net cattle income are evaluated with the gender of the household head into consideration. The study used different matching techniques with the aim of improving the robustness of the results. The methods used included near neighbor with/without replacement, radius matching with different calipers, kernel matching with different bandwidth and stratification. However, only results on near neighbor with replacement, radius matching, and kernel matching are presented. The estimated net cattle income was transformed into natural logarithmic because of the *skewness* of the data. All the matching was based on the implementation of common-support condition; so that the distributions of ITM adopters and non-adopters were on support. All the matching techniques used reveal that uptake of ITM in ECF control had a positive and significant effect on the estimated average household cattle income.

The overall average gain of vaccinating against ECF per annum ranges from 0.28 and 0.30 for MHHs and 0.29 to 0.32 for FHHs as demonstrated by the different matching techniques (Table 22). Since income was expressed in natural logarithmic terms, the results of NN, RM and KM estimates show that farmers who adopted ITM have about 28% to 30% higher income per capita per annum as compared to the non-adopters, for the case of MHHs. In FHHs, results of NN, RM and KM shows that households which have adopted ITM have a net gain in cattle income of about 29% to 32% higher as compared to those of non-adopters. This confirms that the average household income for farmers vaccinating against ECF was higher than non-adopters no matter the matching method employed. These results imply that ITM is better intervention in improving livelihoods of smallholder cattle keepers.

Table 22: Estimated effect of ITM adoption on net cattle income by household headship using PSM methods

	Estimates	Treated	Control	Difference (ATT)	S.E	T- stat
	Dependent variable : Log net household cattle income per annum					
Near neighbor matching (5)	MHHs	11.250	10.956	0.294	0.144	4.621
	FHHs	10.366	10.051	0.316**	0.090	4.153
Kernel matching bandwidth (0.5)	MHHs	11.190	10.889	0.301	0.115	5.324
	FHHs	10.322	10.012	0.312**	0.113	5.291
Radius matching	MHHs	11.173	10.891	0.282	0.106	5.670
	FHHs	10.468	10.176	0.292**	0.097	5.232

Note:

SE represents robust standard errors

*** represents significant at 1%

The bootstrapped SE were obtained after 100 replications

Natural logarithmic differences are reported for the outcome variables; multiplied by 100 these figure were interpreted as percentage effect.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

This chapter draws the main conclusions from the results of this study and on this basis, makes key specific recommendations on interventions, approaches, and strategies. Besides, areas that need further research gaps are presented.

5.1 Conclusion

The study aimed at determining the perceptions, adoption, and welfare effects of ITM for management of ECF in Uasin Gishu County, Kenya using gender-disaggregated data obtained from a sample of 448 smallholder cattle keeping households. The study utilized both descriptive and empirical analysis. The average treatment effects (ATE) framework was adopted to estimate the adoption of ITM, while propensity score matching (PSM) was used to evaluate the impact of the ITM on income generated from cattle.

We investigated whether cattle keepers had a positive perception on the effectiveness of ITM on ECF control. Reduction in mortality rate due to ECF, reduction in the cost of ECF control, increase in milk yield, improvement in cattle growth rate, and improvement in cattle immune systems received positive score from a majority of adopter respondents from both MHHs and FHHs. However, the package of the ITM vaccine, cost of the ITM services, and availability of ITM providers limits its adoption as perceived by respondents in FHHs and MHHs.

The results further underscored the importance of awareness in the adoption of ITM. Findings show that inadequate knowledge regarding ITM restricted actual adoption rates to 41% and 19% for the case of MHHs and FHHs, respectively. Yet, the potential adoption rate in the same year was estimated at 61% and 31% for FHHs and MHHs, respectively. Inadequate awareness of ITM resulted in adoption gaps of 20% and 12% for MHHs and FHHs, respectively. This finding implies that there is potential for up-scaling ITM uptake by 20.50% and 12.00% in MHHs and FHHs, respectively, through broader dissemination of ITM knowledge among the targeted population. The study further indicated that the likelihood of higher demand for ITM among the exposed/aware population from both MHHs and FHHs was influenced positively by the education level of the household-head, access to credit, access to extension services, group membership, and cattle herd size. Household size, age of the household head, and land size were found to have a positive influence among FHHs only.

Results also demonstrate that the uptake of ITM has a positive welfare shift on household income from cattle. According to different PSM estimation methods used in the empirical analysis, ITM adoption results in a shift in annual household income from cattle by between 28% - 30% and 29% -32% for the case of MHHs and FHHs, respectively. These findings reveal the potential impact ITM has on transforming the livelihood of smallholder cattle keepers, hence acting as a significant pathway for reducing poverty among rural households. Thus, inclusion, wider dissemination and uptake of ITM will help improve smallholder cattle keepers' (both in MHHs and FHHs) income from cattle which will translate directly or indirectly to their general wellbeing.

5.2 Recommendations

To improve demand for ITM by smallholder cattle keepers from both MHHs and FHHs, stakeholders should consider overcoming key challenges smallholder cattle keepers face in vaccinating their animals. There is need to come up with smaller packages of ITM vaccine for example batches of five or ten instead of the standard one of forty doses. There is a need to come up with policy which can help reduce barrier to acquiring information and adoption of ITM. Policy makers and other relevant stakeholders should consider using institutional innovation platforms such as community social groups where cattle keepers can be trained, access credit, and even mobilize resources for ECF vaccination. Social groups can help farmers in vaccination as it is easier for them to overcome the issue of the package of the vaccine in batches of 40. Besides, smallholder cattle keepers can use such platforms to share farming information.

These findings suggest that to improve the adoption of ITM, more awareness should be done among the target population. This can be achieved through policy formulation that can strengthen and leverage both government and non-government extension services and rural institutions to promote and create awareness about the ITM. The national government and other relevant stakeholder should train more ITM distributors and vaccinators so that it will be easier for cattle farmers to access them easily.

5.3 Areas of Further Research Gaps

The primary attention of this study was to evaluate, perception, adoption, and the contribution of ITM on the livelihoods of smallholder cattle keepers with a gender lens into perspective. Annual income from cattle was considered as a proxy for measuring changes, if any, in household welfare due to ITM adoption. Despite the positive perception of the effectiveness of ITM and its impact on household welfare as demonstrated by the results, there are several research gaps which need attention:

1. This study mainly focused on direct benefits that were captured using direct income from cattle; it will be wise if comprehensive research is carried out to measure nutritional and other health benefits resulting from vaccination against ECF, especially for young children and expectant mothers. This might help get the association between the increase in milk production and milk consumption within the household; where it will be easier to tell if the ITM adopters allocate enough milk for domestic use.
2. There is a need to establish the association between ITM adoption and other farm enterprises, for example, crop production, as a result of the increase soil fertility due to increase in animal manure from the increasing cattle herd size.

REFERENCES

Ani, A., Ogunnika, O. and Ifah. S. S. (2004). Relationship between Socio-Economic Characteristics of Rural Women Farmers and their Adoption of Farm Technologies in Southern Eboni State, Nigeria. *International Journal of Agriculture and Biology* 6 (5): 802-805.

Asiedu-Darko, E. (2014). Farmers' Perception on Agricultural Technologies: A Case of Some Improved Crop Varieties in Ghana. *Agriculture, Forestry and Fisheries,* 3(1): 13-16.

Auma, J., Kidoido, M. and Rao, J. (2017). Feed the Future Accelerated Value Chain Development (AVCD) Program: Dairy component value chain analysis. Nairobi, Kenya: International Livestock Research Institute (ILRI).

Awotide, B. A., Diagne, A., Awoyemi, T. T. and Ojehomon, V. E. T. (2012). Impact of Improved Agricultural Technology Adoption on Sustainable Rice Productivity and Rural Farmers' Welfare in Nigeria: A Local Average Treatment Effect (LATE) Technique. African Economic Conference, October 30 - November 2, 2012, Kigali.

Bageant, E. R. and Barrett, C. B. (2015). *Gender Differences in Demand for Index-Based Livestock Insurance*. Ithaca, USA: Cornell University.

Bebe, B. O., (2003). Herd Dynamics of Smallholder Dairy in the Kenya Highlands. PhD thesis, Wageningen University, The Netherlands.

Berhanu, G., Adane, H. and Kahsay, B. (2009). Feed Marketing In Ethiopia: Results Of Rapid Market Appraisal. Improving Productivity and Market Success (IPMS) of Ethiopian Farmers Project Working Paper 15. ILRI (International Livestock Research Institute), Nairobi, Kenya.

Caliendo, M. and Kopeinig, S. (2008). Some Practical Guidance for the Implementation of Propensity Score Matching. *Journal of Economic Surveys*, 22(1): 31-72.

Chukuwuji, C. and Ogisi, O. (2006). A Tobit Analysis of Fertilizer Adoption by Smallholder Cassava Farmers in Delta State, Nigeria. *Agricultural Journal*, 1(4) : 240-248.

Conley, T. and Udry, C. (2001). Social learning through networks: The adoption of new agricultural technologies in Ghana. *American Journal of Agricultural Economics*, 83 (3): 668-673.

Dahal, B. M., Nyborgh, I., Sitaula, B. K. and Bajracharya, R. (2009). Agricultural Intensification: Food Insecurity to Income Security in A Mid-Hill Watershed of Nepal. *International Journal of Agricultural Sustainability*, 7(4): 249-260.

De Deken, R., Martin, V., Saido, A., Madder, M., Brandt, J. and Geysen, D. (2007). An Outbreak of East Coast fever on the Comoros: A Consequence of the Import of Immunized Cattle from Tanzania? *Vet Parasitol*, 143:245-253.

Deere, C. D. and Doss, C. R. (2006). *Gender and the Distribution of Wealth in Developing Countries* (No. 2006-115). Helsinki: World Institute for Development Economic Research.

Dehejia, H. R., and Wahba, S. (2002). Propensity Score Matching Methods for Non-Experimental Causal Studies. *The Review of Economics Statistics*, 84(1): 151-161.

Di Giulio, G., Lynen, G., Medley, G., O'Callaghan, C. J., Kiara, H. K. and McDermott, J. J. (2003). Characterization of *theileriosis* in Pastoral Production Systems in Northern Tanzania, In Proceedings of the 10th International Symposium for Veterinary Epidemiology and Economics, Vina-del Mar, Chile, 17–21 November 2003.

Di Giulio, G., Lynen, G., Morzaria, S., Oura, C. and Bishop, R. (2009). Live Immunization Against East Coast fever-Current Status. *Trends in Parasitology*, 25(2): 85-92.

Diagne, A. (2006). Diffusion and Adoption of *Nerica* Rice Varieties in Côte D'ivoire. *The Developing Economies*, 44-2: 208-231.

Diagne, A. (2006). The Diffusion and Adoption of NERICA Rice Varieties in Cote d'Ivoire. *Developing Economies,* 44 (2): 208-231.

Diagne, A. and Demont, M. (2007). Taking a New Look at Empirical Models of Adoption: Average Treatment Effect Estimation of Adoption Rates and their Determinants. *Agricultural Economics,* 37 (2-3): 201-210.

Dibba, L. Diagne, A. Fialor, S. C. and Nimoh, F. (2012). Diffusion and Adoption of New Rice Varieties for Africa (Nerica) in the Gambia. *African Crop Science Journal,* 20: 141 – 153.

Dimara, E. and Skuras, D. (2003). Adoption of Agricultural Innovations as a Two- Stage Partial Observability Process, *Agricultural Economics*, 28 (2003): 187-196.

Dolisca, F., Carter, D. R., McDaniel, J. M., Shannon, D. A. and Jolly, C. M. (2006). Factors Influencing Farmers' Participation in Forestry Management Programs: A Case Study from Haiti. *Forest Ecology and Management*, 236, 324-331.

Dontsop-Nguezet, P. M., Diagne, A. and Okoruwa, O. V. (2010). Estimation of Actual and Potential Adoption Rates and Determinants of Improved Rice Variety among Rice Farmers in Nigeria: The Case of *Nericas*. Contributed Paper Presented at the Joint 3rd African Association of Agricultural Economists (AAAE) and 48th Agricultural Economists Association of South Africa (AEASA) Conference, Cape Town, South Africa, September 19-23, 2010.

Doss, C. (2011). If women hold up half the sky, how much of the world's food do they produce? ESA Working Paper No. 11-04. Rome: Agricultural Development Economic Division, Food and Agricultural Organization of the United Nations.

Doss, C. R. and Morris, M. L. (2001). How Does Gender Affect the Adoption of Agricultural Innovations? The Case of Improved Maize Technology in Ghana. *Agricultural Economics*, 25 (1): 27-39.

Doss, C., Grown, C. and Deere, C. D. (2009). Collecting Individual-Level Asset Data for Gender Analysis of Poverty and Rural Employment. Paper Presented at the FAO-IFAD-ILO Workshop on Gaps, Trends and Current Research in Gender Dimensions of Agricultural and Rural Employment: Differentiated Pathways out of Poverty. Rome, 31 March - 2 April 2009.

Eygelaar, D., Jori, F., Mokopasteso, M., Sibeko, K. P., Collins, N. E., Vorster, I. Troskie, M. and Oosthuizen, M. C. (2015). Tick-Borne *haemoparasites* in African Buffalo (*Syncerus Coffer*) from Two Wildlife Areas in Northern Bostwana. *Parasites and Vectors*, 8: 26-40.

FAO (Food and Agricultural organization of the United Nations). (2011). *Communicating Gender for Rural Development: Integrating Gender in Communication for Development*. Brussels: Food and Agricultural Organization of the United Nations.

FAO (Food and Agricultural organization of the United Nations). (2011). *The State of Food and Agriculture 2010–2011. Women in Agriculture: Closing the Gender Gap for Development.* Rome: Food and Agricultural Organization of the United Nations.

Fern, K. W., Gene, L. T. and Luloff, A.E. (2016). Another Look at Likert Scales. *Journal of Rural Social Sciences*, 31(3):126-139.

Gachohi, J., Skilton, R., Hansen, F., Ngumi, P. and Kitala, P. (2012). Epidemiology of East Coast fever (*Theileria parva infection*) in Kenya: past, present and the future. *Parasites and Vectors*, 5:194-207.

Galie, A., Mulema, A., Mora, B., Onzere, S. N. and Colverson, K. E. (2015). Exploring Gender Perceptions of Resource Ownership and their Implications for Food Security among Rural Livestock Owners in Tanzania, Ethiopia and Nicaragua. *Agriculture and Food Security*, 4 (2): 243-250.

GALVmed (Global Alliance for Livestock Veterinary Medicines). (2009). African Cattle to be Protected from Killer Disease. Scotland: WRENmedia.

GALVmed (Global Alliance for Livestock Veterinary Medicines). (2010). Fostering Commercial Innovation for Better Animal Health in DFID Research 2009-2010: Providing Research Evidence that Enables Poverty Reduction. Scotland: WRENmedia.

GALVmed (Global Alliance for Livestock Veterinary Medicines). (2015). East Coast fever Infection and Treatment Method, Retrieved at: www. galvmed.org / wp-content / uploads / 2015 / 02/GALVmed-Position-Paper-on-ECF-Feb-2015.

Gardebroek, C. (2002). Farm-Specific Factors Affecting the Choice Between Conventional and Organic Dairy Farming. *Xth EAAE Congress "Exploring Diversity in the European Agricultural Food System",* Zaragoza (Spain), 28-31 August 2002.

George, J. E., Pound, J. M. and Davey, R. B. (2004). Chemical Control of Ticks on Cattle and the Resistance of these Parasites to Acaricide. *Parasitol,* 2004 (129): 353-366.

Gezie, D. and Kidoido, M. (2014). The Impact of Dairy Technology Adoption on Smallholder Dairy Farmers' Livelihoods in Selected Zones of Amhara and Oromia National Regional States, Ethiopia. *Global Journal of Agricultural Economics and Econometrics,* 2(1): 104-113.

Gitau, G. K., Mcdermott, J. J., Katende, J. M. and Perry, B. D. (2000). The Epidemiology of *Theileria Parva* Infections on Smallholder Dairy Farms in Kenya. *NYAS Annals of the New York Academy of Sciences*, 916(1): 265-270.

Greene, W. H. (2003). *Econometric analysis*. Upper Saddle River, New Jersey: Prentice Hall.

Gujarati, N. D. (2004). *Basic Econometrics, 4th Edition*. New York: Mcgraw - Hill, 2004. ISBN 978-0070597938.

Harpe, S. E. (2015), How to analyze Likert and other rating scale data, *Currents in Pharmacy Teaching and Learning*, 7; 836–850.

Heckman, J. J., LaLonde, R. J. and Smith, J. A. (1999). The economics and econometrics of active labor market programs. *Handbook of labor economics*, 3: 1865-2097.

Homewood, K., Trench, P., Randall, S., Lynen, G. and Bishop, B. (2006). Livestock Health and Socio-Economic Impacts of a Veterinary Intervention in Maasailand: Infection and Treatment Vaccine against East Coast fever. *Agricultural Systems*, 89(2-3): 248-271.

IFAD (International Fund for Agricultural Development and Food and Agriculture Organization). (2006). Small Holder Dairy Commercialization Programme- Appraisal Report: Africa Division 11, Programme management Department. Rome, Italy.

ILRI (International Livestock Research Institute). (2014). Protecting Africa's Cattle with a Live Vaccine: an East Coast fever Impact Narrative. ILRI Research Brief. Nairobi Kenya: International Livestock Research Institute.

ILRI (International Livestock Research Institute). (2000). Handbook of livestock statistics for developing countries: socio-economics and policy research Working Paper 26. International Livestock Research Institute, Nairobi, Kenya.

Imbens, G. W. (2004). Nonparametric Estimation of Average Treatment Effects under *Exogeneity*, *Review of Economic and Statistics*, 86(1): 4-29.

Irvin, A. D., Mwamachi, D. M. (1983). Clinical and Diagnostic Features of East Coast fever (*Theileria parva*) Infection of Cattle. *Veterinary Record*, 113(9):192–8.

Jumba, H., Teufel, N., Kiara H. and Baltenweck, I. (2016). The use of the Infection and Treatment Method vaccine in controlling East Coast fever in Kenya: Does Gender Matter for Adoption and Impact? - ILRI Research Brief, Nairobi Kenya. International Livestock Research Institute.

Kafle, B. (2011) Factors affecting adoption of organic vegetable farming in Chitwan District, Nepal. *World Journal of Agricultural Sciences.* 7: 604-606.

Kassie, M., Shiferaw, B. and Geoffrey, M. (2011). Agricultural Technology, Crop Income and Poverty Alleviation in Uganda. *World Development*, 39(10): 1784-1795.

Khonje, M., Manda, J., Alene, A. D. and Kassie. M. (2015). Analysis of Adoption and Impacts of Improved Maize Varieties in Eastern Zambia. *World Development,* 66: 695-706.

Kivaria, F. M. (2007). The Control of East Coast fever in Africa: A Constant Battle for Impoverished Dairy Farmers. *Veterinary Journal*, 174(2): 221-222.

KNBS (Kenya National Bureau of Statistics). **(**2009). Kenya Population and Housing Census, Kenya National Bureau of Statistics, Nairobi.

Kothari, C. R. (2004). Research methodology: Methods and Techniques. New Dheli: New Age International.

Kulas, J., T. Stachowski, A. A. (2009). Middle Category Endorsement in Odd-Numbered Likert Response Scales: Associated Item Characteristics, Cognitive Demands, and Preferred Meanings. *Journal of Research in Personality,* 43(4):489-93.

Lambrecht, I., Vanlauwe, B., Merckx, R. and Maertens. M. (2014). Understanding the Process of Agricultural Technology Adoption: Mineral Fertilizer in Eastern DR Congo. *World Development* 59:132-146.

Lawrence, J. A., Perry, B. D. and Williamson, S. M. (1992). East Coast fever. In Infectious Diseases of Livestock. Volume 1. 2nd Edition. Edited by Coetzer JAW, Tustin RC. Southern Africa, Cape Town: Oxford University Press.

Lizundia, R., Sengmanivong, L., Guergnon, J., Muller, T., Schnelle, T., Langsley, G. and Shorte, S. L. (2005). Use of Micro-Rotation Imaging to Study JNK-Mediated Cell Survival in *Theileria Parva* Infected B-Lymphocytes. *Parasitology,* 130(6): 629-635.

Maddala, G. S. (2001). *Introduction to Econometrics,* 3rd Edition, John Wiley & Sons, New York.

Malak, A. K., Mpoke, L., Banak, J., Muriuki, S., Skilton, R. A., Odongo, D., Sunter, J. and Kiara, H. (2012). Prevalence of Livestock Diseases and their Impact on Livelihoods in Central Equatoria State, Southern Sudan. *Preventive Veterinary Medicine,* 104(3-4): 216-223.

Marsh, T. L., Yoder, J., Deboch, T. and Palmer, G. H. (2016). Livestock Vaccination Translates into Increased Human Capital and School Attendance. *Science Advances* 2, e1601410.

Mbassa, G. K., Kipanyula, M. J., Mwamakali, E. D., Bulegeya, F. R. and Kauto-Mboni, K. (2006). *Theileria Parva* Infection in Calves Causes Massive Lymphocyte Death in Thymus, Spleen and Lymph Nodes without Initial Proliferation. *Veterinary Parasitology,* 142: 260-270.

Mbassa, G. K., Luziga, C., Mgongo, F. O. K., Kashoma, I. P. B. and Bundala, S. A. (2009). Theileria parva infection (East Coast fever) is vertically transmitted from pregnant cow to offspring. In *Fourth Annual Scientific Conference of the Programme for or Agricultural land Natural Resources Transformation for Improved Livelihoods held on 19 -21 September 2009 at Morogoro Hotel,* (153-158). Morogoro, Tanzania.

Meinzen-Dick, R., Johnson, N. Quisumbing, A. Njuki, J. Behrman, J. Rubin, D. Peterman, A. and Waithanji, E. (2011). Gender, Assets, and Agricultural Development Programs: A Conceptual Framework. CAPRi Working Paper No. 99. Washington, DC: International Food Policy Research Institute.

Mendola, M. (2007). Agricultural Technology Adoption and Poverty Reduction: A Propensity-Score Matching Analysis for Rural Bangladesh. *Food Policy,* 32 (3): 372-393.

Minjauw, B. and de Castro, J. J. (1999). Host resistance to ticks and TBD: its role in integrated control. 2nd Edition. In: Axford RFE, Bishop SC, Nicholas FW, Owen JB, editors. Breeding for Disease Resistance in Farm Animals. Wallingford, UK: CABI Publisher (1999).

Minjauw, B. and McLeod, A. (2003). Tick-Borne Diseases and Poverty. The Impact of Ticks and Tick-Borne Diseases on the Livelihood of Small-Scale and Marginal Livestock Owners in India and Eastern and Southern Africa. Research report, DFID Animal Health Programme, Centre for Tropical Veterinary Medicine, University of Edinburgh, UK.

Mohamed, K.S. and Temu, A. (2008). Access to Credit and Its Effect on the Adoption of Agricultural Technologies: The Case of Zanzibar. *Savings and Development*. 32. 45-89.

Mugisha, A., McLeod, A., Percy, R. and Kyewalabye, E. (2005). Strategies, Effectiveness and Rationale of Vector-Borne Disease Control in the Pastoralist System of South-Western Uganda. *Tropical Animal Health and Production*, 37(6):479-89.

Mwirigi, J. W., Makenzi, P. M. and Ochola, W. O. (2009). Socio-Economic Constraints to Adoption and Sustainability of Biogas Technology by Farmers in Nakuru Districts, Kenya. *Energy for Sustainable Development*, 13(2): 106-115.

Nchinda, V. P., Ambe, T. E., Holvoet, N., Leke, W., Che, M. A., Nkwate, S. P. and Njualem, D. K. (2010). Factors Influencing the Adoption Intensity of Improved Yam (*Dioscorea Spp*.) Seed Technology in the Western Highlands and High Guinea Savannah Zones of Cameroon. *Journal of Applied Biosciences*, 36: 2389-2402.

Nene, V., Kiara, H., Lacasta, A., Pelle, R., Svitek, N. and Steinaa, L. (2016). The biology of *Theileria parva* and control of East Coast fever -Current status and future trends. *Ticks and Tick-borne Diseases,* 7: 549-564.

Njarui, D. M. G., Gichangi, E. M., Gatheru, M., Nyambati, E. M., Ondiko, C. N., Njunie, M. N., Ndungu-Magiroi, K. W., Kiiya, W. W., Kute, C. A. O. and Ayako, W. (2016). A Comparative Analysis of Livestock Farming in Smallholder Mixed Crop-Livestock Systems in Kenya: 1. Livestock Inventory and Management. *Livestock Research for Rural Development*, 28 (4): 16-29.

Njuguna, E. M., Liani, M. L., Beyene, M. and Ojiewo, C. O. (2011). Exploration of Cultural Norms and Practices Influencing Women's Participation in Chickpea Participatory Varietal Selection Training Activities: A Case Study of Ada'a and Ensaro Districts, Ethiopia. *Journal of Gender, Agriculture and Food Security*, 1(3): 40-63.

Njuki, J. and Miller, B. (2013). Gender-Responsive Livestock Research. Research Brief, Nairobi, Kenya: International Livestock Research Institute.

Njuki, J. and Sanginga, P. C. (2013). *Women, Livestock Ownership and Markets: Bridging the Gender Gap in Eastern and Southern Africa*. London-UK: Routledge.

Njuki, J., Waithanji, E., Sakwa, B., Kariuki, J., Mukewa, E. and Ngige, J. (2014). Can Market-Based Approaches to Technology Development and Dissemination Benefit Women Smallholder Farmers ? A Qualitative Assessment of Gender Dynamics in the Ownership , Purchase and use of Irrigation Pumps in Kenya and Tanzania. IFPRI Discussion Paper: 01357. Washington, D.C.: IFPRI.

Norval, R. A. I., Perry, B. D., Young, A. S. and Lawrence, J. A. (1992). *The epidemiology of theileriosis in Africa*. London: Academic Press.

Obisesan, A. (2014). Gender Differences in Technology Adoption and Welfare Impact among Nigerian Farming Households, Munich Personal *RePEc* Archive (MPRA).

Odero, J. A. (2017). Smallholder Dairy Production in Kenya; a review. *Livestock Research for Rural Development*. 29 (7) 139-151.

Oura, C. A. L., Bishop, R. P., Wampande, E. M., Lubega, G. W. and Tait, A. (2004). Application of a Reverse Line Blot Assay to the Study of Haemoparasites in Cattle in Uganda. *International Journal for Parasitology*, *34*(5): 603-613.

Patel, E., Mwaura, S., Kiara, H., Morzaria, S., Peters, A., Toye, P. (2015). Production and dose determination of the Infection and Treatment Method (ITM) Muguga cocktail vaccine used to control East Coast fever in cattle. *Ticks and Tick-borne Diseases* 7(2): 306-314.

Perry, B. D. (2016). The control of East Coast fever of cattle by live parasite vaccination: A science-to-impact narrative. *One health,* 2: 103-114.

Phiri, H. (2007). *The Role of Credit in the Adoption and use of Improved Dairy Technologies in Malawi: A Case of Central and Northern Milk Shed Areas*. Master's Thesis, Bunda College, Lilongwe, Malawi.

Pretty, J., Toulmin, C. and Williams, S. (2011). Sustainable Intensification in African Agriculture. *International Journal of Agricultural Sustainability* 9:5-24.

Qaim, M. K. S. (2013): Genetically Modified Crops and Food Security. PLoS ONE 8(6) e64879 doi: 101371/journalpone0064879.

Ragasa, C., Sengupta, D., Osorio, M., Ourabah Haddad, N. and Mathieson, K. 2014. Gender-Specific Approaches, Rural Institutions and Technical Innovations. Rome: Food and Agricultural Organization of the United Nations, International Food Policy Research Institute, and Global Forum on Agricultural Research.

Randolph, T. F., Schelling, E., Grace, D., Nicholson, C. F., Leroy, J. L., Cole, D. C., Demment, M. W., Omore, A., Zinsstag, J. and Ruel, M. (2007). Role of Livestock in Human Nutrition and Health for Poverty Reduction in Developing Countries. *Journal of Animal Science*, 85, 2788-2800.

Rao, E. J. O. and Qaim, M. (2011). Supermarkets, Farm Household Income, and Poverty: Insights from Kenya. *World Development*, 39 (5): 784-796.

Rao, N. (2002). Cycling into the Future: The *Pudukkottai* Experience. In Balancing the Load: Women, Gender and Transport, ed. Priyanthi Fernando and Gina Porter, 151–68. London: ZED Books.

Rogers, E. M. (2003). Diffusion of Innovations, 5th Edition, New-York: Free Press.

Rosenbaum, P. R. and Rubin, D. R. (1983). The central role of the propensity score in observational studies for causal effects. *Biometrika*, 70(1): 41-55.

Samish, M., Ginsber, G. H. and Glazer, I. (2004). Biological Control of Ticks. *Parasitology* 129: 389-403.

Shiferaw, B, Obare, G. and Muricho, G. (2006). Rural Institutions and Producer Organizations in Imperfect Markets: Experiences from Producer Marketing Groups in Semi-Arid Eastern Kenya. ICRISAT Socio-economics and Policy Working Paper 23. ICRISAT (International Crops Research Institute for the Semi-Arid Tropics), Patancheru, India.

Shiferaw, B. A., Okello, J., Reddy, R. V. (2009). Adoption and Adaptation of Natural Resource Management Innovations in Smallholder Agriculture: Reflections on Key Lessons and Best Practices. *Environment, Development and Sustainability* 11: 601-619.

Sibeko, K., Geysen, D., Marinda, C. O., Conrad, A. M., Milana, T., Jacobus, A., Coetzer, W. and Nicola, C. E. (2009). Four *P67 alleles* identified in South African *Theileria Parva* Field Samples. *Veterinary Parasitology*, 167, 244-254.

Simtowe F., Asfaw, S. and Abate, T. (2016). Determinants of Agricultural Technology Adoption under Partial Population Awareness: The Case of Pigeon-Pea in Malawi. *Agricultural and Food Economics*, 4(7): 1-21.

Simtowe, F., Kassie, M. M., Diagne, A., Silim, S., Muange, E., Asfaw, S. and Shiferaw, B. (2011). Determinants of Agricultural Technology Adoption: The Case of Improved Pigeon-Pea Varieties in Tanzania. *Quarterly Journal of International Agriculture*, 50 (4): 325-345.

Smith, J. and Todd, P. (2005). Does Matching Overcome Lalonde's Critique of Non-Experimental Estimators? *Journal of Econometrics*, 125(1-2): 305-353.

Staal, S. J., Baltenweck, I., Waithaka, M. M., De Wolff, T. and Njoroge, L. (2002). Location and Uptake: Integrated Household and GIS Analysis of Technology Adoption and Land

Use, With Application to Smallholder Dairy Farms in Kenya. *Agricultural Economics*, 27: 295–315.

Staal, S., Waithaka, M., Njoroge, L., Mwangi, D. M., Njubi, D. and Wokabi, A. (2003). Costs of Milk Production in Kenya. MoA/ KARI/ILRI Collaborative Research Report. Smallholder Dairy (Research and Development) Project, Nairobi, Kenya.

Tanellari, E., Kostandini, G. and Bonabana, J. (2010). Gender Impacts on Adoption of New Technologies: Evidence from Uganda, Paper presented at 2013 Southern Agricultural Economic Association annual meeting, Orlando Florida, February 2-5, 2010.

Taracha, E. and Taylor, D. (2005). *Integrated Control of East Coast fever in Cattle of Small-holder Farmers*. Nairobi, Kenya: International Livestock Research Institute.

Theiler, A. (1912). The Immunization of Cattle against East Coast fever. Second Report. *Dir. Vet. Res.*, 216-314.

Theis, S. Lefore, N., Meinzen-Dick, R. and Bryan, E. (2018). What Happens After Technology Adoption? Gendered Aspects of Small-scale Irrigation Technologies in Ethiopia, Ghana, and Tanzania. *Agriculture and Human*, 35:671-684.

Toye, P.G. and Ballantyne, P.G. (2015). *Improving the Infection and Treatment Method Vaccine for East Coast fever*. ILRI Policy Brief 15. Nairobi, Kenya: ILRI.

Venter, C. J. and Mashiri, M. (2007). Gender and Transport: Towards a Practical Analysis Framework for Improved Planning. Paper prepared for 26th Annual South Africa Transport Conference and exhibition, Pretoria, South Africa, July 9-12, 2007.

Walker A.R. (2007). *Theileriosi*s and the Tick Control Conundrum: A Better Way Forward? *Journal of Veterinary*, 173 (2): 248-249.

Wanyama, R. N., Mshenga, P. M. Orr, A., Christie, M. E. and Simtowe, F. P. (2013). A Gendered Analysis of the Effect of Peanut Value Addition on Household Income in Rongo and Ndhiwa Districts of Kenya, invited paper presented at the 4th International Conference of the African Association of Agricultural Economists, September 22-25, 2013, Hammamet, Tunisia.

Wollni, M. and Andersson, C. (2014). Spatial Patterns of Organic Agriculture Adoption: Evidence from Honduras. *Ecological Economics*, 97, 120-128.

Wooldridge, J. (2002). Econometric Analysis of Cross Section and Panel Data. Cambridge, Massachusetts, USA: The MIT Press.

World Bank, (2007). *Global monitoring report 2007 millennium development goals: confronting the challenges of gender equality and fragile states (English)*. Global Monitoring Report. Washington, D.C.: World Bank.

World Bank, FAO (Food and Agricultural organization of the United Nations) and IFAD (International Fund for Agricultural Development and Food and Agriculture Organization). (2009). *Gender in Agriculture Sourcebook.*, Washington, D.C.: World Bank.

APPENDIX I: QUESTIONNAIRE

HOUSEHOLD SURVEY

Introduction Statement

My name is [*enumerators' name*]. I am working with researchers from Egerton University who are collaborating with International Livestock Research Institute (ILRI), working on a study about vaccination against East Coast fever (ECF) in Kenya. I would like to ask you some questions about your household socio-economic characteristics, perception of the method of controlling ECF through vaccination (Infection and Treatment Method-ITM), and cattle related information. The information you provide will be used to determine attributes that will help researchers and policymakers to design a technology that will meet specific needs of farmers and identify factors that need to be addressed to increase benefits of men and women from adoption. The interview will take approximate forty (40) minutes. Your participation is strictly voluntary. You can choose to withdraw from the interview at any given time after accepting to participate and even request for deletion of part or all data collected from you. Your refusal or termination of the survey has no penalty or loss of any benefits. All the information provided by you will be kept confidential and solely used for research purposes. Your privacy will be protected to the maximum extent provided by the law of Kenya.

Shall I continue with the interview [   ] Yes=1; No=0

SECTION (A): GENERAL IDENTIFICATION

Date of Survey (D/M/Y): ……………….

Sub-County: …………………………….

Ward: …………………………..............

Location: ………………………………..…

Sub-location: ……………………………

Village: ………………………………….

Questionnaire Number: ……………..……

Name of enumerator: ………………........

Name of the respondent: …………………

Mobile Number of the respondent: ……...

Start time (24 hours clock systems): ……..

End time (24 hours clock systems): ……

SECTION B: HOUSEHOLD COMPOSITION AND DEMOGRAPHICS

Household head name (surname and other names):		
Respondent phone number:		
Gender of household head:	(1) Male [ ]	(0) Female [ ]
Household head age in years:		
Marital status of household head	(0) Married **[ ]** (1) Single [ ] (2) Separated [ ]	(6) Divorced [ ] (7) Widowed [ ] (8) Others(specify) [ ]
Can household head read and write:	(1) Yes [ ] (0) No [ ]	
What is the highest level of education completed	(0) None [ ] (1) Primary [ ] (2) secondary [ ]	(3) College [ ] (4) University [ ]
Number of schooling years		
Number of adult living in the household (≥ 18 years)		
Number of children living in the household (≤18 years)		
Is farming your primary income generating activity? 1=Yes, 0=No		

SECTION C: AGRICULTURAL ASSET: VALUE, OWNERSHIP AND ACCESS

Ownership means the person who decides on when to sell or purchase the asset and how and for what the respective asset is used

C_1: Land

Plot ID	Plot description	Size of the plot in (acres)	Tenure system (code)
1			
2			
3			
4			

Codes for plot description: 1= Homestead**;** 2=Cash crop; 3= Food crop; 4= Fodder crop; 5=Grazing land

Codes for land tenure system: 1= Owned with title; 0= others (owned without title, Communal, rented etc.)

C_2: Cattle Herd Details

Cattle type (code)	Type of breeds (1=local, 0=exotic/cross)	Number owned by male	Number owned by female	Number owned jointly	Total number owned by household	Feeding system

Codes for cattle type: 1=cows being milked, 2=cows (dry), 3=heifers, 4=calves, 5=mature bulls.

Codes for cattle feeding systems: 1=zero grazing, 2= mixed, 3=tethering, 4=paddocking

C_3: Farming Experience: For how long have you been keeping cattle (years) [ ]

SECTION D: KNOWLEDGE /AWARENESS, PERCEPTION AND UPTAKE OF ITM

D_1: Knowledge on East Coast fever

i) Do you know ECF disease? 1 = Yes, 0=No [ ]

ii) If yes, where did you get the information from? 1= Media [ ]; 2=seminar [ ]; 3=NGO [ ]; 4=Friend/relative [ ]; 5=others (specify)……………………………..

iii) Which primary method do you use to control ECF disease? 1=use of acaricide/spraying; [ ] 2=bush burning/breeding sites [ ]; 3=hand picking of vectors [ ]; 4=bird picking of vectors [ ]; 6=herd selection [ ]; 7=others (specify)………..

D_2: Knowledge and Perceptions on ITM

i) Are you aware of vaccination of cattle against ECF using Infection and Treatment Method (ITM)? 1=YES, 0=NO [ ]

ii) If yes, where did you get the information from? 1=Media (radio, TV, etc.) [ ]; 2=Seminar [ ]; 3=NGO [ ]; 4=Friend/relative [ ]; 5=others (Specify)……

iii) If NGO, which organization? 1=KDFF [ ]; 2=SIDAIAFRICA [ ]; 3= ILRI [ ]; 3=VETAID [ ]; 4=TECHNOSERVE [ ] 5=others (specify)………

iv) Have you vaccinated your cattle against East Coast fever? Yes=1 No=0 [ ]

v) If yes, how many cattle have you vaccinated [ ]

vi) If yes, on a Likert scale of 1-5 how would you rate the following ITM attributes?

Attributes	1=Strongly disagree	2=disagree	3=neutral	4=agree	5=Strongly agree
Do you think?					
ITM increases milk output (per cattle)					
Vaccination against ECF reduces cattle mortality rates?					
ITM providers are not readily available					
ITM technology is not affordable					
Vaccination against ECF improves cattle market value?					
Vaccination against ECF reduces the frequency of dipping/spraying cattle using acaricide (anti-tick)?					
As a farmers you are not comfortable with the package of the ITM vaccine in batches of forty dosses per batch					

ITM saves farmers labor in controlling of vectors transmitting ECF					
Vaccinated cattle against ECF responds faster to treatment of other diseases apart from ECF unlike unvaccinated ones					
As a farmer do you agree that ECF vaccinated calves grow faster unlike unvaccinated ones					
ECF vaccination improves cattle ploughing/traction power?					

SECTION E: INCOME FROM CATTLE (*USE DURATION OF ONE YEAR*)

E_1: Milk Production and Sale

	No. of cows milked	Average amount produced per cow		Total month of production	Total output (Ltrs/Kgs)	Price per unit (Ksh.)	Total amount received (Ksh.)
		High season	Low season				
Morning (up to 12 pm)							
During the day (12-4 pm)							
Evening (after 4pm)							

E_2: Income from Cattle Products (Other than Milk Products)

In the last 12 month, did you sell any other cattle products a part from milk or milk products? (0=No 1=Yes), If yes, fill the details below:

Products:	Amount sold in the last one year	Unit of measurement (Code)	Average price per unit (codes)
Manure			
Hides and skin			
Cattle			
Others specify			

Codes for units: 1= Piece, 2= Kgs, 3= liters 4=other (specify)

E_3: Sale of Cattle Services

In the last twelve month, did you sell any of the below cattle services? (0=No 1=Yes), if yes, fill the details below:

Service:	Number of services in the last one year	Revenue received (Ksh.)
Bull services		
Draft power		
Other (specify)		

SECTION F: INPUT USE/COSTS OF PRODUCTION

F_1: Feed Expenses

Feed type:	Source of feeds	If purchased, monthly cost during months when purchased		
		unit	quantity	price
Crop residue				
concentrates				
Fodder (purchase)				
Own produced fodder				

Code for source of feeds: 1=Own farm; 2=Purchased; 3=other

F_2: Animal Health Services and Expenses

	Anthelmintic (deworming)	Tick control (spraying /dipping)	Vaccination	Curative treatment	Other (specify)
Did you use the service in the last 12 month? (0= No; 1=Yes)					
If yes, how many times?					
Who provided the service?					
What was your total expenditure in the last 12 month?					

Codes for Service provider: 1=Self/ Neighbor with professional advice, 2= Self/ Neighbor without professional advice, 3 = Animal health service provider/para-vet, 4= Government veterinarian5= Project/ NGO staff, 5= Coop/ group staff, 6 = Agro-vet shop, 7 = Community dip, 8= other (specify).

F_3: Labor Use and Expenses

Did you have a monthly paid laborer(s) in the last production period of 12 month? (0=no, 1=yes). If yes, give details below:

Number of workers	Monthly wage in Kenya shillings	Activities engaged in (codes)	Hours of a working day dedicated to activity

Codes for farming activity: 1=Crop production, 2=Cattle management (feeding, watering among other cattle related activities)

F_4: Breeding Services and Expenses

	Own bull service	Other bull service	AI service
Which are your preferred breeding methods?(Tick where applicable)			
How many times have you used this Service in the last 12 months?			
What is the average cost per service?			

SECTION G: INSTITUTIONAL SUPPORT, INFORMATION, TRAINING AND OFF FARM INCOME

G_1: Group Membership

Are you an active member of any social group (a part from being a member dairy milk cooling plant)? 1=yes 0=No, if yes fill the details in the table below:

Group type	Group activities	Number of meetings attended in the last 12 months

Codes for group type: 1=self-help group (organized and managed by the group members only) 2=county/community development group 3=cooperative society 4= Savings and credit groups/Sacco 5=livestock producer groups (apart from the cooling plants 7= other (specify)

Codes for group activities: 1=Milk marketing 2=input procurement 3= Provides training/ advisory on cattle production 4= other (specify).

G_2: Credit Access and Utilization

i) Did you have access to credit in the last 12 months? 0 = No; 1 = Yes [ ]

ii) If yes what did you use the credit for (more than one option accepted? [, , ,]

iii) Codes; 1: Cattle related activities 2: personal business expenses 3: medical issues 4: others

iv) Has any member of your household received credit in the last 12 months? 0 = No; 1 = Yes [   ]

G3: Institutional Facilities in the Region

i) How long does it take for one to walk from your home to the nearest livestock extension provider? [   ] minutes

ii) How long does one take to walk from your home to the nearest market place? [   ] minutes

iii) How long does one talk to walk from your home to the nearest water source? [   ] minutes

iv) In the last 12 month, did you receive any extension services? [   ] 1= yes 0=otherwise

v) If yes how many times? [   ]

vi) Has anyone in the household attended a farmer training during Jan – Dec 2015? [ ]1=yes 0=otherwise

vii) If yes how many times? [   ]

Enumerators to thank the Respondent for the Time and Assistance

END