IMPACT OF INFORMATION AND COMMUNICATION TECHNOLOGY-BASED EXTENSION SERVICES ON DAIRY PRODUCTION AND HOUSEHOLD WELFARE: THE CASE OF iCOW SERVICE IN KENYA

BY

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DECLARATION

This thesis is my original work and has not been presented for award of degree in any other university.

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DEDICATION

This thesis is dedicated to my loving parents, Gabriel Mwita and Jane Mwita, my brother Vincent Chacha, my sisters Elizabeth Boke and Grace Nyagei, my loving wife Ladona Achieng and my daughter Leona Mogaya.

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ACRONYMS AND ABBREVIATIONS

ACZ	Agro-Climatic Zone
ADC	Agricultural Development Corporation
ADGG	African Dairy Genetics Gain
AI	Artificial Insemination
ATE	Average Treatment Effects
ATIRI	Agricultural Technology and Information Response Initiative
ATT	Average Treatment on the Treated
CEO	Chief Executive Officer
CIA	Conditional Independence Assumption
CRS	Catholic Relief Services
CSA	Common Support Assumption
DOI	Diffusion of Innovation
FAO	Food and Agricultural Organisation
FCS	Food consumption score
FFS	Farmer Field School
FGDs	Focused group discussions
FSR	Farming Systems Research
GDP	Gross Domestic Product
GDT	Green Dream Tech
GIS	Geographical Information Systems
HELB	Higher Education Loan Board
ICT	Information and Communication Technology
ILRI	International Livestock Research Institute.
IV	Instrumental Variable

KACE	Kenya Agricultural Commodity Exchange
KALRO	Kenya Agricultural and Livestock Research Organisation
KBM	Kernel Based Matching
KDB	Kenya Dairy Board
KDFF	Kenya Dairy Farmers Federation
MIS	Market Information Systems
NAFIS	National Farmers Information Service
NALEP	National Agriculture and Livestock Extension Programme
NASEP	National Agricultural Sector Extension Policy
NGO	Nongovernment Organizations
NLMIS	National Livestock Market Information System
NNM	Nearest Neighbor Matching
ODK	Open Data Kit
OLS	Ordinary Least Squares
PSM	Propensity Score Matching
RATIN	Regional Agricultural Trade Intelligence Network
RM	Radius Matching
RML	Reuters Market Light
SSA	Sub Saharan Africa
TOT	Transfer of Technologies
UN	United Nations
VIF	Variance Inflation Factor
WFP	World Food Programme

ABSTRACT

Agricultural extension services play an important role for growth and transformation of the agricultural sector in Sub Saharan Africa. Benefits such as high productivity, quality of produce, reduction of diseases and pest, and increased income among smallholder farmers are attributed to access to quality extension service. Despite of these contributions of extension services, smallholder farmers have the challenge of accessing timely, credible and reliable agricultural information and consequently limiting them in realising maximum farm output. Use of ICT as an agricultural extension tool by smallholder farmers has the potential to reverse the scenario and improve farmers' access to timely and credible agricultural information and consequently lead to improved outputs and incomes leading to increased welfare.

This study examined whether the introduction of iCow platform as an e-extension tool among smallholder dairy farmers could deliver timely, reliable, relevant, and actionable agricultural information and advice to farmers and consequently improving their welfare. Therefore, the main objective of the study was to determine the impact of iCow on milk production, milk and household income and food security.

The study used a random sample of 457 small-householder dairy farmers of which 209 farmers regularly used the iCow services while 248 farmers were non-users. Descriptive analysis showed that there were differences in the means between regular users of iCow and non-users. Specifically, there were significant differences between the users of iCow and non-users with respect to milk production per cow. iCow users in Uasin Gishu and Bomet realised higher average annual milk production per cow of 2550 litres and 2456 litres respectively as compared to non-users whose production was 1833 litres and 2020 litres respectively. However, there was no significant differences in milk production in Nyandarua county. With respect to milk income, on average, users of iCow in Nyandarua, Uasin Gishu

and Bomet earned Ksh.122833, Ksh.169820 and Ksh.155449 respectively compared to non-users who earned Ksh.90036, 89389 and 111816 respectively. In relation to household income, there was a significant and positive difference of Ksh. 153353 between the iCow users and non-users in Bomet and insignificant differences in Nyandarua and Uasin Gishu. Additionally, on food consumption scores (FCS), which measure the food security status, the analysis indicated significant differences between the iCow users and non-users only in Bomet. On average users of iCow in Bomet had significantly higher (72) (i.e. better food security) scores than the non-users (67).

Further, the study used PSM model to analyze impact of iCow on dairy production and household welfare. Impact was estimated as average treatment on the treated (ATT) on milk production, milk income, household income and food security. The finding indicated that use of iCow services among dairy farmers had a positive and significant impact on milk production and milk income in Nyandarua and Uasin Gishu counties and the impact was insignificant in Bomet. Specifically, the figures revealed that users of iCow services increased their milk production per cow by about 466 litres and 797 litres in Nyandarua and Uasin Gishu counties. In relation to milk income, iCow users in Nyandarua and Uasin Gishu earned about Ksh. 28115 and Ksh.76850 respectively more than non-users. However, results showed insignificant impact on household income and food security in all the counties.

This positive impact shows the potential role of ICT-based extension in rural poverty reduction through increased household incomes. The positive correlation of use of phones in getting timely information among farmers suggest that policies should focus on improving infrastructure in the rural areas for the ICT usage. This include, expansion of electrification programs for access of power for charging the ICT devises. Besides, there is also a need for expansion of mobile network coverage in the rural areas where the network is poor to facilitate exchange of information. Additionally, these findings highlight the need to expand

the iCow services in terms of coverage and even to other livestock and crop enterprises other than dairy industry in rural areas, due to its proven capacity of enhancing smallholder farmers` access to simple, timely information and digital solution. Finally, partnerships between network providers and research institutes should be encouraged as part of bridging the extension gap occasioned by reduced public expenditure on extension services. It is through this that that research institutes will refine the content of the e-extension approaches to meet the needs of farmers.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Rural extension services are at the heart of successful agricultural and rural development (ARD) in developing countries. Effective delivery of these services is seen as 'essential if small farms in high potential areas are to intensify production, contribute to economic growth and reduce poverty' (Poulton *et al*., 2010). Agricultural extension is one of services that play an important role for growth and transformation of the agricultural Sector in Sub Saharan Africa (SSA) (Mukembo & Edwards, 2016). Kenya is one of the SSA countries where Agricultural extension service plays a significant role on the performance of agricultural sector (Joseph & Polytechn, 2017). Benefits such as high productivity, quality of produce, reduction of diseases and pest, maintenance of environmental health and increased income among smallholder farmers are attributed to access to quality extension service (Fu & Akter 2010). A study by Muyanga & Jayne (2006) pointed out that useful information like patterns in livestock and crop prices, high yielding seed varieties, good crop and livestock management practices, and marketing is as a result of agricultural extension services.

Kenya's agricultural extension service is delivered by multiple providers. National Agriculture and Livestock Extension Programme (NALEP) was the main public provider. NALEP used a 'focal area approach' where the commodity-specific extension personnel were deployed to train general extension staff on dissemination of specific technologies in a particular area before shifting to other areas. With the new constitution, agriculture has also been devolved to the county governments and consequently extension services are now provided by the county governments (Mukembo & Edwards, 2016). Other extension providers include agro-inputs manufacturers and suppliers who offer commodity-based extension services in addition to sale promotions. In addition, Kenya Agricultural and

Livestock Research Organisation (KALRO)) under Agricultural Technology and Information Response Initiative (ATIRI) provided information to farmer groups to enable adoption of specific technologies developed by KALRO. Non-government Organizations (NGOs) such as Catholic Relief Services (CRS), One-acre Fund and Action Aid also provide agricultural extensions as part of the broader services to the farming community. Over time, there have been different forms of extension services which include; farm management approach, training and visit approach, farming systems approach, farmer field school approach and use of ICT.

For many years in Kenya, accessing agricultural information by farmers from extension workers has been through interpersonal communications. This seems to be inefficient given that the ratio of extension staff to farmers is 1:1000, which is below the FAO recommended ratio of 1:400 (Manfre & Nordehn, 2013). Coverage by a single extension officer remains high ranging from 20 to 50 square kilometers, with large distances between the farmer groups. Factors such as poor infrastructures have also contributed to this inefficiency (Perumalpillai, 2005). During wet seasons, most of the roads in rural remote areas are impassable which prohibits communication between farmers and the extension staff. According to (Perumalpillai, 2005), access to information and knowledge for farmers in remote villages is hindered by poor infrastructure in the rural areas. Extension systems are underfunded making the Ministry lack the resources to cover transport costs to visit farmer groups and provide services in remote locations. Also, farmers have different and diverse needs that need to be handled differently using extension services that meet those different needs (Mukembo & Edwards, 2016).

Given the limitations of previous approaches, extension services continue to evolve with players exploring new approaches, including application of information and communication technologies (ICT) in delivering advisory services. Studies have shown that use of ICT in the

farming community increases production and income thereby leading to improved welfare (Singh 2006; Lio & Liu 2006; Nyaga, 2012). According to Gelb *et al.* (2008), adoption of ICTs in the agricultural sector has yielded substantial economic, environmental and social benefits at local, nationwide, regional and global stages. However, different stakeholders have come up with strategies to improve access to extension services through application of ICTs, one of them being Green Dream Tech (GDT). GDT is a social enterprise whose aim is to improve farmers` livelihoods by providing cost effective, scalable mobile phone extension service through their iCow platform. The iCow platform offers innovative products which include weekly messages on various agricultural topics, Livestock calendars, iCow Soko-digital marketplace, farmer SMS library and expert directory. GDT in partnership with International Livestock Research Institute (ILRI) and Safaricom Foundation has integrated ICTs through the iCow platform to improve dairy farmer's access to timely, credible and reliable information, services and tools.

Dairy industry, being one of the important sectors in the Kenyan economy, can take advantage of the ICT services in accessing simple, timely and digital knowledge and information towards increasing production. It is the single largest agricultural sub-sector in Kenya contributing 14% of agricultural GDP and 4% of total GDP (Wanjala *et al.,* 2015). There has been an increase in milk production with an average of 5.3% annually, processing capacity at an average of 7% per year, per capita consumption of milk averaging at 5.8% annually and export potential (Rademaker *et al*.,2016). Kenya experiences high and increasing demand for milk and dairy products because of urbanization and rising middle class. However, this sector currently faces major challenges in enhancing its production, processing and marketing (Karanja *et al.,* 2013). Specifically, these constraints include, inadequate amount and quality of feeds, seasonality in feed production, lack of quality animal husbandry and good management practices, poor and inadequate breeding services and

animal health. These constraints have affected the participation and competition of the sector in the domestic and regional markets which has consequently affected income among the players.

1.2 Statement of Research Problem

Despite the great contributions that extension services make to Kenya`s agricultural sector, it currently faces many challenges (Mukembo & Edwards, 2016). Some of the major challenges that the extension sector face are poor and inadequate infrastructure and ineffective mechanisms for sharing and exchanging relevant and useful agricultural knowledge and technologies that is generated from research centers in a timely and reliable ways (Rafea, 2009). In view of these challenges, Cole & Fernando (2012) suggest that reduction of these inefficiencies may lead to improved agricultural productivity and farmer welfare.

Given the stated challenges, extension services continue to evolve with players exploring new approaches, including application of information and communication technologies (ICTs) in delivering advisory services. The use of ICTs in extension service in disseminating agricultural information in a timely, credible, reliable and less costly manner has been explored (Stienen, 2007). Studies have shown that use of ICT in the farming community increases production and income leading to increased welfare (Singh, 2006; Lio and Liu 2006; Nyaga, 2012). According to Gelb *et al*. (2008) adoption of ICTs in the agricultural sector has yielded substantial economic, environmental and social benefits at local, nationwide and global stages. Use of ICTs by extension agents in gathering, retrieving, adapting, and disseminating a broad range of information needed by rural farming communities has made positive contributions towards rural development (Stienen, 2007). Fu & Acter (2010) reported that the use of mobile phone technology in the farming community improved the quality and speed of the delivery of extension services significantly. In line with these developments, several ICT-based programs have been developed in Kenya to

address the challenge of low farm productivity and to improve agricultural performance among smallholder farm households. These programs include; iCow program, Kenya Agricultural Commodity Exchange (KACE), National Livestock Market Information System (NLMIS), Regional Agricultural Trade Intelligence Network (RATIN), National Farmers Information Service (NAFIS) and M-farm among others. However, the current study focused on the iCow`s ICT-platform and services as a tool for dissemination of information among smallholder farmers dairy farmers. The expectation is that, farmers participating in iCow would use the acquired technical information and apply superior production technologies and husbandry practices to realize higher outputs. The surpluses in milk production is sold leading to increased income from dairy. This would subsequently have an effect on household food security through directly consumption of milk and indirectly through increased income.

Although previous studies have assessed the use of ICTs in agriculture, most of these studies focused mainly on the application of ICT tools in market information systems (MIS) and ignored other aspects of the value chain (Ogutu *et al* 2014; Hassan *et al.,* 2008; Okello *et al.,* 2010; Oyeyinka *et al.,* 2013). Additionally, more attention has been given on the use if ICTs by extension officers (Tata and Mcnamara 2018; Fu and Akter 2012). However, there remains a dearth research on the use of ICT extension tools at the production level by smallholder farmers. The study evaluated whether the agricultural advisory services delivered by iCow are better placed to strengthen productive capacity of the smallholder dairy farmers to ensure improved incomes and food security.

1.3 Purpose and Objective

The purpose of this study is to determine the impact of iCow service on milk production, milk and household income, and food security among smallholder dairy famers' in Uasin Gishu, Nyandarua and Bomet counties of Kenya.

1.4 Specific Objectives

a) To evaluate the socio-economic factors that determine the participation in the iCow program among smallholder dairy farmers.

b) To determine the impact of iCow service on milk production among smallholder dairy farmers.

c) To determine the impact of iCow service on milk and household income among smallholder dairy farmers.

d) To determine the impact of iCow service on food security among smallholder dairy farmers.

1.5 Hypotheses

i. Individual socio-economic factors like age, education, household size etc. have no influence on participation in iCow among smallholder dairy farmers.

ii. The iCow service has no impact on milk production and household income among the dairy smallholder farmers.

iii. The iCow service has no impact on milk and household income among the dairy smallholder farmers.

iv. Use of iCow service has no impact on food security among smallholder dairy farmers.

1.6 Justification of the study

The information generated from this study will be valuable to extension agents, farmers, agricultural and livestock policy makers, extension delivery systems and researchers. The results on the impact of iCow service will provide information to smallholder farmers on potential benefits of ICT extension approaches in the dissemination of knowledge and skills.

Results on the impact and the factors that determine farmers' participation in ICT extension tools, will provide useful insights to policy makers in designing effective educational approaches for disseminating information particularly that targeting smallholder farmers. As such, the estimates will also provide project partners with sufficient information needed for the investment decisions of promoting the iCow service.

The study will provide an objective basis for re-evaluation of future development and packaging of technologies that contribute to food security in the Kenya. This is study is in line with the country's agenda of big four which focuses to improve food security in country. The outcome will be a valuable reference for any future necessary improvements on the ICT extension approach.

1.7 Limitations of the study

This study investigated the impact of iCow services on milk production, household income and food security among dairy farmers in Uasin Gishu, Nyandarua and Bomet Counties of Kenya. The iCow service was designed to relay information to farmers through short messages service (SMS). There could be a possibility of the messages being forwarded by the registered farmers to the non-users leading to contamination of the control group.

1.8 Organization of the thesis

This thesis is organized into five chapters. Chapter two includes review of both empirical and theoretical literature. Chapter three encompasses the methodology used to analyze data collected. Chapter four reports on both descriptive and econometric analysis. The final chapter includes summary, conclusions and policy recommendation.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Dairy Sector in Kenya

The dairy sub-sector contributes to the livelihoods and nutrition of the rural communities hence has the potential of contributing to the country's goals such as Vision 2030 (Wanjala *et al.,* 2015). The sector contributes about 4% of gross domestic product (GDP). There has been an increase in milk production with an average of 5.3% annually and increase in processing capacity at an average of 7% per year, per capita consumption of milk averaging at 5.8% annually (Rademaker *et al*.,2016). Kenya experiences a growing demand for milk and dairy products due to urbanization and a rising middle class.

The sector is mainly dominated by smallholders with approximately 3.5 million dairy cattle, and production is estimated at 5 billion litres of milk annually (Kenya National Bureau of Statistics, 2016). Smallholder dairy farmers contribute more than 70% of gross dairy product marketed. Other players in dairy production are co-operative societies and farmers groups who handle 40% of total milk marketed (Wanjala *et al.,* 2015). Dairy sector has been linked to significant contributions to livelihoods and income generation among smallholder farmers. It is a source of employment and income generation, which includes both self-employment and market agents, hired labour on farm and in the market (Smale *et al*., 2012). Small scale Dairy farming is majorly practiced in the highlands of the Rift Valley and Central regions and the Coastal lowlands. Smallholder dairy farms are highly concentrated in peri-urban area mainly due to the ease of access to channels of marketing milk. Most of the Smallholder dairy farmers keep 2 or 3 dairy cows, on approximately one hectare of land. According to Staal (2014), large-scale dairy farms are mainly owned by both public institutions, private firms, such as the Agricultural Development Corporation (ADC). Friesian cattle are the

dominant breed, but Jersey and Ayrshire breeds are also found with some farms in the dry areas keeping cross breed of Sahiwal with Bos Taurus breeds.

2.2 Milk Production Status and Trends

There are significant and positive changes in the dairy industry which has resulted in a major shift and focus towards market-oriented production among the smallholders. This could be mainly caused by climatic conditions, high and rising urban population, significantly improved fodder technology among dairy cattle population, high incomes and the high consumption of milk and dairy products (Kinambuga, 2010). Kenya is among the leading African milk producing countries, in terms of volume accounting for 48% together while Sudan, Egypt, South Africa and Algeria each producing 52% of the total milk in Africa. Kenya is estimated to produce more than 4 billion litres of milk per year, mainly from central and rift valley regions.

Due to growth in human population, the demand for livestock products has risen and it is estimated that twice as much milk and meat will have to be produced in the next 30-35 years to satisfy this demand (Wamjala *et al.*, 2011). Thus, livestock production will have to be even more intensive. It will also depend heavily on efficient and effective use of inputs, which will require increased knowledge of better farm or enterprise management. In addition, information will be required to support new enterprise development in response to changing farming systems, increased demand for livestock products and opportunities for investment in livestock as financial incentives increase (Kinambuga, 2010).

2.3 History of extension services in Kenya

Agricultural extension services have been instrumental in ensuring that farmers stay abreast of new developments to improve their productivity and economic livelihoods (Mukembo & Edwards, 2016). Major transformations and developments have been seen in the agricultural

extension se since the precolonial, during colonization and after independence in Kenya. Before 1914, the extension services in the African countries were offered by the missionaries while spreading the gospel who established demonstration farms (Jones & Garforth, 1997). In the Scramble for Africa, departments of agriculture of colonial governments involved more in administration hence putting less focus in agricultural extension (Jones & Garforth, 1997). However, during colonization and before independence, British colonies in Sub-Saharan Africa used agricultural extension as a tool to encourage rural African population to adopt new technologies and practices that would enable them improve production but mainly benefitted their colonial masters (Birmingham, 1999; Alonge, 2003; Davis, 2008). According to Wichramasinghe (1981), farmers had little inputs and their views were never considered at all. The approach that was mainly used was the top-down approach extension, characterized by coercion whenever farmers failed to adhere and follow what was required of them in adopting new practices (Alonge, 2003).

Historically, according to National Agricultural Sector Extension Policy (NASEP,2012), Kenya had two extension delivery systems. One extension service system was geared towards the white settlers that was well packaged with subsidized inputs and credit, and the other was indigenous Africans that was considered coercive in general. After Kenya gained independence, it was the responsibility of the National Government to deliver agricultural extension services through its Ministry of Agriculture (Davis & Place, 2003; Nambiro *et al.*, 2006). The government mainly provided extension services focusing on food production. The commodity-based extension was supported by the parastatals, private sector, and corporations producing crops of commercial purposes (Muyanga & Jayne, 2006, 2008). Davis & Place (2003) noted that research and extension in Kenya mainly aimed at serving large-scale farmers and smallholders in high and relatively medium-potential areas. Transfer of

Technologies (ToT) majorly were developed in research centres where demonstrations and trials were mainly carried on research stations without engaging farmers.

During 1970s, Kenya adopted the system of whole farm approach which used integrated agricultural development approach (NASEP, 2012,) establishing extension services that targeted small-scale farmers. Farming Systems Research (FSR) was introduced focused on on-farm testing and refining of technologies (Nambiro *et al.*, 2010). The FSR model was decentralized in nature with a lot of trials of on-farm and involving farmers which provided linkage between farmers, researchers, and extension providers, but this approach could not effectively address the multiple and often diverse needs of farmers (Nambiro *et al.,* 2010).

In 1980s, a new extension approach of Training and Visit (T&V) was introduced and its aim was to transfer information and technology through extension workers and contact farmers to the general farming community. However, T&V approach used poor channels of communication between researchers and farmers, the so called a "'cookbook'" model (Davis & Place, 2003; Nambiro *et al.,* 2010) and could not address the varying needs of heterogeneous groups of farmers. Field staff were not able to account to the rural people and hence they ignored the priorities of local people while trying to satisfy supervisory personal (Muyanga & Jayne, 2006). Additionally, T&V did not work due to high expenses and low coverage of extension workers as the ratio of extension worker to farmer was very high.

To improve the situation, a new extension approach based on Farmer Field School (FFS) was introduced in 2001. The FFS uses participatory methods in enhancing farmers` knowledge and skills in the use of the agricultural technologies. It is a group extension teaching method, which teaches basic farm management skills to make farmers experts in their own farms. The knowledge acquired during the learning process enables farmers to adapt their existing technologies to be more productive, profitable, and responsive to changing conditions, or to

test and adopt new technologies (Mweri & Khisa, 2001). However, use of these methods of extension to some extent improved the production of farmers but did not fully meet their needs.

In the early 1990s, World Bank provided funds that were geared towards reforming extension systems in Sub- Saharan Africa whereby Kenya became the first beneficiary (Venkatesan & Kampen, 1998). There was some shift from system of top-down to a horizontal, farmer-driven and participatory approach of extension system which led to a decentralization extension service (Nambiro *et al.,* 2006). This decentralization included structural reforms with the objective of shifting extension services to the other institutions (Nambiro *et al.,* 2006). It also aimed at increasing the farmer`s participation in decision making. Decentralization of extension services also facilitated the entry of other organizations including the private sector, community-based organizations, cooperatives, faith-based organizations, non- governmental organizations (NGOs), parastatals, (Muyanga & Jayne, 2006; Nambiro *et al.,* 2006; NASEP, 2012). According to Rivera (1996), decentralization of extension services enables farmers to make decisions that are independent and are suitable for their needs. This promotes sustainability and increases the likelihood of commitment and collective responsibility amongst farmers regarding the decisions they make. The government of Kenya has encouraged a demand-driven system and participatory approach in the delivery of extension services Farmer Field Schools (FFS) being a good example (NASEP, 2012).

2.4 Challenges in livestock extension

Livestock production extension has in the past faced institutional problems, being marginal to both agricultural extension and animal health services. Until 1986, Livestock Production did not exist as a department in the Ministry and neither fitted in the department of agriculture, nor in that of Veterinary Services (Nambiro *et al.,* 2006). The institutionalization of livestock extension was also affected by repeated changes of policy over the existence of a

separate livestock ministry, which resulted in frequent separation and merging of the Ministries of Livestock Development and that of Agriculture. These ministries were merged in 1984, separated in 1987 and merged again in 1992. Dairy farmers therefore benefited more from ODA/World Bank Project than the general government extension service (Muyanga & Jayne, 2006). The public sector extension system may not be capable of providing all the information that farmers might need due to the broad nature of its clientele and limited resources. Some of the other stakeholders in provision of such information are NGOs, farmers' organisations, the private sector, and even individual farmers (Evans, C. L., 2014). There have been many instances of successful collaboration in the field between the public sector extension services and NGOs, farmer organisations and the private sector to strengthen the quality of extension services (Evans, C. L., 2014). For instance, there is collaboration between the MALDM and NGOs such as Plan International, Heifer Project International, World Vision, private companies such as Cooper (K) Ltd, Unga Feeds Ltd and Dairy Co-operatives.

2.5 Linkage between Agricultural extension services farm productivity and incomes

Agricultural extension involves transferring knowledge and information to farmers through educating and advising them in decision making and enabling them to be able to clarify their goals and possibilities and hence stimulating desirable development in agriculture. Strengthening of national agricultural extension service system has been advocated as a strategy towards increasing agricultural production in Sub-Saharan Africa by governments in the region (World Bank, 1983).

Extension services has a positive effect on productivity, income and improving the welfare (Joseph & Polytechn, 2017). Dercon *et al.* (2008) noted that there is a positive impact of extension on poverty and consumption growth in Ethiopia. World Bank (2005) studying the impact of agricultural extension on household income in Mozambique concluded that

agricultural extension services have positive effects on rural livelihoods in Mozambique, which contradicted the earlier study of Walker *et al.* (2004) which found a statistically insignificant negative impact of agricultural extension on individual and household income in Mozambique. These contradictions in impact studies could be as a result of predictability, complexity, affordability and acceptability of innovation packages, dissemination methods and innovation packages of impact for adoption by a targeted group (Dan, 2015).

Bonye *et al.* (2012) argued that extension provides a source of information on new technologies for farming communities which when adopted can improve production, incomes and standards of living. Through extension services, farmers' problems are identified for further investigation and policy direction. Swanson (2008) argued that extension service goes beyond technology transfer to general community development through human and social capital development, improving skills and knowledge for production and processing, facilitating access to markets and trade, organizing farmers and producer groups, and working with farmers towards sustainable natural resource management. Where market failures such as limited access to credit and non-competitive market structures that provide a disincentive to farmers to produce exist, extension services tend to provide solutions.

Lapple *et al.* (2013) found a positive relationship of €310 per hectare (12%) of the gross margin for the farmers who participated in dairy discussion groups. Bogue (2014) evaluated the beef discussion group scheme and found that on average, discussion group members had higher margins as well as increased profit, animal performance and grazing seasons. Additional benefits were identified due to enhanced management practices learned from the discussion groups, and that discussion group members were more likely to adopt emerging technologies and practices. Evidence indicate that when agricultural extension systems are well designed and implemented, it results into improved agricultural productivity, increased

food security, improved rural livelihoods, and pro-poor economic growth (Muyanga & Jayne, 2006; Swanson *et al.,* 2007; FAO, 2015).

2.6 The iCow services

The iCow services are offered by Green Dream Technology (GDT) in partnership with Safaricom Foundation and International Livestock Research Institute (ILRI) with the aim of improving extension services among smallholder farmers. The iCow platform achieves this through a cost effective scalable mobile phone extension service, which provides farmers with basic, simple, timely knowledge and digital solutions that would improve their production. The iCow platform offers innovative products which include weekly messages on various agricultural topics, Livestock calendars, iCow Soko-digital marketplace, farmer SMS library and expert directory.

The iCow services were rolled out in Uasin Gishu, Nyandarua and Bomet counties of Kenya where dairy farming is practiced and contributes highly to the smallholder livelihoods. The services were zero rated and farmers received three content rich SMS on animal husbandry practices each week to enable them to improve their practices on the farm

2.7 Role of ICTs in enhancing knowledge and information access among smallholder farmers

Information communication technologies (ICTs) can be referred to as software, hardware, media and networks for collecting, processing, storing, transmitting and presenting information in the format of data, voice, images and text (World Bank, 2002). Different types of ICTs include internet, computers, mobile phones, geographical information systems (GIS), television and radio which have been used to deliver agricultural information to the farmers (Stienen *et al.,* 2007). The contribution of ICTs to agricultural and rural development has been recognized (Singh, 2006). According to Stienen (2007), ICTs have shown positive

contributions towards rural development. Extension agents use ICTs in gathering, retrieving, adapting, and disseminating a broad range of information needed by rural farming communities. The use of the existing information and communication technologies (ICTs) can highly improve networking between farmers, buyers and extension agents (Nyaga, 2012). A study in India conducted by Fu & Acter (2010) found that use of Mobile phone technology improved significantly the quality and speed of the extension services. Singh (2006) noted that radio and TV programs significantly helped the farmers in South Korea in receiving support for improved crop production, quality control, processing, packaging and marketing indicating that ICTs have helped to fill the gap existing in extension service provision, hence improving agricultural productivity.

Agricultural value addition also requires institutional, technological and price incentives which needs to be designed raising the productivity of the smallholder farmers (Salih, T.M., 2000). Studies from rural Thailand and Columbia indicated that introduction of mobile phones helped farmers in checking prices, and this led to increased farm incomes (Brynolfsson & Hitt ,1995). Lio & Liu (2006) found that adopting modern industrial inputs in the agricultural production depends and relies mostly on the communication and information infrastructure. (Brynolfsson & Hitt ,1995) also found out that the use of ICT has a significant and positive impact on the agricultural outputs for bigger farms in the USA. A study by Jensen (2007) in India, indicate that fishermen who adopted the use of mobile phones helped to reduce price dispersion, eliminated waste and sticking to one price, hence benefitting both the traders and fishermen. According to the study conducted by Kwadwo & Ayalew (2011), a local company implemented a Cocoa link to provide cocoa farmers useful and beneficial information about farm safety, crop disease prevention, improving farming practices postharvest and production. Through the program, farmers were able to receive information and answers in regard to questions without charging them through voice and SMS messages

in the local language or English. India used Reuters Market Light (RML) to send its subscribers four text messages in a day. Farmers subscribed to this system and consistently received information and knowledge on their crops, weather and the projected and current commodity prices in different markets (Kwadwo & Ayalew, 2011).

ICT is a useful tool of contributing to development at local, national and even around the world (UNDP, 2001). ICT enables transparent and efficient storage, processing and presentation of information and innovation that can lead to economic and social change (Kaushik & Singh, 2004). Investing more in ICT has a positive association with growth in both GDP and productivity (Kraemer & Dedrick, 1994).

Mobile devices like phones and tablets are some of ICT tools that can be used to accomplish the reduction of challenges faced by farmers because they are becoming the most popular forms of global connectivity (World Bank, 2005). In 2010, mobile phone subscribers from developing countries were 75 per cent of the total global subscriptions (Baumüller, 2012). The devices can be used to help farmers reduce information and transport costs, market their produce and provide a platform to deliver services and innovations hence raising famers` income (World Bank, 2011; Muriithi *et al.,* 2009). It is reported that Mobile phones is the ICT tool that is widely possessed among farmers (Hassan *et al.,* 2008; Okello *et al.,* 2010). This indicates the high level of penetration of technologies among rural populations which should be appropriately used to offer large scope for growth and development in rural areas. Mobile technology has been significant to people living in rural areas in terms of information sharing and its importance cannot be ignored during urgency and emergency (Sife *et al.,* 2010). For example, farmers use ICTs in knowing market days, where to sell their products and in identifying different market location for efficient and effective marketing of their produce (Oyeyinka & Bello, 2013). However, ICT applications like calls and Short

Messaging Services are often used by farmers in accessing information in a timely manner which has contributed to higher production (Mtega & Msungu, 2013).

2.7 Constraints in the usage of ICTs in dissemination of information

Despite the benefits ICTs in dissemination of information, they are also faced with constraints which mainly are infrastructural in nature. The research findings from Chilimo (2008) and Ajani (2012) revealed that low network connectivity and low power supply are the main constraints that affect use of ICTs among the farmers. For instance, using mobile phones entirely depend on the availability of infrastructure of mobile phone and recharging the batteries (Mtega & Msungu, 2013). Also, poor electrification in the rural areas has been the major challenge in the expansion of ICT facilities (Oyeyinka & Bello, 2013). There has been low know how, lack of confidence and fear in operating ICTs which greatly hinders the use ICT among farmers (Agwu *et al.*, 2008). However, some farmers are not aware of opportunities and benefits of using ICTs in agriculture and rural development purposes (Asian Development Bank, 2008). Other challenges include; lack of practical exposure of operating the ICT tools, long distance to repair and maintain ICT tools and high cost of hardware and software (Agwu et al., 2008 and Oyeyinka & Bello, 2013).

2.8 Theoretical framework

This study was informed by three theories; i) theory of expected utility ii) Diffusion of Innovation (DoI) Theory and, iii) Theory of change.

2.8.1 Theory of expected utility

The theory of expected utility as developed by Bernoulli (1738), has been applied in several studies on farmer decision-making in many aspects (Babcock and Hennessy, 1996; Gomez-Limon *et al.*, 2004). Following Bernoulli (1738), participation in iCow ICT program is viewed as a binary choice decision problem by farm households that try to maximize utility

or net returns. Utility is determined by a set of variables *Z*, which influence the cost of adjusting to a new extension approach involving ICT (such as the cost of acquiring a mobile phone and the time spent on reviewing messages relayed by the platform). Variables in *Z* also determine the relative returns that a farmer can earn from adopting iCow approach to extension. Thus, *Z* can include household characteristics such as educational status and farming experience, both of which influence ability to synthesize relayed information and optimize farm decisions based on provided information.

The probability that farmers participate in iCow platform is therefore determined by a comparison of the expected utility of participation in iCow extension program, U_{ip}, against expected utility of participating in conventional extension program, U_{iN}. In making this comparison farmers evaluate both benefits and the cost of adjustment mentioned above. Farmers therefore participate in iCow program only if $U_{ip} > U_{iN}$, implying that the potential benefits outweigh the constraints and this difference in utility can be represented by a latent variable, R_i^*, i.e., $R_i^* = U_{ip} - U_{iN} > 0$. However, R_i^* and is a latent variables; what is observed is actual participation in iCow program, R_i, with $R_i = 1$ if $U_{ip} > U_{iN}$ and $R_i = 0$ if $U_{ip} \leq U_{iN}$. Participation in iCow program can therefore be represented as follows:

$$R = Z\alpha - v \quad \text{.....2.1}$$

where α is a vector of parameters, and v is an error term with zero mean and variance σ^2. Since farmers are heterogeneous in their characteristics, not all of them participated in the iCow program. Participation in the iCow program is expected to result in higher farm returns that may also affect household livelihood outcomes such as income and food security.

2.8.2 Diffusion of Innovation (DoI) Theory

Diffusion of Innovation (DoI) theory (19962), commonly referred to as Rogers' innovation diffusion theory presumes that a new practice, idea, or object has a perceived channel, time

and mode of being adopted by individuals or organizations. Rogers has defined diffusion as 'a process by which an innovation is communicated through certain communication channels over time among members of a social system' (Rogers 1995). In this study diffusion is seen as a process by which the innovation, that is, iCow service, is communicated over time among smallholder dairy farmers. Each adopter's willingness and ability to adopt an innovation would depend on the utility derived and other socio-economic factors.

2.8.3 Theory of change

The theory of change as developed by Weiss (1995, 1998) shows a model of linking program inputs and activities that lead to observed outcomes (Rogers *et al.*, 2000; Rogers, 2014). Rogers (2008) points out that in this theory, there is need to include the context of the program under evaluation and characteristics of the participants. In the iCow program, the inputs include the information sent to dairy farmers while the expected outputs include higher milk production increased incomes and attaining sustainable producer's food security

In the microeconomic theory of welfare, each *i* individual will attempt to maximize welfare W_i and this will depend on the bundles of available to them at a given time c_i such that;

$$W_i = w_i\ (c_i) \quad \text{..... 2.2}$$

Where W_i is the individual welfare function. However, the same bundle of goods has different welfare levels for different individuals' depending on observable characteristics vector x, such as age, marital status, farming experience and education.

$$W_i = w_i\ (c_i; x_i) \quad \text{..... 2.3}$$

Theoretically, if we have bundle of goods c_i and observable characteristics x_i then we can obtain W_i. However, sometimes bundles of goods c_i may not be fully observed for due to some complexities.

Then, the level of welfare achieved by an individual, can be measured according to the availability of resources, r_i to the i[th] individual and their capabilities;

$$W_i = w[c_i^*(r_i); x_i] = w(r_i; x_i) \quad \text{.....2.4}$$

where c_i^* (bundle of goods) will depend on resources r_i available . As pointed out by Jena *et al.* (2012) the bundle of goods c_i^* specified by the society are not the same as observable goods c_i observed for an individual because of diverse preferences. Individuals will choose bundles of goods resources that will improve their welfare. iCow program is an opportunity which individuals can take up to achieve expected outcomes. In this theory iCow is introduced as a proxy resource r_i with the aim of increasing individual`s welfare W_i and rewritten as;

$$W_i = w[c_i^*(r_i); x_i] = w(c_i^*(T_i; x_i) \quad \text{..... 2.5}$$

where T_i represents is a dummy variable for iCow; i=1 for regular iCow users (treatment group) and i=0 for non-users (control group).

Individual welfare, w_i, was measured as the total milk production, household income and food security of each individual household as a function of household characteristics, participation in iCow program and error term.

$$w_i = (Y_i = \beta_i X_i + \gamma T_i + \varepsilon_i) \quad \text{..... 2.6}$$

Then the regression equation is estimated as follows:

$$Y_{it} = \beta_i X_i + \gamma T_i + \varepsilon_i \quad \text{.....2.7}$$

Where Y_{it} a binary outcome variable of interests, i.e., Y_{i1} for iCow regular users and Y_{i0} for non-users. X_i are household, farm characteristics and institutional characteristics, T_i is a binary variable for participating in iCow program and ε_i, the error term.

CHAPTER THREE

3.0 METHODOLOGY

3.1 Conceptual Framework

Participation in iCow by smallholder dairy farmers is determined by access to institutional support services, farm and farmer characteristics as shown in Figure 1. These factors have an influence on farmers' decision to participate in iCow platform.

For those who participate, it is expected that iCow platform will provide timely and reliable information on husbandry practices that will have an impact on the general production in the farm. There will be improved animal health through the information the farmers receive on vaccination, spraying, mastitis control and deworming. Nutrition will improve due to information on fodder management, feed quality.

Information on record keeping will help farmer to enhance planning and forecasting. Proper application of good management practices on dairy cows will reduce the incidences of diseases and consequently there will be reduced intake of antibiotics and this will improve both human and animal health. Information from iCow will help the farmers improve animal and human hygiene and this will influence the production of clean milk and reduce human disease outbreak.

Finally, it is expected that iCow will positively influence access to agricultural knowledge, leading to improved yields and increased surpluses will be sold to increase dairy income. This would subsequently impact on household income. Food security will improve through increased consumption of milk and indirectly through increased income. With higher incomes farmers can buy and diversify into other food stuffs that improve their food security.

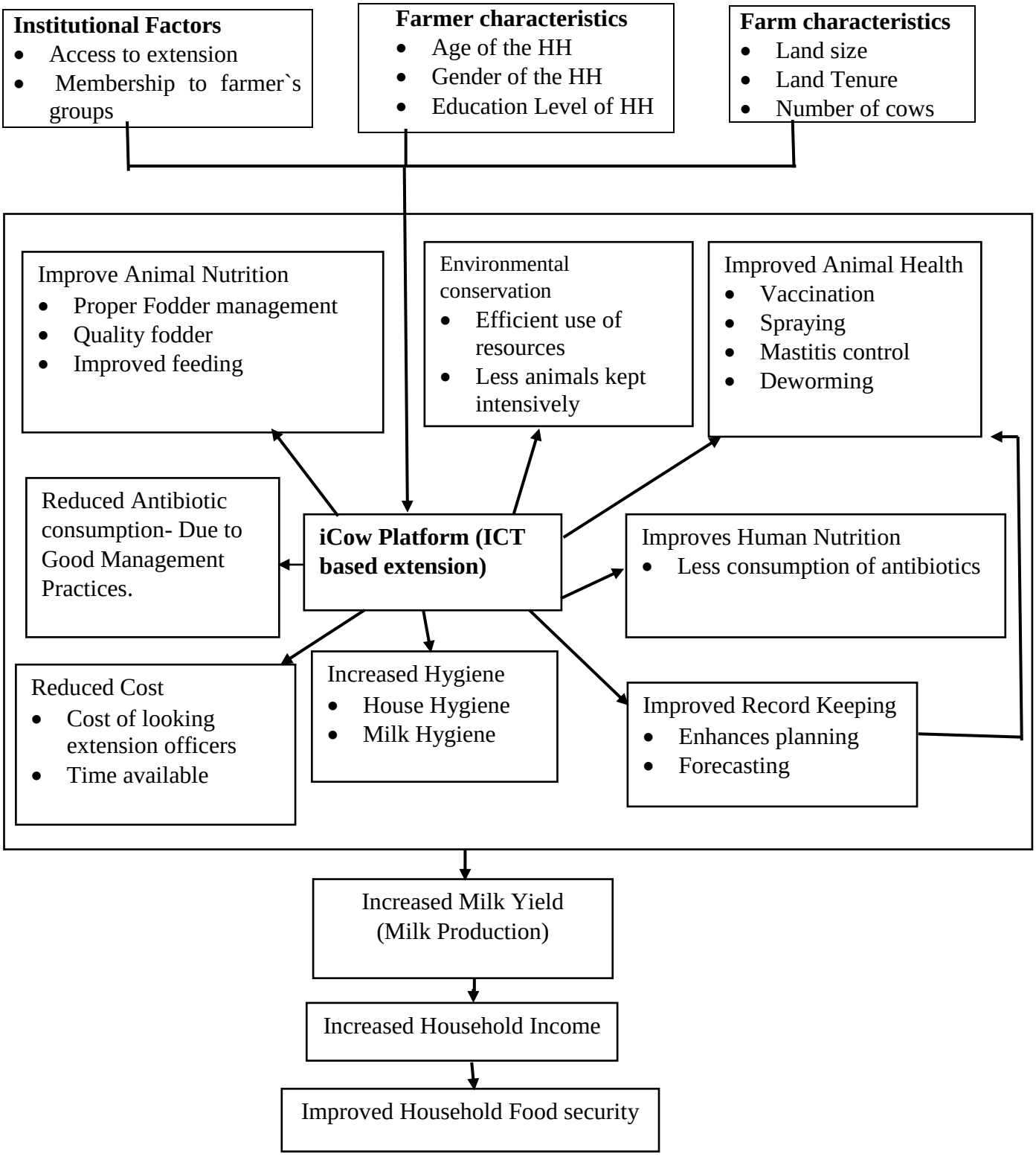

Figure 1: Conceptual framework on the expected impact of iCow program on milk production, income and food security

Source: Author's conceptualization

3.2 Study area

The study was carried out in Uasin Gishu, Nyandarua and Bomet counties of Kenya as shown in Figure 2. These three counties were purposively selected for the study because of the high percentage of smallholder dairy farmers and also iCow program was piloted and rolled out in these counties. Treatment group (regular users of iCow) was obtained from Sirikwa, Olkalao and Siongirio Dairy cooperatives in Uasin Gishu, Nyandarua and Bomet respectively. To address the challenge of spill overs, the control group (non-users of iCow) were selected from different dairy cooperatives within each county, but approximately 15 kilometres from the dairy cooperatives that were regular users of iCow platform. These control Dairy cooperatives were; Tarakwa, Miharati and Ndanai in Uasin Gishu, Nyandarua and Bomet counties respectively.

3.2.1 Uasin Gishu County

Uasin Gishu County covers a geographical area of 3,327 sq km, which 2,995 sq km is arable land while the rest (332.78, 23.4, 196) sq is hilly and rocky, water mass and urban respectively. It receives an average rainfall of from 900mm to1200mm per annum with peak in May and October with temperatures ranging from 8.4^0 C to 26.2^0 C. The county has three agro ecological zones; lower, upper highland and upper midland zones. It is subdivided into five sub counties namely; Turbo, Moiben, Ainabkoi, Wareng, Kesses and Kapsaret, however, this study covered Kesses and Moiben sub-counties.

The county has a human population of 894,179 people and 167,887 households (NPC, 2009). The average farm size in the county is between 2-10 acres. There are three main livelihoods in the County i.e., mixed farming (food crops and livestock), mixed farming (commercial crops and livestock –dairy) and formal/casual employment. Agriculture sector comprises of livestock production, veterinary, agriculture and fisheries departments.

The dairy sector is a crucial and important enterprise among farmers in the county. There are approximately 375,287 dairy animals of which 81,838 are exotic grades. The average milk production from dairy cattle is 5 litres per cow per day which is only 50% of the average potential yield. Access to markets for dairy products is constrained by inadequate market information, disease outbreaks which result in the closure of livestock markets, poor infrastructure especially roads, livestock holding grounds. Moreover, processing facilities like milk processing plants, coolers, are inadequate forcing farmers to sell their products with little value addition

3.2.2 Bomet county

Bomet county has a geographical coverage of 1,630.0 km^2 and with a population density of 384 per sq. km (BCIDP,2013) and it lies between latitude 0° 29′ S and 1 ° 03′S and between longitudes 35º 05′ East and 35° 35′ East. The county is a highland county with high rainfall that favors dairy production which is the main socioeconomic activity. Other agricultural activities in the county include growing tea and maize, horticulture. The county has five sub-counties namely, Bomet East, Bomet Central, chepalungu, Sotik and Konoin, but this study focused on Sotik and Chepalungu sub-counties.

The population of Bomet County was estimated at 723,813 (50.3% women and 49.7% men) in the 2009 Population and Housing Census. The county has road networks which are mainly gravel and earth surface which are highly affected during the rainy season. The main livelihood in the county is through crop and livestock production.

Bomet County records a daily total production of about 397,000 litres of milk with dairy farmers selling their produce to local dairy cooperatives who sell to processors including, KCC, Highlands, Brookside and Daima dairies among others. The existence of local coolers

assists farmers to store and preserve milk as they negotiate on better milk prices through respective cooperative societies.

3.2.3 Nyandarua county

Nyandarua County has a population of 596,268 and an area of 3,304 km². It borders Laikipia County to the North, Nyeri and Muranga Counties to the East, Thika and Kiambu Counties to the South, and Nakuru County to the West. Agriculture is the main activity of the county with Dairy farming being the main activity in the area. Production of irish potatoes is also another sector that contributes to the economy of the county. It has five sub-counties namely, Ol Jorok, Kinangop, Kipipiri and Ndaragwa. However, the study was carried out in Olkalao and Kipipiri sub-counties.

The county experiences two rainfall seasons in a year- the long rains season start during the month of March and end during the month of May while the short rains season start in the month of September and end in the month of December. Maximum rainfall is received during the long rains season while the minimum rainfall is received during the short rains season. Annual rainfall ranges between 400mm and 1700mm. The County experiences moderate to low temperature which ranges between of 25^0C and 12°C.

The livelihood activities in the County include; livestock keeping, crop farming, small businesses (retailing) with minimal mining, tourism and industry. Crop production for subsistence and livestock keeping are the main agricultural activities. Dairy farming is the main activity in livestock subsector with about 317,0000 heads of dairy cattle and annual milk production of 234 million litres.

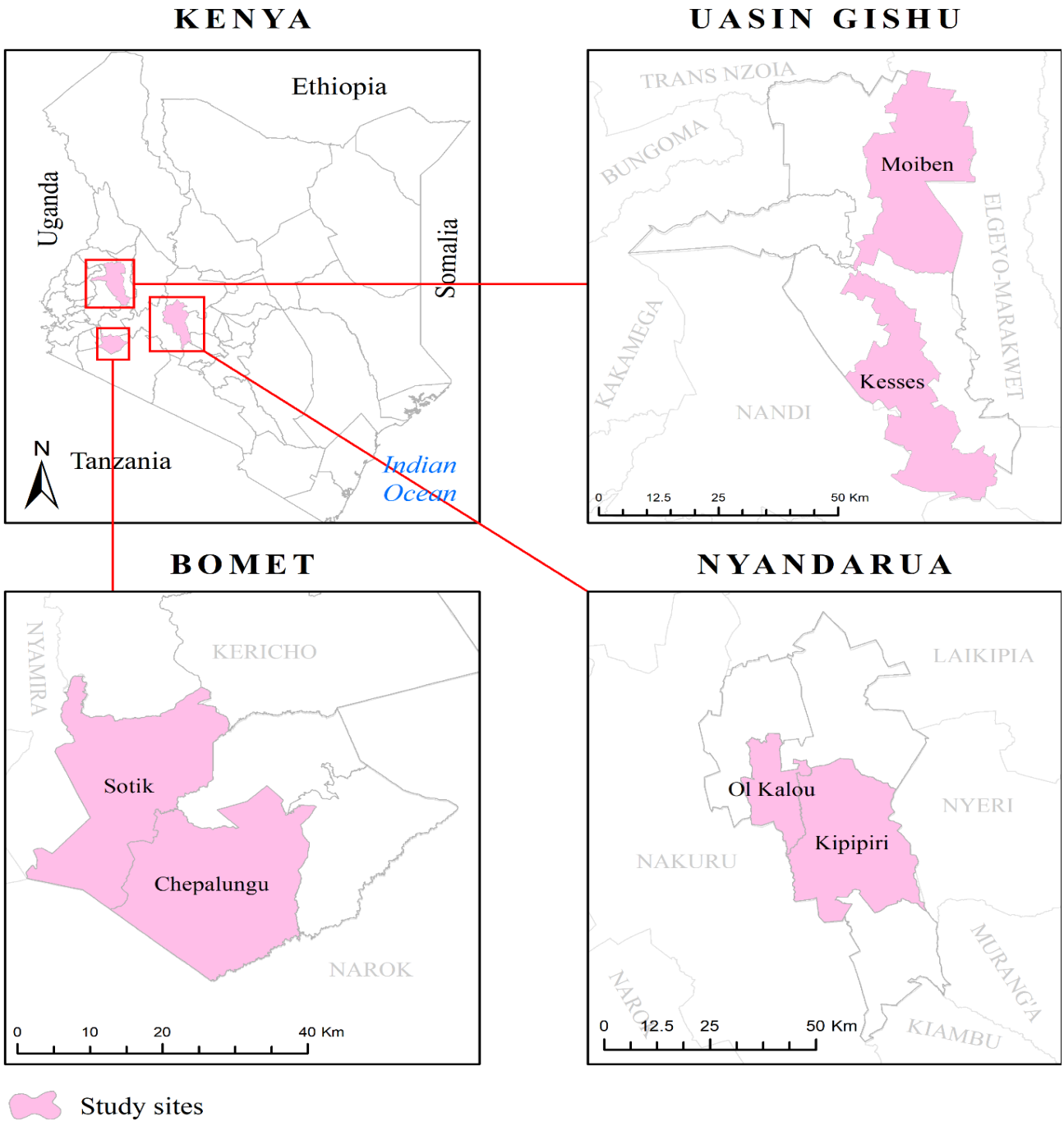

Figure 2: Map of Nyandarua, Uasin Gishu and Bomet counties

Source; created from Arc-GIS by Author

3.3 Methods and procedure

3.3.1 Research design

The research was quantitative in nature with household data being collected using semi-structured questionnaires. iCow services were introduced in 2013 among the small holder

dairy farmers in Nyandarua, Uasin Gishu and Bomet counties. The current survey was therefore conducted to determine the impact of iCow on milk production and household welfare. The respondents in each county were categorized into two groups comprising of the treatment and control group. The treatment group received text messages three times a week from iCow on dairy management practices while the control group (non-users of iCow) on the other hand comprised of farmers that did not receive text messages from iCow. This research design was important in comparing any differences in milk production, incomes and food security between the two groups. Furthermore, it was instrumental in assessing the role socio-economic factors that influence participation in iCow.

3.3.2 Sampling procedure

The study used a three-stage stratified random sampling procedure to obtain respondents for the study in the three counties. In the first stage, three dairy cooperatives namely Sirikwa (Uasin Gishu), Olkalao (Nyandarua) and Siongirio (Bomet) were purposively selected to provide the sampling frame for users of iCow services. These are the counties that had been targeted by GDT for piloting and eventual rollout of the iCow services. Since GDT targeted the entire membership of these cooperatives, it was not possible to find reasonable number of non-users of iCow services among members of the 3 dairy cooperatives. Moreover, any non-users may have been influenced in their livestock husbandry practices owing to their proximity to users. The study therefore also purposively selected three other dairy cooperatives within the same counties, but with almost similar observable characteristics like age, education, land size, number of animals kept with the treatment cooperatives. It was made sure that the members of these cooperatives had not participated in the iCow services. To address the challenge of spill overs, these control cooperatives were significantly far away from the treatment dairy cooperatives that participated in the initial rollout of iCow services. These control cooperatives were; Tarakwa, Miharati and Ndanai in Uasin Gishu, Nyandarua

and Bomet respectively. Their membership formed the sampling frame for non-users of ICow services.

In the second stage respondents were randomly selected from the list of users of iCow service (members of the treated cooperatives) as well as non-user (members of control cooperatives where iCow services had not been piloted). The lists of members that formed the sampling frame in each case were obtained from the list of registered farmers as contained in the Kenya Dairy Farmers Federation (KDFF) registry. The respondents were randomly sampled from the two lists using proportionate to size approach. Meaning more respondents were sampled from the list with more names. The study used the Cochran (1963) formula to determine the sample size as specified in equation;

$$n = \frac{z^2 pq}{e^2} \quad \text{.......} \quad (3.1)$$

where n is the sample size; Z is the desired confidence level taken as 95%, p is the maximum variance taken as 0.5 since the population of dairy farmers was unknown, q is 1-p and e is the desired level of precision taken at 5% level of precision. The sample size was given as:

$$\frac{(1.96)^2(0.5)(0.5)}{(0.5)^2}$$

n=385

Due to variations in the three counties, the study targeted a sample size of 450 respondents but at the end of field work a total of 457 respondents had been interviewed, of which 209 farmers were regular users of iCow services and 248 farmers were not enrolled in the platform as shown in Table 2.

Table 1: Sample size in the three counties including iCow users and non-user's households

County	Dairy Cooperative	Sample	Total (n) per county
Uasin Gishu	Sirikwa (Treated) Tarakwa (Control)	74 78	152
Bomet	Siongirio (Treated) Ndanai (Control)	62 82	144
Nyandarua	Olkalao (Treated) Miharati (Control)	91 70	161
Total		**457**	**457**

3.4 Data types

This study used cross- sectional data from interviews conducted by enumerators to the household decision makers among smallholder dairy farmers in Nyandarua, Uasin Gishu and Bomet counties. Data needed was characterized into; socio-economic characteristics of the household head, animal details and food consumption details.

Specifically, data on socio-economic characteristics included; demographic data such as age, education, household size, gender and main occupation of the household head. Data on support services included; access to extension services, access to credit and social capital of the household head. Data on farm characteristics such as size of land, type of land tenure as well as, data on infrastructure such as distance from the farm to the road.

3.5 Data collection methods

The study conducted key informant interviews with Kenya Dairy Farmers Federation (KDFF) and management of cooperatives to identify and provide a list of farmers that had enrolled in the iCow program and those who had not in the three counties. Additionally, these key informant interviews provided information on the iCow program and the benefits realized by the cooperatives

Focused group discussions (FGDs) were conducted with iCow users and non-user farmers to help improve the questionnaire by including omitted issues and obtain a broad understanding of the dairy sector in the counties. Two FGDs were conducted in each county where both the iCow users and non-users were engaged to get their views before the start of the household survey.

Finally, primary data was collected through personal interviews using a pre-tested questionnaire on an Open Data Kit (ODK) platform for both the treated and control groups. The household survey was conducted in June and July 2018 and information on farm-specific characteristics, farmers-specific characteristics, animal details, location characteristics and food consumption were collected (see more in Sections 3.5.1-3.5.3).

3.5.1 Collection of data on milk production

As part of the primary data, milk production was computed considering the breed type, lactation length of the lactating cows and season of lactation. Farmers were asked information on all lactating cows including milk production for each cow. Then milk for all the cows were summed which resulted to total milk production for every household. Average milk production per cow was computed by dividing total milk production in each household by the number of lactating cows.

3.5.2 Collection of data on incomes

Information on price of milk per litre was collected in each household then this was used to compute milk income by multiplying the total milk production by the Price as stated by each farmer, while household income was computed by summing up total milk income, total on-farm income and total off-farm income.

3.5.3 Collection of data on food security

Food consumption score (FCS) was used as a measure of food security of the households in the study sites as computed by World Food Program (Gina *et al*., 2010). FCS measures food security qualitatively and is constructed using data collected at a household level. Methods like FCS have been widely used by many organizations and are advantageous because constructing them require information that is less consuming and less costly unlike quantitative methods which are more tedious and costlier to use (WFP, 2006; WFP, 2008; Gina *et al*., 2010). Additionally, FCS was adopted and used in this study because it provides a more accurate measurement of the quality of the household diet and it also accounts for the nutritional value of food, number of different types of food consumed (diversity) and the frequency of consumption of every food stuff. However, there are some weaknesses with FCS; i) it does not consider foods consumed outside the household and it fails to provide information of intra-household food distribution, ii) to some extent, using the 7-day recall, it is impossible to consider quantity of food eaten by a household. Despite its setbacks, FCS is still considered be a very useful measure of household food security.

World Food Programme (WFP), provides the procedure of using FCS in food security analysis. FCS is measured based on food frequency, dietary diversity, and the relative nutritional importance of 9 different food groups. These standard food groups were staples, vegetables, pulses, fruits, milk, meat and fish, sugar, oil and condiments. The design of FCS reflects the quantity and quality of the diet of the household. A composite score is derived from a weighted sum based on the frequency and food type of consumption during the last seven (7) days period. Precisely, recall questions on dietary are asked that aid the collection of information on the consumption of selected food groups. The respondents are asked about frequency of consumption of various food stuffs by a recall period of past 7 days. Household FCSs are computed using the formula as proposed by WFP (2006). The FCS are derived by

multiplying the weight for each food group by the number of days these foods were consumed (frequency); then these values for all food groups are summed up and generates the FCS. The formula can be expressed as follows:

$FCS = a_1 \times f(\text{staples}) + a_2 \times f(\text{pulse}) + a_3 \times f(\text{milk}) + a_4 \times f(\text{fruit}) + a_5 \times f(\text{meat and or fish}) + a_6 \times f(\text{sugar}) + a_7 \times f(\text{vegetables}) + a_8 \times f(\text{oils}) + a_9 \times f(\text{condiments}) + \text{error term}$

Where, FCS = Food Consumption Score, $\boldsymbol{f}$ = number of days each food group was consumed in the past 7 days (frequency), and $\boldsymbol{a}$ = nutritional weighted value of each food group (WFP,2006). Assignment of weights to the food groups were done to reflect their nutritional density. The FCS has three thresholds categories of consumption; poor food consumption, borderline food consumption and acceptable food consumption as shown in Table 1.

Table 2: Food consumption score thresholds and their categories

Food consumption score (FCS)	Food security Status
0-28	Poor
28.5-42	Borderline
>42	Acceptable

Source: WFP (2006)

3.6 Data analysis

Data collected was captured in the excel sheet and analyzed using STATA version 15 after undergoing cleaning to ensure there were no outliers. The analysis included a descriptive analysis and econometric modelling. The descriptive analysis involved calculating the means of both regular users of iCow and non-user's smallholder dairy farmers in the three counties. T- Tests were also calculated to show differences in the means between the iCow users and non-users. A binary logistic regression was used to determine factors that influence participation in iCow while PSM model was then applied to estimate the impact (ATT) of participating in iCow program on milk production, milk and household income and food security. Detailed analysis is presented in the following sections.

3.6.1 Determination of socio-economic factors influencing participation in iCow program

The decision of a farmer to participate in iCow service can be modeled as a choice between two alternatives; whereby a farmer can make a choice of participating or not participating. The random variable Y is a binary choice that takes the value of 1=participate and 0=otherwise therefore a binary logit model was used.

Following McFadden (1974), since the dependent variable Y is discrete; the probability that farmer *i* participates in iCow can be modeled as;

Pr (Y_{ij} = Participation) = exp (βXi)/ 1 + exp (βXi) ..... (3.1)

Where the subscripts *i* and *j* denote farmer and farmer participation in iCow service (1=participate, 0=otherwise) respectively. The *Xi* is the vector of explanatory variables (socioeconomic, institutional and farm specific factors) for the *i*th farmer.

3.6.2 Model Diagnostic Tests

3.6.2.1 Test for multicollinearity

Multicollinearity test was performed to show if there was any relationship among the independent variables included in the regression model. Presence of multicollinearity may have led to inflated standard error of the fitted coefficients which would have affected the confidence intervals. Additionally, multicollinearity may also mislead in failing to reject the null hypothesis which could not be true due to inflated standard errors and deflated t – test values.

3.6.2.2 Testing for Heteroscedasticity

The heteroscedasticity test was performed to determine whether the variance of the error term is constant or not. The presence of heteroscedasticity makes the estimates from a regression

not to be regarded as 'best' and 'efficient' however they are still unbiased and linear. (Gujarati and Porter, 2009). Therefore, any inferences and conclusion drawn from such estimates are often misleading.

Table 3: Variable definition and hypothesized signs for the determinants of participation in iCow service

Variable	Unit of measurement	Expected sign
Household income in Ksh.	continuous	+
Education of the household head in years	continuous	+
Experience of the household head in dairy farming in years	continuous	+/-
Age of the household head in years	continuous	+/-
Plot size in acres	continuous	+
Number of Lactating cows in a household	continuous	+
Distance from the farm to the road (Km)	continuous	+/-
Gender of the household heard(1=Male,0=Female)	Dummy	+/-
Access to extension services (1=Yes,0=No)	Dummy	+/-
Access to internet services(1=Yes,0=No)	Dummy	+
Access to Credit services(1=Yes,0=No)	Dummy	+
Membership to other social groups(1=Yes,0=No)	Dummy	+
Occupation (1=Farmer,0=Otherwise)	Dummy	+
Marital status (1=Married,0=Otherwise)	Dummy	+/-

Income of the household was expected to influence participation in iCow positively. Because it is likely that farmers with higher incomes are likely to adopt and invest in new technology. Similar conclusions were made by Wejnert (2006), who observed that participation in the ICT tools depends on income of the farmer.

Education was expected to influence participation in iCow positively because it is expected that an increase in years of schooling increases the likelihood of the farmer participating in

the in an innovation because it is likely that farmers who are educated can read more about a technology and its usefulness, therefore making informed decisions (Blomley, 2003).

Age was expected to influence participation either negatively or positively. Age can be used as a proxy for farming experience. Older farmers have more experience in farming and hence they are able to appreciate the innovations more compared to younger farmers. On the other hand, younger farmers tend to be more digital and they can operate digital equipment as compared to older farmers.

Experience in dairy farming was expected to influence participation positively. It is likely that farmers who have more years of experience know the importance and impact of technologies increasing production. Mignouna *et al.* (2011) and Uaiene *et al*. (2009) made similar conclusions that uptake of new technologies is directly associated with experience.

Access to extension was hypothesized to positively and negatively influence participation in iCow. Access to extension services can be a medium for spreading the knowledge on a new technology making the farmers to participate while at the same time if farmers can easily access extension services from extension agents, then they may see no need of using ICTs as an extension tool.

Access to internet services was expected to influence participation. Because availability of internet connectivity, farmers are able to read more about the benefits of a technology and this will enable them to make informed decisions in adoption.

Membership to social groups was also expected to influence farmers to participate in iCow. This is because farmers may interact with other farmers in the group and learn more on the usefulness and benefits of various technologies available. Therefore, through this interaction with fellow farmers, they can share and learn from each other and this informs the decision to adopting and using technologies. This argument is similar to Katungi & Akankwasa, (2010)

who found that participation of farmers in community-based organizations made farmers to learn more about a technology hence raising their likelihood to adopt the technologies.

Plot size was expected to positively influence participation in iCow because farmers who have larger farm size are likely to participate in new technologies because they can afford to devote a section of their land to try new technologies unlike those with smaller farm size (Uaiene *et al*., 2009). Similarly, many studies have reported a positive and significant relationship between farm size and adoption of new agricultural technologies (Mignouna *et al.*, 2011; Uaiene *et al*., 2009; Gabre-Madhin & Haggblade, 2001)

3.6.3 Estimation of impact of iCow service on various indicators

3.6.3.1 Impact indicators

Quantitative indicators were used to measure the impact of the iCow ICT based extension services delivery. The quantitative measures included milk production, milk and household income and food consumption scores. Therefore, impact was considered as changes in farmers milk production per cow, milk and household income and food security due to introduction of iCow ICT based extension service provision.

3.6.3.2 Impact assessment methods

When it is not possible to undertake randomized experiments, either due to ethical considerations, non – random quasi experimental designs are ideal to use. They include; instrumental variable, Heckman selection correction model, regression discontinuity (RD), Double in Difference design (DD) and propensity score matching (PSM) (UNICEF, 2014).

Instrumental variables (IV) are useful in correcting selection bias due to unobserved factors (Heckman, 1998), but it is hard to find a suitable IV that influences the probability of treatment without having a correlation to the error term, therefore, this is the central

limitation of this method (woodridge,2002) in the current study. Use of OLS will yield biased and inconsistent results because only a section of the population involved in the program is used (Greene, 2002). While Double Difference (DD) method compares the differences before and after the intervention for the treatment and control groups separately but it is limited in its ability to handle selection bias (UNICEF, 2014) and it is only applicable to studies that have baseline surveys. The study could also apply regression discontinuity (RD) method that fits regression line to estimate the average effects based on the outcomes of interest. However, it is not always easy to establish the selection criteria.

To overcome the setbacks of the discussed methods, this study employed Propensity Score Matching (PSM) to control selection bias. This method corrects for selection bias due to observed factors by matching treatment and control groups based on observable characteristics not affected by the intervention.

3.6.3.3 Propensity Score Matching

PSM Involves constructing comparison group based on individual's probability of participating in a program conditional on observable characteristics (Ravallion 2008; World Bank, 2010). Followed by matching participants to non-participants based on these probability and the average treatment effects (ATE) calculated as the mean differences between the two groups. The matching is done based on observed individual or household characteristics to develop a propensity score or index (Rosenbaum & Rubin, 1981). The assumption of this method is that the biasness is based on observed characteristics. According to UNICEF, (2014), using PSM to estimate average effects may be biased if there are unobservable characteristics affecting participation. This method rests on two conditions; one is the presence of conditional independence meaning that unobserved characteristics do not influence participation (Heckman, 1998). The second condition seeks to develop a common support overlap of participants and non- participants propensity scores. This assumption

ensures that participants and non-participants have similar observable characteristics for proper matching of subjects (Blundell & Dias, 2000: World Bank, 2010). A common support region also requires that there is a large and almost equal number of participants and non-participants. The treatment units without similar non -treatment units in terms of propensity scores may have to be dropped to only include comparable subjects. In particular, the propensity scores distribution of the treated and comparison groups must be similar to ensure there is no sampling bias (World Bank, 2010).

The estimation of the effects of a program on individual's outcomes is the theory behind impact evaluation and is given as;

$$T_i = (Y_i \;/\; T = 1) - (Y_i \;/\; T = 0) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.2)}$$

However, there is a problem of `missing data` because it is hard to observe both outcomes such as yield or income for an individual with or without the program at the same time while using cross- section data (Ravallion, 2008). This challenge was resolved because the study used matching methods to find a good counterfactual. In addition, there is the limitation of researchers estimating causal effects of a program on individuals in non-random experiments (Rosenbaum, 2002). However, Caliendo & Kopein (2008) suggest that estimation of average treatment effect (ATE) on the population is ideal. Comparing the differences in stated outcomes for regular iCow users and non-user groups the study estimated the ATE as shown in equation 3.3 below.

$$\text{ATE} = E[\, Y_{it} \,/ t{=}1] - \text{E}\,[Y_{it} \,/\, t{=}0] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.3)}$$

where Y_{i1} is the expected outcome of interest for being in the program for individual *i*, *t*=1 for regular iCow users (treated) and Y_{i0} is the expected outcome of the treated group before being exposed to the iCow program for individual *i*.

In randomized experiments, there exists no differences between the treated and control individuals due to observable or unobservable characteristics, therefore, selection bias is highly minimal. However, due to the nature of this study (non-random experiment) there was a possibility of self-selection bias, measurement error and simultaneity (Rosenbaum & Rubin, 1983; World Bank, 2010; Jena *et al.,* 2012). One of the limitations of using cross sectional data for impact measurement is the challenge of selection bias, hence the average effects as estimated in Equation 3.3 may not be due to just the iCow program and this limits researchers from attributing causality to the intervention. Therefore, the study used PSM to estimate the average treatment effect on the treated (ATT) by resolving the problem of selection bias that could have led to endogeneity (Rosenbaum & Rubin 1983; Heckman *et al.,* 1998). Estimating the difference between the regular iCow users (treated) and non-users (control) including the bias (ε) is the ATT, where the bias represents the outcome of the treated had they not participated iCow program and for the control group had they participated.

$$ATT = E[Y(1) \,/\, T = 1] - E[\,Y(0) \;/T = 1] + \varepsilon \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.4)$$

Where $E[Y(1) \,/\, T = 1]$ is average the outcome for regular iCow users, $E[\,Y(0) \;/T = 1]$ is the average outcome for non-users of iCow had they participated in the program and ε is the selection bias.

$$ATT = E[\,Y_{it} \,/\mathrm{T}{=}1] - \mathrm{E}\,[Y_{it} \,/\, \mathrm{T}{=}0] + \{E[Y_{i1}(T = 0)] - E[Y_{i0}(T = 1)]\} \ldots\ldots\ldots\ldots \quad (3.5)$$

where $\varepsilon = \{E[Y_{i1}(T = 0)] - E[Y_{i0}(T = 1)]\}$ is the bias due to differences between the treated and control used to estimate average effects of iCow program. Hence,

$$ATE + \varepsilon = E[Y_{i1}/\,\mathrm{T}{=}1] - E[Y_{i0}/\,\mathrm{T}{=}0] = ATT \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.6)$$

where Y_{i1} is the average outcome of the treated group (regular iCow users), Y_{i0} is the average outcome of control group (non-users of iCow), T=1 for the iCow users and T=0 for the non-users of iCow.

The PSM model was used to reduce the bias(ε) hence the condition of unconditional confoundedness was satisfied. It is a requirement that researchers ensure that the outcomes of both the treatment and control are independent of the assignment to either one of the groups (Rosenbaum & Rubin, 1983; Lechner, 1999). Consequently, after matching both the control and treatment groups should have similar observable socio- economic characteristics. The study also used PSM to correct the problem of 'missing' data and statistically designed a good counterfactual. Both probit and logit models have been commonly used in predicting the probability of individuals participating in a program. They both yield similar results, but this study used the logit model because it is easier to estimate the propensity scores of households (Aldrich & Nelson, 1984).

$$P(X) = pr(T = 1/\text{x}) \quad \text{..... (3.7)}$$

where T= 1=iCow users 0= non-users (a binary choice representing a household that is use iCow or non-users respectively), X is the vector of covariates and P(X) is the predicted propensity score of each household. The logit model is specified as below and noted by Gujarati (2004).

$$T_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots \beta_i X_i + \varepsilon \quad \text{..... (3.8)}$$

Where T_i is a binary variable; $T_i = 1$ for iCow users and $T_i = 0$ for non-users, X is the vector of household and farm characteristics. The logit model specifies the conditional probability of participating in iCow program as shown below;

$$pr(T_i = 1/x) = \frac{1}{1+e^{-\beta_0+\beta_1 X_1+\beta_2+\cdots\beta_i X_i}} = \frac{e^{\beta_0+\beta_1 X_1+\beta_2 X_2+\cdots\beta_i X_i}}{1+e^{\beta_0+\beta_1 X_1+\beta_2+\cdots\beta_i X_i}} \quad \text{..... (3.9)}$$

While the conditional probability for non-users of iCow is as given in Equation 3.10

$$pr(T_i = 0/x) = 1 - \frac{1}{1+e^{\beta_0+\beta_1 X_1+\beta_2 X_2+\cdots\beta_i X_i}} = \frac{1}{1+e^{\beta_0+\beta_1 X_1+\beta_2 X_2+\cdots\beta_i X_i}} \quad \text{..... (3.10)}$$

where pr $(T_i = 1)$ for treated (iCow users) and pr $(T_i = 0)$ for the control (non-users) are the propensity scores, β are the estimated and x represents covariates used for estimation.

Matching of the household of both the treatment and control groups was done using the nearest neighbor (NNM), kernel matching (KBM) and caliper matching (RM techniques to show robustness (Legesse, 2013). Balancing tests were performed to ensure that the comparison group and the treated are systematically indifferent (had similar observable characteristics) except for iCow program after matching (World Bank, 2010). Additionally, sensitivity analysis was done by to show the level of hidden bias to which the ATT are sensitive.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

4.1 Sample Descriptive statistics

Section 4.1 to 4.3 presents descriptive statistics of the sampled farmers in the three study counties. Socio-economic factors of the of the interviewed farmers, comparison between the iCow users and non-users, challenges farmers facing, patterns of food consumption and food security status are all discussed in these sections.

4.1.1 Socio-economic characteristics of smallholder dairy farmers

Annual milk production per cow was highest in Uasin Gishu with an average of 2187 litres followed by Bomet and Nyandarua which had 2186 and 2067 litres respectively (Table 4). The cause of the difference in milk production could be the fact that farmers in Uasin Gishu county had more years of experience in dairy farming then Bomet and Nyandarua. Income from milk sales was highest in Uasin Gishu with an average of Ksh. 129,075, followed by Bomet and Nyandarua with Ksh. 128,484 and 106,129 respectively. In terms of household income, farmers from Uasin Gishu had a higher income followed by Nyandarua and Bomet with an average income of Ksh. 398,999, 382,221 and 228,796 respectively. This difference could be as results of the reported higher production in Uasin Gishu which led to surplus for sale, hence increasing incomes. With respect to Food Consumption scores (FCS), a measure food security, Uasin Gishu had the highest average score of 73.9 followed by Bomet and Nyandarua scoring 69.48 and 60.75 respectively. This difference in the scores could be because of higher production in Uasin Gishu, hence more milk was consumed which raised the score. Additionally, higher incomes realised in Uasin Gishu, may have led diversification in consuption which raised the score.

Table 4: Socio Economic characteristic of smallholder dairy farmers in study areas

	Nyandarua (n=161)		Uasin Gishu (n=152)		Bomet (n=144)	
Variable	**Mean**	**Std.D**	**Mean**	**Std.D**	**Mean**	**Std.D**
Total Annual Milk production per cow (Litres)	2067	1137	2187	1529	2186	1138
Total Annual Milk income (Ksh)	106129	65737	129075	142017	128484	90648
Total Annual Household income (Ksh)	382221	370396	398999	684948	228796	186034
Food consumption scores (Food Security)	60.75	17.76	73.92	16.9	69.48	18.33
Household head Education (Year)	10.53	3.96	9.08	4.56	7.31	5.08
Experience in Dairy farming (years)	11.07	9.75	14.81	9.54	12.94	9.28
Household head Age (years)	45.60	14.41	45.82	13.29	41.47	13.41
Plot size (Acres)	1.07	0.42	2.17	2.17	1.26	0.69
Number of Lactating cows	1.70	0.80	1.70	0.8	1.8	0.80
Number of breeds kept	1.00	0.20	1.10	0.500	1.00	0.30
Distance from the farm to the road (Km)	2.10	1.90	2.40	3.50	7.70	5.70
Membership period to cooperative(years)	5.90	4.00	6.20	5.00	9.00	6.20
Household head Gender(1=Male,0=Female)	0.74	0.43	0.79	0.40	0.65	0.47
Growing fodder(1=Yes,0=No)	0.81	0.38	0.50	0.50	0.61	0.48
Access to extension services (1=Yes,0=No)	0.37	0.48	0.75	0.43	0.63	0.48
Access to internet services(1=Yes,0=No)	0.26	0.44	0.36	0.48	0.19	0.39
Milking (1=Yes,0=No)	0.99	0.07	0.94	0.23	0.91	0.27
Access to Credit services(1=Yes,0=No)	0.32	0.46	0.30	0.46	0.2	0.4
Membership to other social groups(1=Yes,0=No)	0.42	0.49	0.28	0.45	0.31	0.46
Occupation (1=Farmer,0=Otherwise)	0.72	0.44	0.78	0.41	0.67	0.47
Marital status (1=Married,0=Otherwise)	0.68	0.46	0.92	0.27	0.84	0.36
Household Decisionmaker (1=Joint ,0=Otherwise)	0.52	0.50	0.36	0.48	0.54	0.49

On average, years of schooling in Nyandarua county was 11 years as compared to 8 and 7 years in Uasin Gishu and Bomet respectively, implying that farmers in Nyandarua had undergone slightly longer schooling periods compared to Uasin Gishu and Bomet. In relation to age, the average age for household head was 45.60, 45.82 and 41.47 years in Nyandarua, Uasin Gishu and Bomet counties respectively. This implies that the three counties are more less similar in respect to the age of the household head. In relation to land, farmers in the three counties were characterised by land scarcity with average land owned of 1.07, 2.17 and 1.26 acres in Nyandarua, Uasin Gishu and Bomet respectively.

At the time of this study over 90% of the households in the three counties had lactating cows with most of them keeping 2 lactating cows each. This high percentage of households having lactating cows can be explained by the fact that dairy farming is the main activity in these counties. In relation to distance from the farm to the road, farmers in Bomet county were far from the road with an average of 7.7 kilometres, compared to Uasin Gishu and Nyandarua which have an average of 2.4 and 2.1 kilometres respectively. This difference could be because Uasin Gishu and Nyandarua have more road networks as compared to Bomet. All respondents interviewed in the three counties belonged to a dairy cooperative with an average membership duration of 6 years. In terms of gender, 74, 79, and 65% of the respondents in Nyandarua, Uasin Gishu and Bomet respectively were males implying that most households in the study counties are male headed. In terms of decision making at household level, 54% of the households in Bomet make decisions jointly as compared to 52% and 36% in Nyandarua and Uasin Gishu respectively. This higher percentage in Bomet can be explained by the low percentage of male

headed household in the county implying that, in this county women are given the opportunity to lead and make decisions.

On average, 81% of the surveyed households Nyandarua County grow their own fodder, nappier grass being the dominant one compared to 61% and 50% in Bomet and Uasin Gishu. This low percentage in Uasin Gishu could be because the county is known for maize production, therefore farmers use maize stalks to feed their cows. Regarding access to extension services, on average, 37%, 75% and 63% of the respondents in Nyandarua, Uasin Gishu and Bomet respectively received extension services which was majorly provided by the extension agents belonging to the dairy cooperatives. In relation access to internet services, less than 37% of the respondents in the study counties were able to access to internet services. This could be attributed to the fact that most farmers live in remote areas where network connectivity is a challenge and additionally, most of them possess phones that are unable to access internet services. These findings are similar to Chilimo (2008) and Ajani (2012) who revealed that low network connectivity and low power supply are the main constraints that affect using of ICTs among the farmers.

4.1.2 Comparison of iCow users and non-users' socio-economic characteristics

As presented in Tables 5, 6 and 7, there were significant differences between the users of iCow and no-users in the three counties. With respect to milk production per cow, iCow users in Uasin Gishu and Bomet realised significantly higher average annual milk production of 2550 litres and 2456 litres respectively as compared to non-users whose production was 1833 litres and 2020 litres respectively. However, there was no significant difference in milk production in Nyandarua county.

Table 5: Comparison of iCow users and non-users' characteristics in Nyandarua County

	Nyandarua County (n=161)			
	Mean (SD)			
Variable	**iCow users (n=79)**	**Non-users (n=82)**	**Differences**	**t statistics**
Total Annual Milk production per cow (Litres)	2110.52(975)	2025.87(1279.6)	84.65	0.47
Total Annual Milk income (Ksh)	122833.2(73931)	90036.49(52329.62)	32796.3***	3.25
Total Annual Household income (Ksh)	423430.7(388541)	342519.4(349820)	80911	1.38
Food consumption scores (Food Security)	62.64(17.7)	58.94(17.6)	3.70	1.32
Household head Education (Year)	11.24(0.43)	9.84(4.03)	1.30**	2.26
Household head Experience in Dairy farming (years)	10.58(9.86)	11.54(9.67)	-0.96	0.62
Household head Age (years)	48.32(14.26)	42.98(14.14)	5.30**	2.38
Plot size (Acres)	1.11(0.57)	1.03(0.18)	0.07	1.15
Number of Lactating cows	1.94(0.93)	1.62(0.78)	0.32**	2.42
Number of breeds kept	1.06(0.24)	1.01(0.11)	0.05*	1.71
Distance from the farm to the road (Km)	2.48(2.56)	1.67(1.04)	0.81***	2.64
Membership period to Dairy cooperative(years)	5.63(3.43)	6.26(4.51)	0.63	1.00
Household head Gender(1=Male,0=Female)	0.78(.41)	0.70(0.45)	0.07	1.12
Growing fodder(1=Yes,0=No)	0.81(0.39)	0.820(.37)	-0.01	0.31
Breed-type (1=pure-exotic, 0=Otherwise)	0.62(0.48)	0.52(0.50)	0.09	1.22
Access to extension services (1=Yes,0=No)	0.36 (0.48)	0.37(0.48)	-0.01	0.14
Access to internet services(1=Yes,0=No)	0.37(0.48)	0.14(0.35)	0.23***	3.42
Milking (1=Yes,0=No)	0.98(0.11)	1.00(0.00)	-0.01	1.01
Access to Credit services(1=Yes,0=No)	0.37(0.48)	0.26(0.44)	0.11	1.51
Membership to other social groups(1=Yes,0=No)	0.45(0.50)	0.39(0.49)	0.06	0.83
Occupation (1=Farmer,0=Otherwise)	0.68(0.46)	0.76(0.42)	-0.08	1.20
Marital status (1=Married,0=Otherwise)	0.67(0.47)	0.68(0.46)	-0.01	0.16
Household Decision maker (1=Joint ,0=Otherwise)	0.48(0.50)	0.54(0.50)	-0.06	0.85

***significant at 10% **significant at 5% and *** significant at 1%**

Table 6: Comparison of iCow users and non-users' characteristics in Uasin Gishu County

	Uasin Gishu County (n=152)			
	Mean (SD)			
Variable	**iCow users (n=75)**	**Non-users (n=77)**	**Differences**	**t statistics**
Total Annual Milk production per cow (Litres)	2550.4(2013.52)	1833.33(665.24)	717.07***	2.96
Total Annual Milk income (Ksh)	169820.2(18123)	89389.51(69681)	80430.51***	3.62
Total Annual Household income (Ksh)	462315.3(533279)	337329.1(80462)	124986	1.12
Food consumption scores (Food Security)	75.13(15.4)	72.75(18.2)	2.30	0.86
Household head Education (Year)	9.85(4.32)	8.33(4.68)	1.5**	2.07
Household head Experience in Dairy farming (years)	13.96(9.68)	15.65(9.38)	-1.68	1.09
Household head Age (years)	42.40(11.77)	49.15((13.91)	-6.75***	3.22
Plot size (Acres)	2.58(2.74)	1.77(1.32)	0.80**	2.31
Number of Lactating cows	1.86(0.82)	1.550(.81)	0.30**	2.30
Number of breeds kept	1.29(0 .63)	0.98(0.25)	-0.30**	3.93
Distance from the farm to the road (Km)	3.03(4.71)	1.80(1.46)	1.22**	2.17
Membership period to Dairy cooperative(years)	5.28(0.58)	7.05(6.47)	-1.77**	2.20
Household head Gender(1=Male,0=Female)	0.80(.40)	0.79(0.40)	-0.007	0.11
Growing fodder(1=Yes,0=No)	0.60(.49)	0.41(0.49)	0.18**	2.29
Breed-type (1=pure-exotic, 0=Otherwise)	0.26(0.44)	0.19(0.39)	0.07	1.04
Access to extension services (1=Yes,0=No)	0.84(0.36)	0.66(0.47)	0.17**	2.56
Access to internet services(1=Yes,0=No)	0.40(0.49)	0.33(0.47)	0.06	0.79
Milking (1=Yes,0=No)	0.94(0.22)	0.93(0.24)	0.01	0.30
Access to Credit services(1=Yes,0=No)	0.26(0 .44)	0.33(0.47)	-0.07	0.94
Membership to other social groups(1=Yes,0=No)	0.38(9.49)	0.19(0.39)	0.19***	2.65
Occupation (1=Farmer,0=Otherwise)	0.81(0.39)	0.75(0.43)	0.06	0.89
Marital status (1=Married,0=Otherwise)	0.93(0.25)	0.90(00.28)	0.02	0.55
Household Decisionmaker (1=Joint ,0=Otherwise)	0.33(0 .47)	0.38(0.49)	-0.05	0.71

***significant at 10% **significant at 5% and *** significant at 1%**

Table 7: Comparison of iCow users and non-users' characteristics in Bomet County

	Bomet (n=144)			
	Mean (SD)			
Variable	**iCow users (n=55)**	**Non-users (n=89)**	**Differences**	**t statistics**
Total Annual Milk production per cow (Litres)	2456.13(1408.92)	2020.08(902.24)	436.05***	2.26
Total Annual Milk income (Ksh)	155449.7(112388.2)	111816.8(69759.8)	43632.9***	2.87
Total Annual Household income (Ksh)	323576.9(222336)	170223.5 (129694)	153353***	5.23
Food consumption scores (Food Security)	72.89(17.3)	67.38(18.70	5.5*	1.76
Household head Education (Year)	7.84(5.01)	7.00(5.13)	0.8	0.95
Household head Experience in Dairy farming (years)	14.34(8.93)	12.07(9.42)	2.27	1.43
Household head Age (years)	39.14(12.28)	42.92(13.94)	-3.77*	1.65
Plot size (Acres)	1.42(0.96)	1.15(.42)	0.26**	2.3
Number of Lactating cows	2.01(1.04)	1.71(0.60)	0.29**	2.17
Number of breeds kept	1.09(0.34)	0.94(0 .34)	0.14**	2.45
Distance from the farm to the road (Km)	1.67(1.92)	1.44(1.23)	9.78	0.85
Membership period to Dairy cooperative(years)	13.36(6.38)	6.34(4.30)	7.01***	7.87
Household head Gender(1=Male,0=Female)	0.67(0.47)	0.64(0.48)	0.03	0.39
Growing fodder(1=Yes,0=No)	0.70(0.45)	0.55(0.50)	0.15*	1.9
Breed-type (1=pure-exotic, 0=Otherwise)	0.29(0.45)	0.13(.34)	0.15**	2.32
Access to extension services (1=Yes,0=No)	0.69(0.46)	0.60 (0.49)	0.08	1.01
Access to internet services(1=Yes,0=No)	0.32(0.47)	0.11(0.31)	0.21***	3.25
Milking (1=Yes,0=No)	0.96(0 .18)	0.88(0.31)	0.075	1.6
Access to Credit services(1=Yes,0=No)	0.29(0.45)	0.15(0.36)	0.13	1.92
Membership to social groups(1=Yes,0=No)	0.34(0.47)	0.30(0.46)	0.04	0.52
Occupation (1=Farmer,0=Otherwise)	0.63(0.48)	0.68(0.46)	-0.04	0.6
Marital status (1=Married,0=Otherwise)	0.85(0.75)	0.84(0.76)	0.01	0.19
Household Decisionmaker (1=Joint ,0=Otherwise)	0.34(0.47)	0.67(0.47)	-0.32***	4.03

***significant at 10% **significant at 5% and *** significant at 1%**

The observed difference in milk production can be attributed to the effects of the information received from iCow messages on good managements practices for dairy cows. A study by Chaula (2014) had similar findings who concluded that use of ICT in agriculture had a positive impact on productivity.

There are also significant differences in milk income of the iCow users and non-users in all the three counties. Specifically, on average, users of iCow in Nyandarua, Uasin Gishu and Bomet earned Ksh.122,833, 169,820 and 155,449 respectively compared to non-users who earned Ksh.90,036, 89,389 and 111,816 respectively. This differences in milk income can be attributed to the existence of iCow services which provided users with information on good management practices leading to the observed milk increase hence more sales raising the milk income. In relation to household income, there was a significant and positive difference of Ksh. 153,353 between the iCow users and users in Bomet. However, there was no significant differences in Nyandarua and Uasin Gishu. The observed difference in Bomet could be because income from milk contributed the highest percentage to the household income hence the observed increment in milk income among the iCow users led to increase in household income. Similar results were observed by Hill (2010), who pointed out that the use of mobile phones among farmers in accessing agricultural information played positive impact on their income. With respect to Food consumption scores (FCS), which measure the food security status, the analysis indicated there was significant differences between the iCow users and non-user only in Bomet. On average users of iCow in Bomet had significantly higher (72) (i.e. better food security) scores than the non-users (67). This difference in FCS could be as result of the increment in milk and incomes among the users of iCow which raised the frequency and diversity in consumption contributing to the observed FSC among the iCow users. The result is consistent with the findings by Das *et al.* (2016) who concluded

that ICT contributed to increase in food security due to access to agricultural information by rice farmers in Bangladesh.

On average, years of schooling for iCow users in Nyandarua and Uasin Gishu were 11years and 10 years respectively compared 9 and 8 years for non-users respectively. The differences in Education for the two groups were significantly different at 5%, implying that iCow users had attained more years in schooling than the non-users. Regarding the age of the household head, there were differences between the iCow users and non-users in all the three counties. There was a positive and significant difference of 5 years of age in Nyandarua, and a negative and significant difference of 7 and 4 years of age in Uasin Gishu and Bomet respectively. This implies that in Nyandarua iCow users were older than non-users, while in Uasin Gishu and Bomet, non-users were older than the users. In relation to plot size under dairy production, on average, iCow users in Uasin Gishu and Bomet had about 2.6 acres and 1.4 acres respectively compared to 1.7 acres and 1.1 acres respectively for the non-users. These values are statistically different at 5 % implying that iCow users in the two counties had put more of their total land on dairy production as compared to non-users.

The results reveal that iCow users in all the three counties had significantly more lactating cows than the non-users which mostly were pure breeds and cross breeds. These difference in the number of lactating cows could be attributed to the likelihood that iCow users had gone commercial as they had pure exotic lactating cows more than the non-users. Contrary to expectation, the distance from the farm to the road for iCow users in the three counties was significantly higher than the non-users, implying that most of the non-users were closer to the roads as compared to iCow users. This also can be a reason as to why most of the iCow users have larger plot size than the non-users because as you move closer to the road demand for land increases which leads to subdivision leading to less land among the households.

In relation to membership period to dairy cooperatives, on average, iCow users in Uasin Gishu had significantly less years (5 years) as members of dairy cooperatives than non-user (7 years) while in Bomet, iCow users had significantly more years (13 years) as members in the dairy cooperatives than non-users (7 years). This can be explained by the age differences in the two counties, where in Uasin Gishu, iCow users had a lower age than the non-users hence the reason why the membership period in the cooperatives was low. In relation to access to internet services, there was differences among the iCow users and non-users in Nyandarua and Bomet counties. Results reveal that 37, and 32% of iCow users in Nyandarua and Bomet respectively access to internet services compared to 14 and 11% respectively for non-users. Although there is observed differences, the percentages are of both the iCow users and non-users are generally low suggesting that the smallholder farmers in the three counties have the challenge in accessing the internet services. This could be attributed to the challenge of network connectivity and most of them possess phones that are unable to access internet services.

The differences in access to extension services between the users and non-users was positive and significantly in Uasin Gishu county. About 84% of the iCow users had access to extension services compared to 66% of the non-users. Regarding the decision making at household level, there were negative and significant differences between the iCow users and non-users in Bomet county. About 34% of iCow users, jointly made decisions regarding dairy enterprise as compared to 67% of the non-users who made decisions jointly.

4.2 Challenges facing both iCow users and non-users

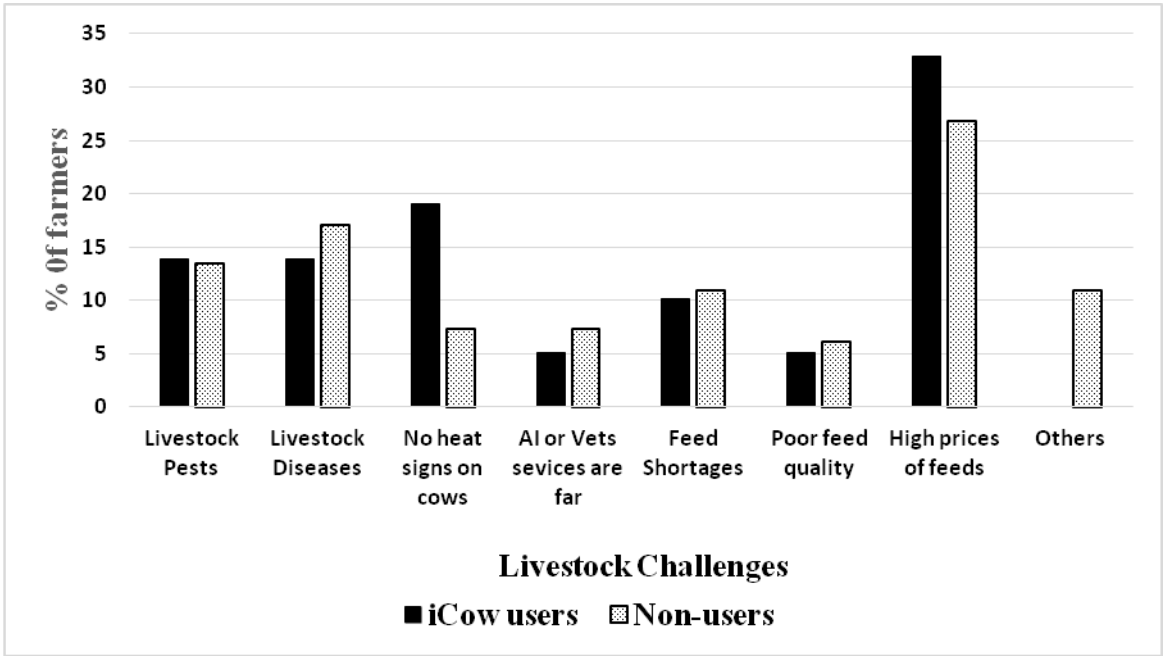

Figure 3: Challenges facing dairy farmers among the iCow users and non-users in Nyandarua county

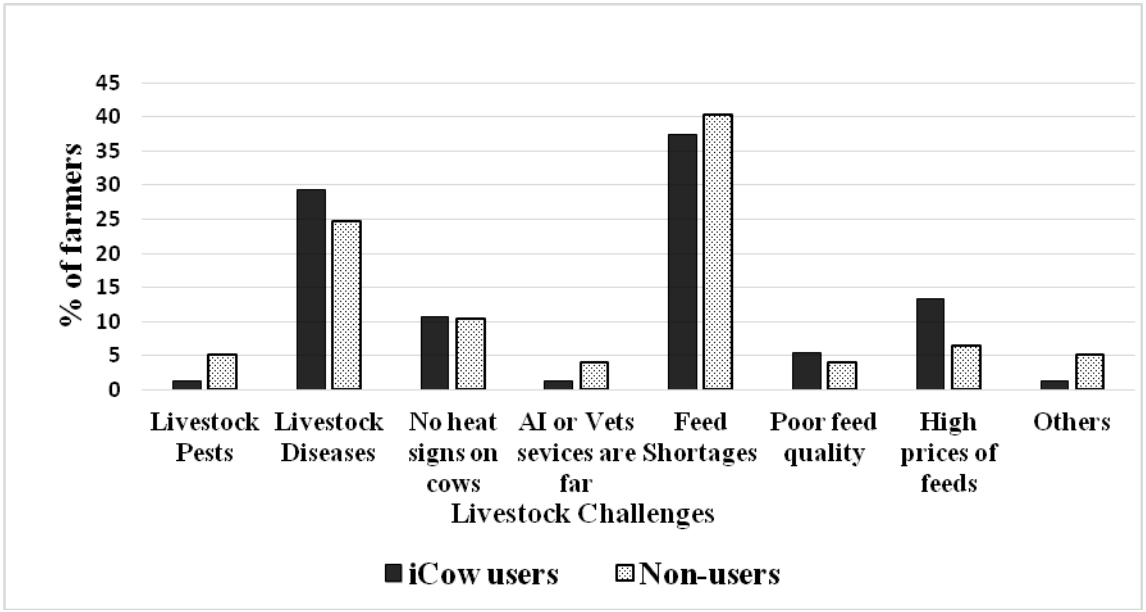

Figure 4: Challenges facing dairy farmers among the iCow users and non-users in Uasin Gishu county

When farmers from Nyandarua were asked to state major challenges they face in dairy production a majority of the iCow users and non-users in stated high prices of feeds was the

major challenge followed lack of heat in cows and Livestock diseases (Figure 3). The challenge of high prices of feeds could be as result of the reported scarcity in land size which limits farmers from growing enough fodder resulting to purchasing feeds which are relatively expensive.

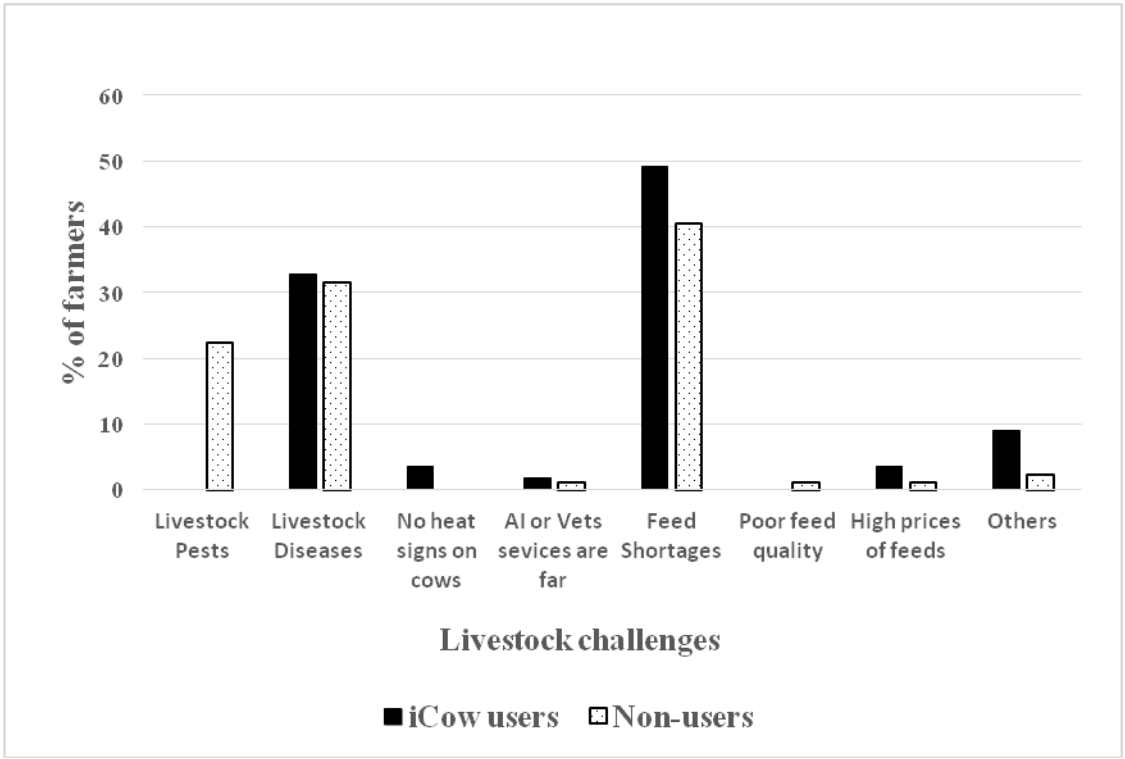

Figure 5: Challenges facing dairy farmers among the iCow users and non-users in Bomet county

In Uasin Gishu and Bomet, both the iCow users and non-users cited feed shortages and livestock diseases as the major challenge they faced (Figure 4 and 5). These findings are similar to Waswa & Akhaukwa (2004) who pointed that lack of feeds and diseases especially ECF among cattle cows were major constraints among dairy farmers. Similar conclusions were made by Tacken *et al.* (2009) and Kamau (2011) who stated that the high cost of feed and poor knowledge of husbandry best practices were the major hinderances to optimal production and earnings among dairy farmers.

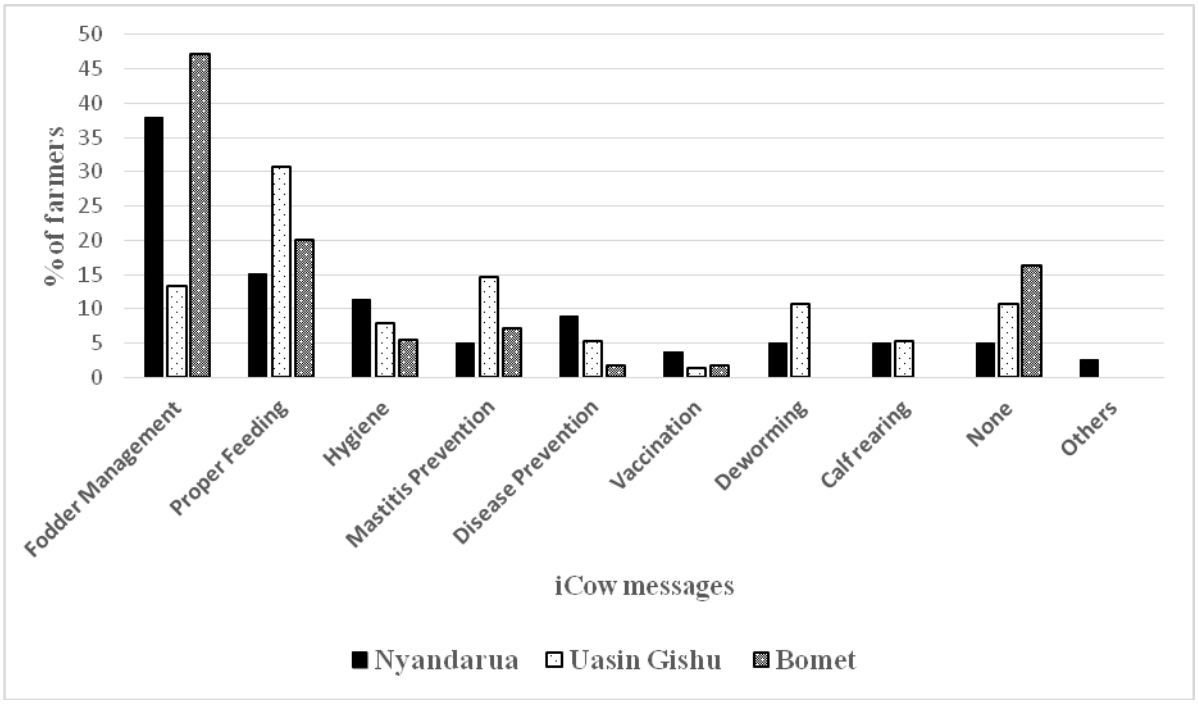

Figure 6: Various iCow messages mainly put into practice by regular users of iCow

As shown in Figure 6, most farmers in Nyandarua and Bomet reported that they had focused so much on practising the information on fodder management followed by proper feeding while in Uasin Gishu most farmers reported they had mostly put into practice information on proper feeding and mastitis control. This pattern can be explained by Figures 3,4 and 5 which pointed out that the major challenges the farmers faced were feed shortages and livestock diseases, therefore most farmers focused on these challenges by putting into practice the information from iCow that would give a solution.

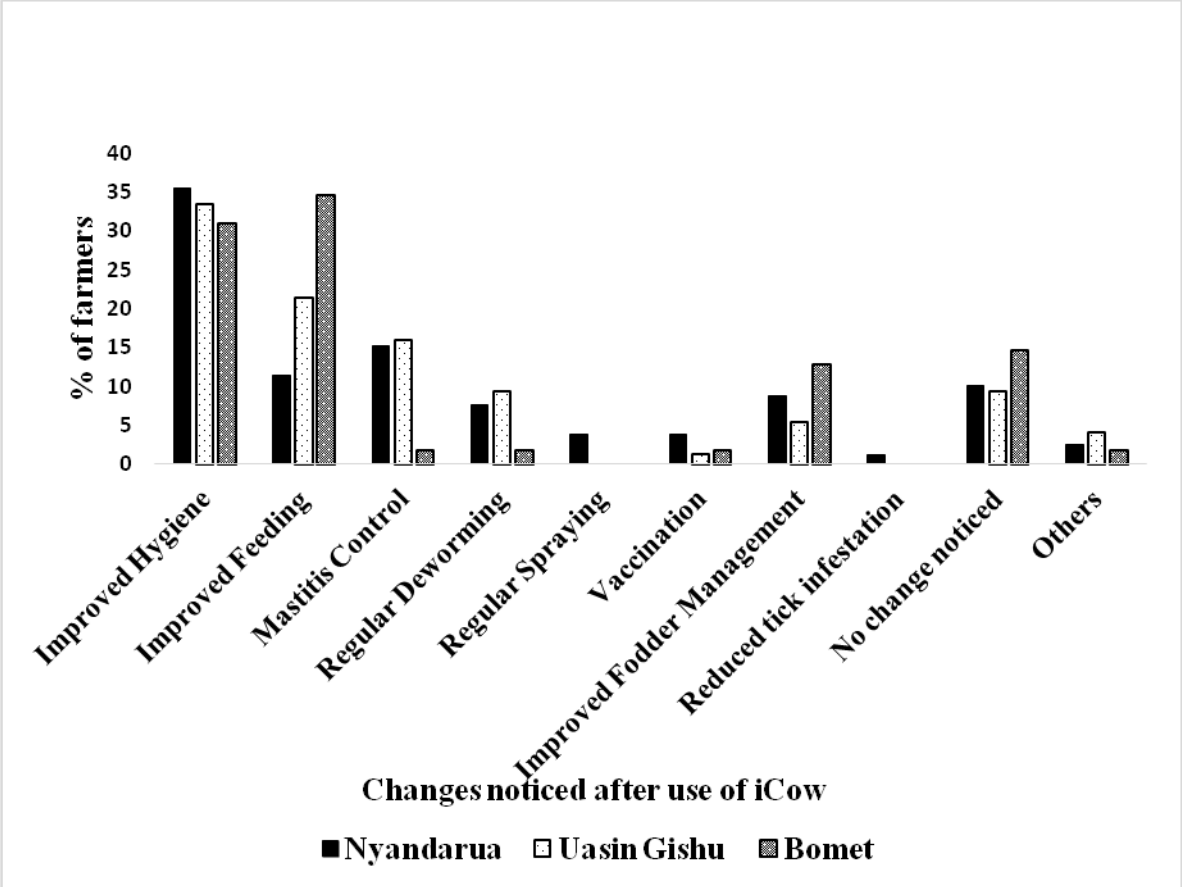

Figure 7: Changes noticed by iCow users after using the messages received from iCow

From Figure 7, about 35% and 33% of the iCow users in Nyandarua and Uasin Gishu respectively reported that hygiene had improved due to the usage of the iCow messages they had received, while 34% of the iCow users from Bomet reported that feeding had improved. The improvement in feeding was mainly because of the more focus put on the information on fodder management and proper feeding as reported in Figure 6. In addition, the reported improvement in feeding could be because at many times dairy farmers do suffer from lack of knowledge on nutrition and proper hygiene. With the information they receive from iCow, they were able to put it into practice resulting in the observed changes.

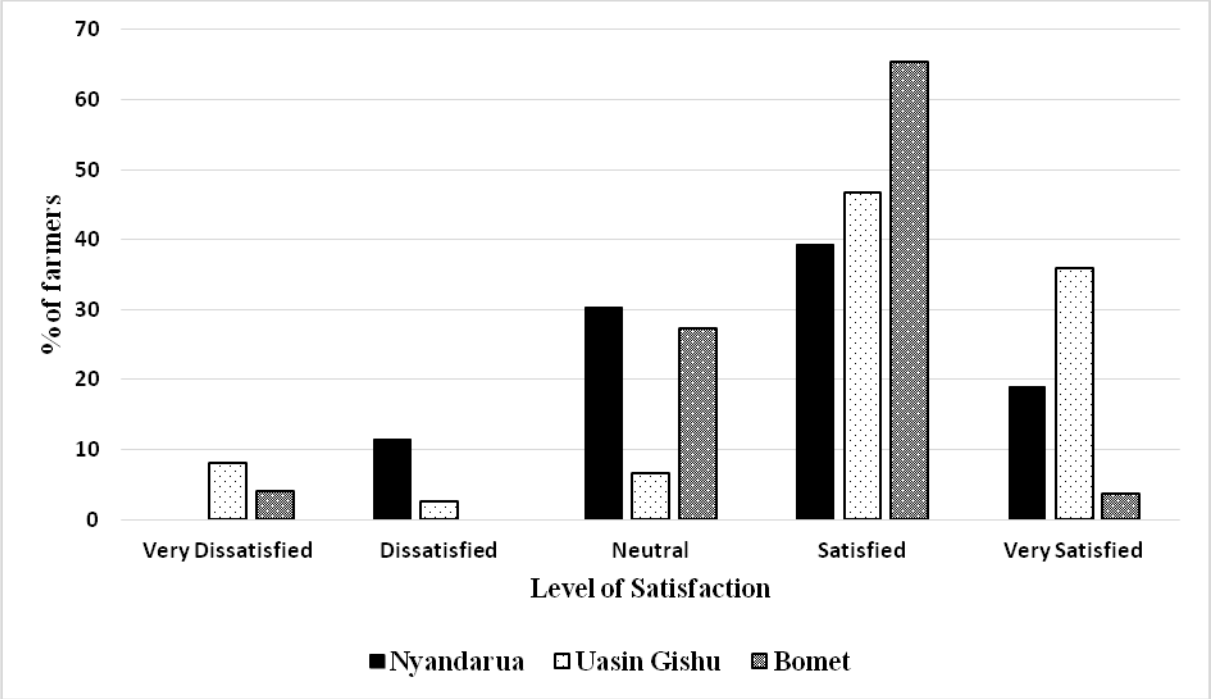

Figure 8: Level of satisfaction of iCow services among the regular users of iCow

The findings revealed that, about 60, 80 and 70% of iCow users in Nyandarua,Uasin Gishu and Bomet respectively were satisfied with services of iCow and they were happy that it had made them change how they do things in their farms (Figure 8). Those who pointed out that they were not satisfied gave a reason of lack of ability to read the messages hence they were not able to put the information into practice. This is similar to Agwu *et al.* (2008) who found that there is low know how and lack of confidence in operating ICTs among farmers.

4.3 Food consumption patterns

As presented in Table 8, the most regular and widely consumed staple was maize which accounted 99% of households with a frequency of about 6 days a week. This implies that, on a daily basis, almost every household in the study area consumes maize. After maize, the other widely consumed staples included wheat and rice which accounted for 85 and 78% of the households with a frequency of 3 and 2 days in a week respectively.

Vegetables were also highly consumed which accounted for about 99% of the households with a frequency of 6 days a week. Among the sources of animal proteins, milk was the main source which accounted for 80% of the household with a frequency of about 5 days a week. This implies a widespread consumption of milk and dairy products among the surveyed counties. Eggs and red meat contributed second and third respectively accounting for about 68 and 50% of the household respectively. Although the consumption of eggs and meat was high, the frequency of consumption in a week was very low of about 1 day in a week. Consumption of fish remained relatively low with only about 11% of the household having consumed fish.

Table 8: Food consumption patterns among the dairy farmers in the three counties

Food stuff	% of households that consumed these food stuffs (N=457)	Average number of days consumed in a week	% of respondents citing their primary source of various food commodities consumed (N = 457)	
			Own Produce	Purchases
Millet	59.52	2.4	61.05	38.58
Sorghum	42.23	1.8	59.79	39.68
Maize	99.78	5.9	94.52	4.82
Rice	77.90	2.1	3.72	96.28
Wheat	84.68	2.8	10.40	89.02
Tubers	73.52	2.6	76.67	22.42
Vegetable	98.91	5.9	88.60	10.91
Fruits	72.21	2.3	26.28	73.08
Pulses	89.93	3.3	75.74	24.02
Red meat	49.89	0.9	7.58	92.42
White meat	24.07	0.3	90.74	8.33
Eggs	67.61	0.2	93.77	5.90
Fish	10.72	0.2	2.13	95.74
Milk & milk products	79.65	4.9	93.11	6.89
Milk in tea	99.12	6.7	85.94	14.06
Oil & fats	96.06	6.5	18.08	81.69
Sweets, sugar & honey	73.3	4.6	15.89	84.11
condiments	77.24	5.2	19.08	80.06

In relation to the sources of these food stuffs, the results reveal that most of the households (95%) produce their own maize. This result explains the high consumption (99%) with a frequency of 6 days. A high number of farmers (93%) cited that they produce their own milk, this is as expected because the study counties are dairy producers. Equally, a bigger percentage of farmers produced their own eggs and white meat which accounted for 94% and 91% respectively of household consumption. The main source of the white meat and eggs was mainly from poultry chicken, which most of the households reared. Among the food stuffs purchased, 96% of the households cited that purchased rice followed by fish and red meat accounted for 96 and 92% of the households respectively. This result is expected because the counties where the study was carried are neither rice nor fish producing counties. Therefore, we can conclude that farmers mostly produce their own food stuffs that do not require more processing.

The contribution of each Food Consumption Group to Food Consumption scores (FCS) among the iCow users and non-users in the three counties is shown in Figure 9. The findings reveal that consumption of milk contributed highly to food security in Uasin Gishu and Bomet accounting for about 31% and 35% respectively. The high contribution of milk is because these counties are high dairy producers, and it was expected that milk consumption must have been high. In Nyandarua, Staples contributed highly to food security accounting for about 22% and 24% for ICow users and non-users respectively. This could be because Nyandarua is a producer of potatoes which are consumed by the households contributing to food security.

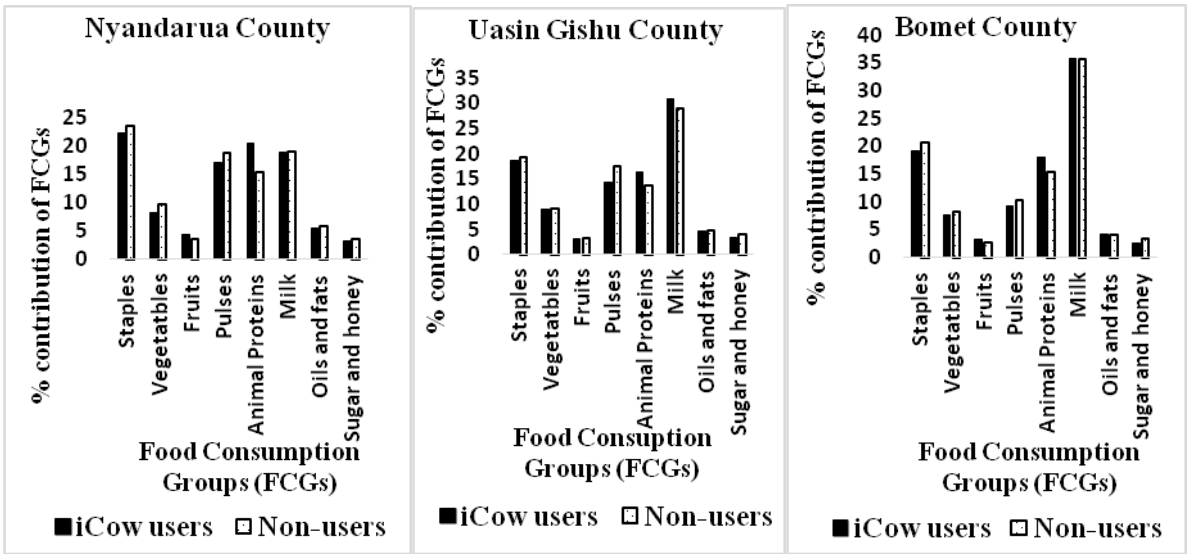

Figure 9: Contribution of each food consumption group (FCG) to food security among the iCow users and non-users

In relation to other animal proteins, they contributed 20% 18% and 19% to food security among the iCow users in Nyandarua, Uasin Gishu and Bomet respectively, however, these percentages are higher among iCow users than non-users. Equally, consumption of fruits had a higher percentage contribution to the food security among iCow users as compared to non-users. The difference in percentage contribution of animal proteins and fruits to food security among the iCow users and non-users can be attributed to the differences in income between the two groups. With more incomes among the iCow users, they had the ability to purchase more and diversify their consumption. On the other hand, staples, vegetables and pulses had higher percentage contribution to FCS mean among the non-iCow users than the regular users.

4.3.1 Food security status

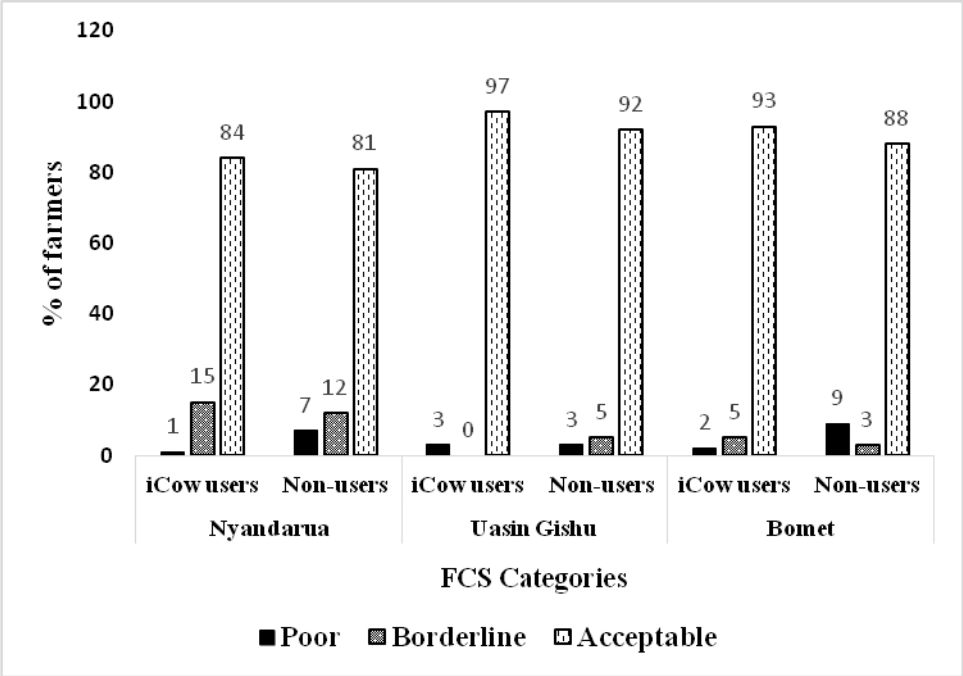

Figure 10: Distribution of households in the three food consumption score categories

The graphical representation in Figure 10 shows the distribution of households who belong in the three Food Consumption Categories among the regular iCow users and non-users. Results confirmed that some of the households in the three counties are food insecure. About 1%, 3% and 2% of the households among the iCow users in Nyandarua, Uasin Gishu and Bomet counties respectively were found to be food insecure. The figures are even higher among the non-users whereby 7%, 3% and 9% in Nyandarua, Uasin Gishu and Bomet respectively were food insecure. This result suggests that the estimated number of households which are food insecure are lower among iCow users as compared to non- users. This distribution of food insecure households is probably because of iCow program in the counties. Additionally, on average, about 15% and 5% of the iCow users in Nyandarua and Bomet respectively were found on the borderline. However, no household in Uasin Gishu was found to be in the borderline. Equally, about 12%, 5% and 3% of the non-users in Nyandarua, Uasin Gishu and Bomet respectively were on the borderline of food security. Despite the results revealing food insecurity, most households both iCow users and non-users were found to be food secure.

About 84%, 97% and 93% of the households among iCow users in Nyandarua, Uasin Gishu and Bomet respectively were found to be in the acceptable food consumption range. On the other hand, about 81%, 92% and 88% of the households among the non-users were in the acceptable food consumption. Although the results reveal that most of the household in the three counties are food secure, the iCow users are slightly food secure that the non-users in all the three counties.

4.4 Factors influencing farmers' participation in the iCow program

The Logit regression model fitted the data well at 1 % level of significant with Prob >Chi^2= 0.0000 in all the counties and Pseudo R^2 of 0.18, 0.27 and 0.23 in Nyandarua, Uasin Gishu and Bomet respectively (Table 9).

To check for existence of multicollinearity, Variance inflation factor (VIF) was estimated for independent variables that were included in the logit model. The rule is, if VIF is greater than 5 then there is multicollinearity between the independent variables (Greene, 2002). The VIF calculated ranged between 1.03- 1.68 with the mean VIF being 1.22 indicating that there was no multicollinearity.

To detect heteroscedasticity, Breusch- Pagan test was conducted and the null hypothesis was that there was no homoscedasticity (constant variance). The chi square was 2.02 with one degree of freedom and was insignificant at (p- value= 0.15 implying no heteroscedasticity.

Table 9: A logit regression estimates of the factors influencing participation in iCow service

Variable	Nyandarua (n=161)			Uasin Gishu (n=152)			Bomet (n=144)		
	Coef	dy/dx	p-value	Coef	dy/dx	p-value	Coef	dy/dx	p-value
Total Annual Household income (Ksh)	0.00	0.00	0.37	0.00	0.00	0.55	0.07	0.05	0.02**
Household head Gender(1=Male,0=Female)	-0.06	-0.01	0.90	0.04	0.01	0.94	0.06	0.01	0.89
Household head Education (Year)	0.05	0.01	0.28	0.10	0.02	0.07*	0.08	0.01	0.17
Household head Age (years)	0.03	0.00	-0.05**	-0.05	-0.01	-0.00***	-0.03	0.00	-0.09*
Experience in Dairy farming (years)	0.01	0.00	0.65	-0.04	-0.01	0.11	0.06	0.01	0.01***
Access to extension services (1=Yes,0=No)	-0.05	-0.01	0.90	0.97	0.16	0.05**	0.12	0.02	0.79
Access to internet services (1=Yes,0=No)	1.24	0.24	0.00***	-0.03	-0.01	0.94	0.75	0.13	0.09*
Number of Lactating cows	0.24	0.05	0.27	0.42	0.07	0.11	0.00	0.00	1.00
Plot size (Acres)	0.41	0.08	0.50	0.24	0.04	0.07*	0.49	0.08	0.19
Membership to social groups(1=Yes,0=No)	0.17	0.03	0.67	1.46	0.25	0.00***	-0.27	-0.05	0.57
Occupation (1=Farmer,0=Otherwise)	-0.63	-0.12	0.16	-0.71	-0.12	0.28	-0.83	-0.14	0.19
Distance from the farm to the road (Km)	0.33	0.06	0.01***	0.11	0.02	0.12	-0.10	-0.02	0.61
Number of breeds	2.18	0.43	0.06*	1.75	0.29	0.00***	0.96	0.16	0.16
Constant	-5.81	-	0.00	-2.00	-	0.09	-2.93	-	0.03
PseudoR2		0.18			0.27			0.23	
Prob>chi2		0.00			0.00			0.00	

significant at 10 percent, ** at 5 percent and *** at 1 percent level

The results indicate that in Nyandarua county; age, access to internet services, distance from the farm to the road and number of breeds significantly influenced the household's decision to participate in iCow program. In Uasin Gishu; education, age, access to extension, plot size, membership to social groups and number of breeds influenced participation. Finally, in Bomet, participation in iCow was influenced by income, age, experience in dairy farming and access to internet services.

Income of the household positively and significantly influenced participation of Bomet farmers in iCow at 5%, however it had no significant influence in the Uasin Gishu and Nyandarua counties. In Bomet the results imply that a one unit increase in income increases the probability of a dairy farmer in Bomet county participating in the iCow program by 5%. It is likely that farmers with higher incomes are likely to adopt and invest in new technology. Similar conclusions were made by Wejnert (2006), who observed that participation in the use ICT tools depended on income of the farmer.

Education was positive and significant at 10% for participation in iCow program among dairy farmers in Uasin Gishu county but insignificant in Bomet and Nyandarua counties. This implies that an increase of one year of schooling of Uasin Gishu dairy farmer, increases the likelihood of the farmer participating in the iCow program by 2%. It is likely that farmers who are educated can read more about a technology and its usefulness, therefore making informed decisions in adoption due to the information they have. Farmers with higher education level can obtain; process and use information that is relevant to adoption of a new technologies (Mignouna *et al.,* 2011; Namara *et al.,* 2003; Lavison 2013.) Similar conclusions have been made by Wejnert (2006) who concluded that use of an ICT tool depends more on education level.

The findings revealed that age negatively and significantly influenced participation in iCow at 5%, 1% and 5% in Nyandarua, Uasin Gishu and Bomet respectively. These results suggest that younger farmers are likely to participate in the iCow program than older farmers. This is because young farmers are more digital and more educated which makes them operate digital tools hence, they are highly likely to participate in ICTs related programs than older farmers. These results are similar to Lavison 2013, who concluded that young farmers participated more in ICTs than older farmers.

Experience in dairy farming positively and significantly influenced Bomet farmers' participation in iCow at 1%. A one-year increment in experience in dairy farming increases the likelihood of a dairy farmer in Bomet participating in the iCow program. It is likely that farmers who have more years of experience in dairy farming know the importance and impact of technologies increasing production. This finding is consistent to Mignouna *et al,* (2011) and Uaiene *et al*. (2009) who made conclusions that uptake of new technologies was directly associated with experience.

Access to extension services positively and significantly influenced farmers in Uasin Gishu farmers to participate in iCow at 5%, however insignificant in Nyandarua and Bomet counties. Access to extension services increased the likelihood of a farmer in Uasin Gishu participating in iCow which could be because farmers who are visited by extension agents are taught about the availability of new technologies and their usefulness hence their adopting them. Equally, the marginal effects also indicate that access to internet services significantly increased the likelihood of a farmer in Nyandarua and Bomet to participate in the iCow program by 24% and 13% respectively. The reason for this is that with availability of internet connectivity, farmers are able to read more about the benefits of a technology and this will enable them to make informed decisions in adoption.

Results also indicated that membership to social groups significantly increased the probability of farmers participating in the iCow program in Uasin Gishu. This can be attributed to the fact that, through trainings and interactions the farmers get from the groups, they learn the usefulness and benefits of various technologies available. Therefore, through this interaction with fellow farmers, they can share and learn from each other and this informs the decision to adopting and using technologies. The result is consistent with the findings of Katungi & Akankwasa, (2010) who found that participation of farmers in community-based organizations make farmers to learn more about a technology hence raising their likelihood to adopt the technologies. In addition, being a member of a social group enhances social capital which leads to trust amongst members and therefore idea and information exchange is facilitated. Therefore, farmers from these groups learn from each other about the benefits and usage of a technology. Uaiene *et al*. (2009) made similar observations, that social networks have effects on decision making of individuals and in the context of agricultural innovations, farmers can share information and learn from each other hence increasing the likelihood of adoption of these innovations

Plot size was significantly and positively associated with the probability of a farmer participating in the iCow program in Uasin Gishu county but insignificant in Nyandarua and Bomet counties. This imply that farmers who have larger farm size are likely to participate in new technologies because they can afford to devote a section of their land to try new technologies unlike those with less farm size (Uaiene *et al*., 2009). Similarly, many studies have reported a positive and significant relationship between farm size and adoption of new agricultural technologies (Kasenge, 1998; Haggblade, 2001; Gabre-Madhin & Ahmed, 2004; Uaiene *et al*., 2009; Mignouna *et al.,* 2011).

Finally, the distance from the farm to the road positively and significantly influenced farmers to participate in iCow program in Nyandarua county. Farmers who are far away from the road

are likely to adopt new technologies. This is because these farmers in most cases are not able to access the training and hence, they prefer getting information in a digital way that is timely.

4.5 Impact of iCow on smallholder milk production and household welfare

4.5.1 Estimating Propensity scores

The Logit regression models in Table 10, 11 and 12 are for the purpose of estimating the probability of being in the treatment group of all sampled units. The results also represent factors affecting participation in iCow program. These have however been purpose of an earlier objective and thus the current study does not expound on the same. The results are only relevant in as far as they are a step to impact assessment using the Propensity Score Matching method.

Table 10: Logit model for estimation of propensity scores in Nyandarua county

Variable	Coef	SE	Z	p value
Household head Education (Year)	0.07	0.04	1.56	0.12
Experience in Dairy farming (years)	0.00	0.02	0.26	0.80
Number of Lactating cows	0.42	0.20	2.05	0.04**
Access to Credit services(1=Yes,0=No)	0.43	0.37	1.16	0.25
Membership to other social groups(1=Yes,0=No)	0.12	0.35	0.36	0.72
Household head occupation (1=Farmer,0=Otherwise)	-0.38	0.40	-0.95	0.34
Household head Marital status (1=Married,0=Otherwise)	0.09	0.39	0.23	0.82
Household Decision maker (1=Joint ,0=Otherwise)	-0.23	0.37	-0.62	0.03**
Constant	-1.41	0.74	-1.91	0.06
Pseudo R^2 0.18		$LR\chi^2$ (p value) 40.73(0.0000)		

***significant at 10% **significant at 5% and *** significant at 1%**

Table 11: Logit model for estimation of propensity scores in Uasin Gishu county

Variable	Coef	SE	z	p value
Household head Education (Year)	0.02	0.05	0.44	0.66
Experience in Dairy farming (years)	-0.03	0.02	-1.57	0.12
Number of Lactating cows	0.75	0.25	3.01	0.00***
Access to Credit services(1=Yes,0=No)	-0.65	0.42	-1.54	0.12
Membership to other social groups(1=Yes,0=No)	1.43	0.43	3.29	0.00***
Household head occupation (1=Farmer,0=Otherwise)	-0.11	0.51	-0.22	0.83
Household head Marital status (1=Married,0=Otherwise)	1.03	0.69	1.51	0.13
Household Decisionmaker (1=Joint ,0=Otherwise)	-0.69	0.40	-1.7	0.09*
Constant	-1.85	0.89	-2.08	0.04**
Pseudo R^2 0.23	$LR\chi^2$ (p value) 24.35 (0.0000)			

***significant at 10% **significant at 5% and *** significant at 1%**

Table 12: Logit model for estimation of propensity scores in Bomet county

Variable	Coef	SE	z	p value
Household head Education (Year)	0.14	0.06	2.45	0.01***
Experience in Dairy farming (years)	0.06	0.03	2.10	0.04**
Number of Lactating cows	0.50	0.25	2.04	0.04**
Access to Credit services(1=Yes,0=No)	0.77	0.47	1.62	0.10
Membership to other social groups(1=Yes,0=No)	0.02	0.44	0.06	0.96
Household head occupation (1=Farmer,0=Otherwise)	-1.12	0.64	-1.74	0.08*
Household head Marital status (1=Married,0=Otherwise)	0.29	0.65	0.44	0.66
Household Decisionmaker (1=Joint ,0=Otherwise)	-1.53	0.42	-3.63	0.00***
Constant	-2.08	0.75	-2.76	0.01**
Pseudo R^2 0.16	$LR\chi^2$ (p value) 32.34 (0.0000)			

***significant at 10% **significant at 5% and *** significant at 1%**

4.5.2 Validating application of PSM for impact assessment

4.5.2.1 Testing for common support assumption (CSA)

The estimated propensity scores were used to construct a counterfactual group for comparison. As pointed out by Imai and Ratkovic (2014), propensity scores are useful in balancing the distribution of observable covariates across the treatment and the control group. When the two groups have similar observable characteristics, any differences observed can be attributed to the effect of participating in the iCow program.

The distribution of the estimated scores of PSM and the common support region in study counties is shown in Figure 11, 12 and 13. The horizontal axis shows the estimated propensity scores and while the vertical axis shows the observed frequency. The visual analysis of the density distribution for the treated and control groups in the three counties indicate that a majority of the treated and control individuals fall within the common support region, therefore most individuals had a positive probability of being a participant or a non-participant in the use of iCow program. Thus, the common support assumption (CSA) was satisfied, which requires that the treated household should have a corresponding untreated household as a match.

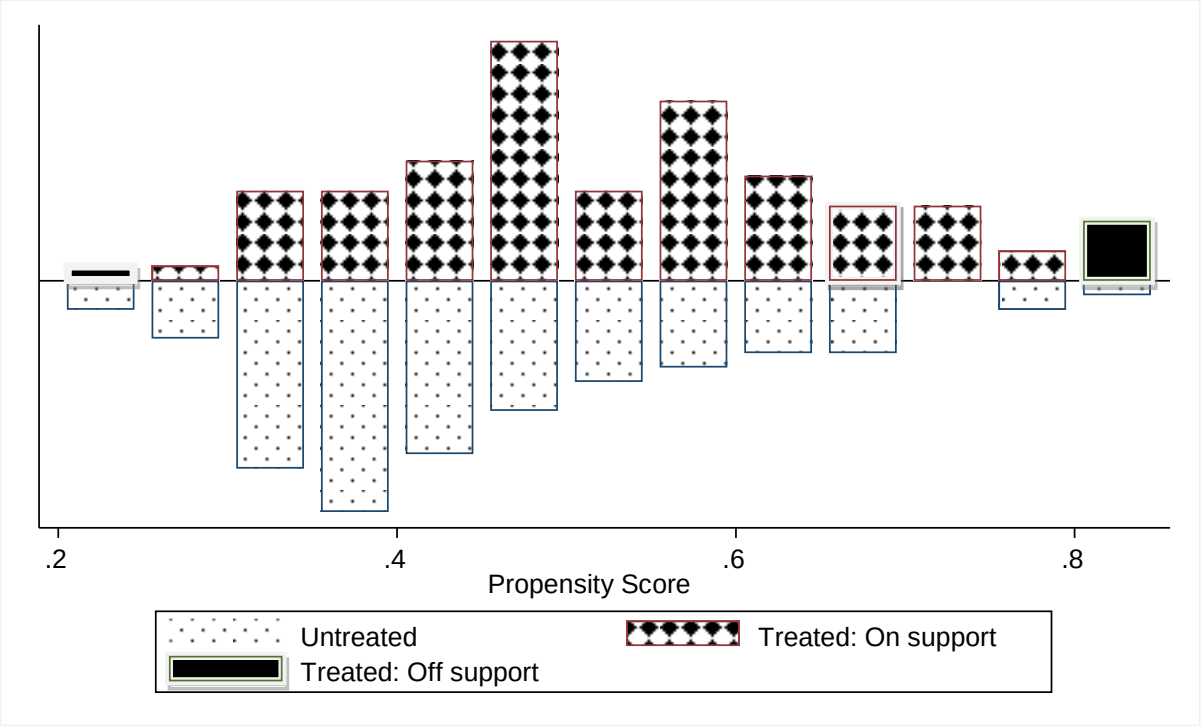

Figure 11: Propensity score histogram Nyandarua county

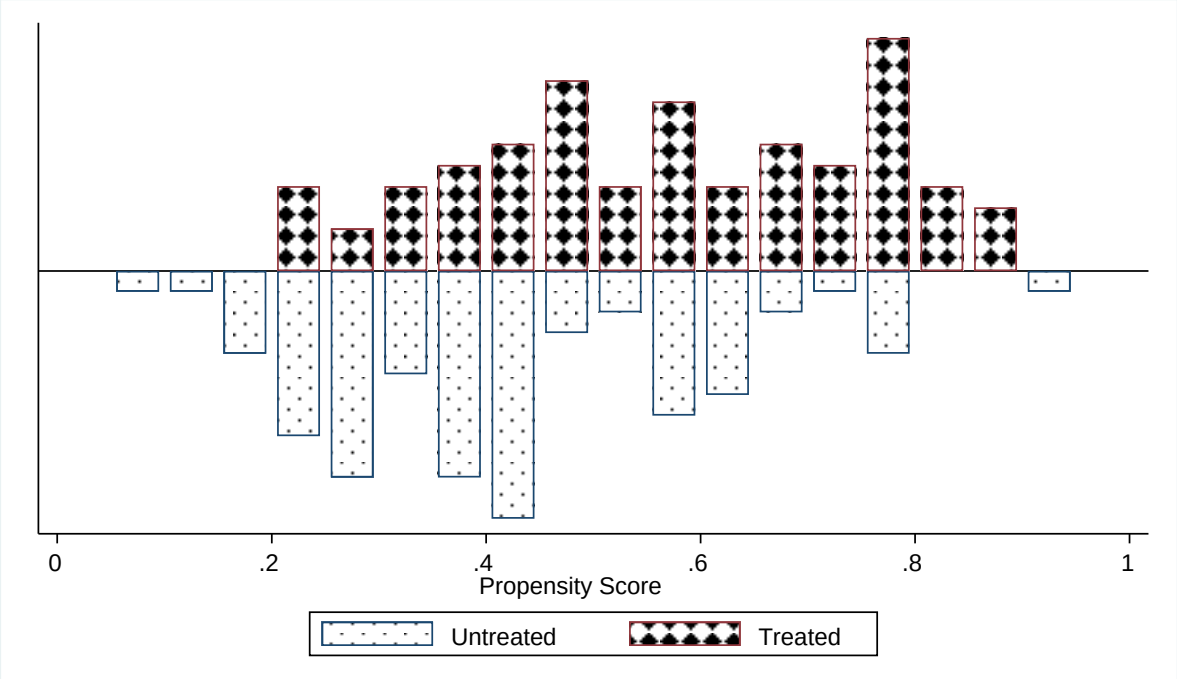

Figure 12: Propensity score histogram Uasin Gishu county

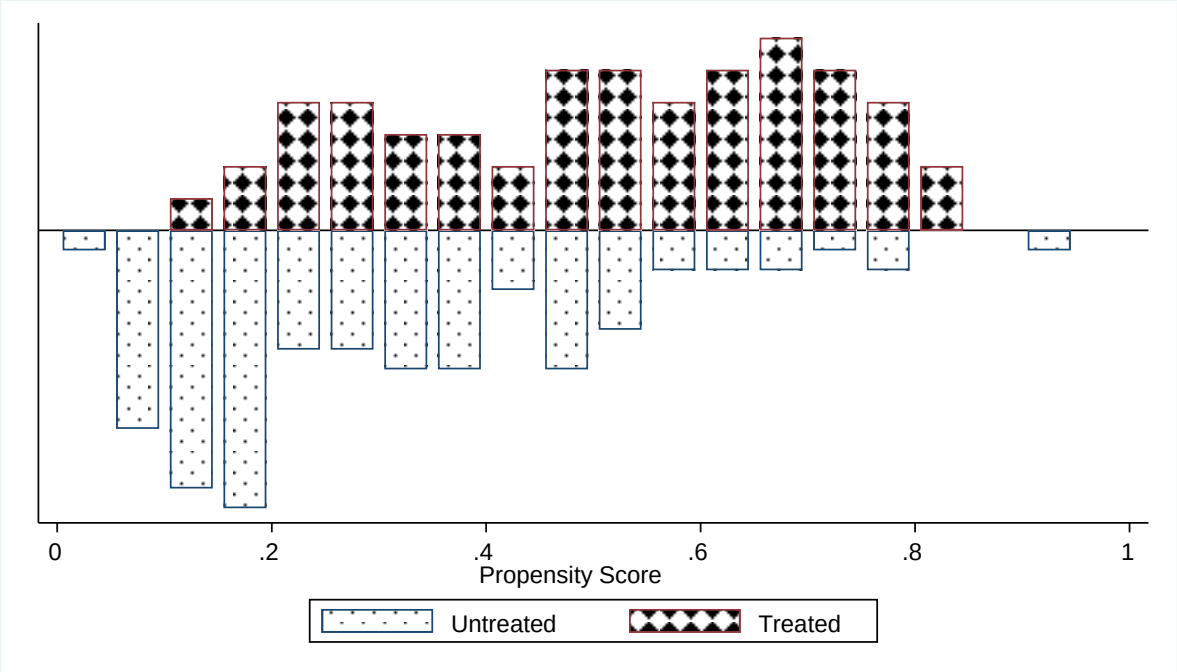

Figure 13: Propensity score histogram Bomet county

4.5.2.2 Assessing the Matching Quality

According to Rosenbaum and Rubin (1983), the success of estimating of propensity scores, is to balance the distribution of covariates among participants and non-participants. This balancing eliminates the differences in the covariates between the treatment and control groups that is observed before matching. If this condition is satisfied, then the control is considered as a good counterfactual (Caliendo & Kopeinig, 2008). One suitable indicator of balancing powers of the estimations is determined by considering the reduction in the mean absolute standardized bias between the matched and unmatched models as shown in Table 13. The high percentage values of reduced standardized bias indicate the effectiveness of matching in reducing biases in the estimates.

Table 13: Covariate balancing tests of the matching methods used

Test Indicator	Nyandarua	Uasin Gishu	Bomet
Before Matching			
Pseudo R^2	0.18	0.27	0.23
Mean Bias	19.5	22.8	25
LRχ^2 (p value)	22.71 (0.000)	24.32 (0.000)	32.25(0.000)
After Matching using NNM			
Pseudo R^2	0.005	0.08	0.01
Mean Bias	5	14.1	8.9
LRχ^2 (p value)	1.06 (0.99)	6.43 (0.56)	2.07 (0.98)
After Matching using KBM			
Pseudo R^2	0.008	0.03	0.04
Mean Bias	7.1	12.2	16.3
LRχ^2 (p value)	1.23 (0.99)	5.94 (0.65)	5.22 (0.73)
After Matching using RM			
Pseudo R^2	0.002	0.06	0.036
Mean Bias	10.5	14.1	16.9
LRχ^2 (p value)	4.08 (0.85)	12.41(0.53)	2.93(0.94)

Another way to test for proper matching is the comparison of the pseudo R^2 before and after matching (Sianesi, 2004). The rule is the estimated pseudo R^2 should be low after matching to indicate that there are no systematic differences in the distribution of covariates (Ashimwe, 2016). From table 13, Pseudo R^2 indicates how well the regressors X explain probability of participation in the iCow program. Caliendo & Kopeinig (2008), suggest that Pseudo R^2 below 10% after matching indicates no systematic differences between the treatment and control. Thus, the results showed that, before matching the Pseudo R^2 were fairly high i.e 18, 27 and 23% in Nyandarua, Uasin Gishu and Bomet respectively, but reduced after matching to show that there were no systematic differences between iCow users and non-users after matching in all the matching algorithms. Hence any difference in the outcome variable can be attributed to treatment i.e. use of iCow services.

The P-values of the likelihood ratio tests before and after matching are also presented. Low p-values before matching shows that hypothesis that the regressors are jointly insignificant in

determining probability of participation is always rejected before matching. After matching the p-values increases considerably, thus we fail to reject the same hypothesis, suggesting that there is no systematic difference in the distribution of covariates between iCow users and non-users after matching.

4.5.3 Impact assessment results

4.5.3.1 Impact of iCow on milk production

Impact of iCow services on milk production was estimated with Nearest Neighbour matching (NNM), Radius matching (RM) and Kernel-based matching (KBM) (Table 14). These matching methods indicated that the use of iCow services among smallholder dairy farmers had a significant and positive impact on milk production in Nyandarua and Uasin Gishu, however there was no impact in Bomet county. Based on the findings, there was a rejection of the null hypothesis that there is no significant difference between regular iCow users and non-users in terms of milk production per cow in Nyandarua and Uasin Gishu. Equally, failed to reject the null hypothesis in Bomet county and therefore concluded that the iCow services had a significant impact on milk production in Nyandarua and Uasin Gishu counties.

Table 14: Treatment effects on milk production per cow in the study counties

	Nyandarua			Uasin Gishu			Bomet		
Matching Algorithm	**ATT**	**t-stat**	**Gamma Level**	**ATT**	**t-stat**	**Gamma Level**	**ATT**	**t-stat**	**Gamma Level**
NNM	402	2.18**	1.35-1.40	797	2.92***	1.90-1.95	172	0.59	-
KBM	466	1.92*	1.40-1.45	741	3.02***	2.15-2.20	284	1.00	-
RM	414	1.88*	1.60-1.65	627	2.16**	1.25-1.30	40	0.13	-

***significant at 10% **significant at 5% and *** significant at 1%**

The average treatment effect on the treated (ATT) for the annual milk production per cow in Nyandarua was 402 Litres in the Nearest neighbour matching (NNM), 466 Litres in the Kernel based matching (KBM) and 414 Litres in the Radius Matching (RM) and it was significant from zero at 1% for the NNM and at 10% for the KBM and RM methods. In Uasin Gishu, the ATT for the annual milk production per cow was 797 Litres in NNM, 741 Litres in KBM and 627 Litres in RM and it was significant from zero at 1% for both NNM and KBM, and at 5% for RM methods. This has an implication that regular users of iCow services increased milk production per cow between 402 Litres and 466 Litres in Nyandarua and 627 Litres and 797 Litres in Uasin Gishu. The increment in milk production can be attributed to iCow users being able to apply knowledge on husbandry practice that they acquire via use of iCow extension advise. The result is consistent with the findings by Das *et al.* (2016) that revealed that use of ICT in accessing agricultural information increased production of rice in Bangladesh. Similarly, Chaula (2014) and Ali *et al.* (2016) concluded that use of ICT in agriculture had a positive impact on productivity.

4.5.3.2 Impact of iCow on milk and household income

As presented in Table 15 and 16, the results indicate that use of iCow services among smallholder dairy farmers had a significant and positive impact on milk income in Nyandarua

and Uasin Gishu and no significant impact on household income in all the counties. In relation to the income generated from milk, results from Table 15 indicate that the ATT for annual milk income was Ksh. 28115 in NNM, Ksh. 28106 in KBM and Ksh. 25167 in RM in Nyandarua and Ksh. 75334 in NNM, Ksh. 76850 in KBM and Ksh. 26505 in RM in Uasin Gishu. This ATT was significantly different from zero at 1% in NMM and KBM, and 5% in RB in Both Nyandarua and Uasin Gishu. This suggests that income from milk for the regular users of iCow was higher by about Ksh 25167 and 28115 than the non-users of iCow in Nyandarua.

Table 15: Treatment Effects on milk income in study counties

	Nyandarua			**Uasin Gishu**			**Bomet**		
Matching Algorithm	**ATT**	**t-stat**	**Gamma Level**	**ATT**	**t-stat**	**Gamma Level**	**ATT**	**t-stat**	**Gamma Level**
NNM	28115	2.43**	1.40-1.45	75334	3.01***	1.95-2.00	15513	0.69	-
KBM	28106	2.00**	1.10-1.15	76850	3.41***	1.70-1.75	7813	0.35	-
RM	25167	2.00**	1.10-1.15	26505	2.22**	1.30-1.35	4054	0.17	-

***significant at 10% **significant at 5% and *** significant at 1%**

Table 16: Treatment Effects on household income in study counties

	Nyandarua			Uasin Gishu			Bomet		
Matching Algorithm	**ATT**	**t-stat**	**Gamma Level**	**ATT**	**t-stat**	**Gamma Level**	**ATT**	**t-stat**	**Gamma Level**
NNM	5666	0.08	-	-8967	-0.4	-	130426	1.19	-
KBM	40743	0.55	-	81135	0.72	-	116432	1.43	-
RM	-29060	-0.33	-	-54050	-0.2	-	118701	1.59	-

***significant at 10% **significant at 5% and *** significant at 1%**

Equally, the figures show that income from the sale of milk for the regular users of iCow was higher by about Ksh 26505 and 76850 than the non-users of iCow in Uasin Gishu. It is likely that application of knowledge on livestock practices as advised via iCow services improves milk yield resulting into more surpluses for sale by farmers. These findings are similar to those of Agnes (2010) and Hill (2005) who pointed out that the use of mobile phones among farmers in accessing agricultural information played positive impact in their income and productivity. Similar observation was made by Surya (2012) who showed that use ICTs in accessing information led to increase of farmers' income up to 36% in countries such as Kenya, Ghana, Uganda and Morocco. Also, McKinsey (2013) concluded that use of SMS by the Ethiopian Commodity exchange provided transparency on demand supply and prices and this increased farmers' share of revenue

While the results show that there was significant impact on milk income in Nyandarua and Uasin Gishu counties, the results in Table 16 indicate that there was no significant impact on the household income in the three counties. This can be explained by the fact that the percentage contribution of milk income to the total household income is small hence any contribution would have been so marginal and wouldn't have changed much the value of total

household income of the iCow users. In addition, descriptive statistics showed that most of the farmers in these counties have about 1 to 3 lactating cows, which in my view shows that there is low commercialization hence the contribution of milk income to the household income could be small.

4.5.3.3 Impact of iCow on household food security

Impact of iCow services on food security was estimated using the three matching methods as presented in Table 17. The results indicate that use of iCow services among smallholder dairy farmers had no significant impact on household food security in all the three counties.

Table 17: Treatment effects on food security in the study areas

	Nyandarua			Uasin Gishu			Bomet		
Matching Algorithm	**ATT**	**t-stat**	**Gamma Level**	**ATT**	**t-stat**	**Gamma Level**	**ATT**	**t-stat**	**Gamma Level**
NNM	4.6	1.38	-	4.7	1.2	1.15-1.20	4.9	1.22	1.15-1.20
KBM	2.4	0.6	-	2.8	1.01	1.25-1.30	3.6	0.81	-
RM	4.2	0.98	-	8.2	1.49	1.45-1.50	4.3	1.23	1.15-1.20

***significant at 10% **significant at 5% and *** significant at 1%**

The insignificant impact of iCow on food security can be explained by the descriptive results in Figure 9 and 10 which shows that both iCow users and non-users in all the counties had similar patterns of consumption in all the Food Consumption Groups (FCGs). Graphical representation in Figure 10 also revealed that over 85% of the iCow users and non-user were food secure and there were no significant differences between the two groups in all the counties even after iCow services were introduced. This could be an explanation why even after matching there was no significant impact. Impact on food security, would have been because of consumption of milk or through increased income that would have led to diversification in consumption. But this was not the case because from Figure 9, milk was

consumed highly in both the iCow users and non-users. Equally, from Table 16, there was insignificant impact in household income that would have led to diversification in consumption raising the FCS for the iCow users.

Following the results in Table 13 and 14, it can be argued that iCow positively influenced access to agricultural knowledge, leading to improved yields and increased surpluses that is sold for increased dairy income. Use of iCow platform reduced information asymmetry, enabling regular users of iCow to access sufficient information on dairy management practices such as proper feeding, hygiene, disease and parasite control, feed management, all of which enhanced their productive capacity. This concurs with the results of Humphrey (2002) and Baumueller, (2012) who concluded that use of ICT can help small agricultural producers to reduce information asymmetries and transaction costs.

4.5.4 Testing for sensitivity and Hidden bias

In observational studies, hidden bias due unobserved covariates is a challenge that can affect the results of the outcome variables (Rosenbaum, 2002). PSM reduces bias on only the observed covariates but does not address potential bias due to unobserved covariates. However, the use of PSM is validated by the Conditional Independence Assumption (CIA), which states that there should be independence of the outcome from the treatment assignment after controlling for X observable covariates. This was assured by inclusion of all variables that simultaneously affect the participation in iCow and the outcome variables. Results of sensitivity analysis addresses the question of unobserved covariates that would alter the value of the outcome variables (Rosenbaum, 2002).

The results of sensitivity analysis of the hidden bias are presented in Table 14, 15, 16, and 17 with their critical levels of gamma where the significant impact of iCow may be questioned. According to Hujer *at al.* (2004) it is not meaningful to perform sensitivity analysis on

insignificant ATT and therefore the Rosenbaum bounds are only calculated for the ATT that is significant. The test procedure involved changing the level of Γ and deriving the bounds on the significance levels of the ATT under the assumption of endogenous self-selection into use of iCow services. This allows for identification of the critical levels of Γ at which the estimated ATT would become insignificant. Results showed that the impact estimates are relatively insensitive to hidden bias in the outcome variables. For example, for impact of iCow on milk production, the sensitivity analysis showed that at the gamma level of 1.35 to 1.65 and 1.25 to 2.10 in Nyandarua and Uasin Gishu, ATT due to use of iCow would need to be viewed critically. These critical values of gamma imply that if individuals who have similar observable covariates in Nyandarua and Uasin Gishu, will differ in their odds of using iCow services due to unobserved heterogeneity by 35-65% and 25-110% respectively, then the significant impact of iCow services on milk production may be questionable. The lowest critical value of gamma is 1.25-1.30, where.as the largest is 2.15-2.20. These critical levels were pretty high and therefore conclusion was made that the results were robust, and the unobserved heterogeneity did not affect or alter the estimated ATT hence Conditional Independence Assumption (CIA) was satisfied.

CHAPTER FIVE

5.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

Despite the existence of various approaches to extension, smallholder farmers have the challenge of accessing timely, credible and reliable agricultural information which consequently limits them in realising maximum farm output. Use of ICT as an agricultural extension tool by smallholder farmers has the potential to reverse the scenario and improve farmers` outputs and incomes leading to increased welfare. Green Dream Technology (GDT) in partnership with International Livestock Research Institute (ILRI) have taken the initiative to improve extension services among smallholder farmers through the introduction of iCow platform.

The study determined the impact of iCow service on milk production, milk and household income and food security among smallholder dairy famers' in Uasin Gishu, Nyandarua and Bomet counties of Kenya. The three counties were purposely selected because of the higher percentage of smallholder dairy farmers and the iCow program was piloted and rolled out in these counties. Regular iCow users and non-users were sampled for the survey through a two-stage stratified random sampling procedure. Socio-economic characteristics of regular iCow users and non-users among smallholder dairy producers were profiled using descriptive statistics. The study then utilized PSM to estimate the impact of iCow program on milk production, milk income and household income and food security.

The descriptive statistics show some differences in demographic characteristics of regular iCow users and non-user households in the three counties. In relation to differences in the outcome variables, iCow users in Uasin Gishu and Bomet counties realised higher average annual milk production per cow (2550 and 2456 litres respectively) as compared to non-users (1833 and 2020 litres respectively). There were also significant differences in incomes where

regular iCow users in Nyandarua, Uasin Gishu and Bomet on average earned Ksh. 32796, 80430 and 43632 respectively more income from milk than non-users. Regarding household income, there was significant difference in Bomet County only where iCow users earned Ksh. 153353 more income than the non-users. With respect to food security, there was a significant difference in mean of Food Consumption scores (FCS) in Bomet where users of iCow had a score of 72 (i.e. better food security) than the non-users with a score of 67. Additionally, about 7%,3% and 9% of the households among the non-users of iCow in Nyandarua, Uasin Gishu and Bomet were found to be food insecure compared to 1%, 3% and 2% of the household of iCow users in Nyandarua, Uasin Gishu and Bomet respectively. Over 80% of the households of both iCow users and non-users were found to be food secure having fell into the acceptable food consumption range.

Results also indicate that several variables do influence the likelihood of adopting and use of the iCow services in the three counties. In particular, level of education, age, experience in dairy farming, access to extension, access to internet services, land size under dairy enterprise, membership to other social groups, membership period to dairy cooperatives, and number of breeds kept had a significant influence on participation on iCow services.

However, impact results indicate that the use of iCow services among smallholder dairy farmers in Nyandarua and Uasin Gishu counties had a significant and positive impact on milk production and milk income and no impact on household income and food security.

5.2 Conclusions

Smallholder dairy farmers in developing countries have a challenge in accessing timely agricultural advisory information to enable them to increase their production. Such challenges include lack of adequate information on feed management, pest and disease control, hygiene among others. This study evaluated the impact of participation in the mobile based extension

service, the iCow service on milk production, income and food security among smallholder dairy farmers in Nyandarua, Uasin Gishu and Bomet counties of Kenya using PSM model.

The results reveal that participation in iCow service has a positive and significant impact on milk production and milk income in Nyandarua and Uasin Gishu counties and insignificant impact in Bomet counties. However, the results showed insignificant impact on household income and food security across all the study counties. Level of Education, membership period to dairy cooperatives were found to have an influence on the decision to participate on the iCow program. These variables demonstrate that increased access to education and exposure to cooperatives has influence on participation decisions. Similarly, access to internet services and land size had a significant influence on iCow uptake.

Based on the result, it can be argued that iCow positively influenced access to agricultural knowledge, leading to improved yields and increased surpluses that was sold for increased dairy income. Use of iCow platform reduced information asymmetry, enabling regular users to access sufficient information on dairy management practices such as proper feeding, hygiene, disease and parasite control, feed management, all of which enhanced their productive capacity. These findings highlight the vital role that iCow can play in increasing smallholder farmers production and incomes, hence providing avenues for policy making.

5.3 Recommendations

The positive impact of iCow on milk production and income highlight the need for Green Dream Technology limited to expand the iCow services in terms of coverage to other counties. The iCow services should also be applied to other livestock and crop value chains other than dairy industry in rural areas, due to its proven capacity of enhancing smallholder dairy farmers` access to simple, timely information and digital solution, subsequently improving their production, incomes.

The positive correlation of use of phones in getting timely information among farmers suggest that policies should focus in improving infrastructure in the rural areas for the ICT usage. This includes expansion of electrification programs for access of power for charging the ICT devices. Besides, there is also a need for expansion of mobile network coverage in the rural areas where the network is poor to facilitate exchange of information in uninterrupted manner.

Based on the findings from this study it is important for the County and National governments in Kenya to increase smallholder farmers access to support services such as; education and access to internet services to improve their levels of ICT usage and participation. Membership in the dairy co-operatives have a positive and significant influence on the participation on ICT related programs. There is a need to create awareness among farmers about the importance of collective action which should be done by government extension officers, and civil society organizations and media advertisement and talk shows.

Future studies can focus on cost-benefit analysis associated with the use of iCow and this will help determine if farmers will be willing to pay for the service. Additionally, this study focused on dairy enterprise only, future studies can also focus on the role iCow on other farm enterprises other than dairy, i.e., intra-farm spill over effects.

References

Agwu, A.E., Uche-Mba, U.C and Akinnagbe, O.M. (2008) Use of Information and Communication Technologies among researchers, extension workers and farmers in Abia and Enugu states: Implications for a national agricultural extension policy on ICTs. *Journal of Agricultural Extension, 12 (1):37-48.,*

Ajani, E.N. and Agwu, A.E. (2012) Information Communication Technology needs of small scale farmers in Anambra state, Nigeria. *Journal of Agricultural and Food Information.*

Ali, A., & Abdulai, A. (2010). The adoption of genetically modified cotton and poverty reduction in Pakistan. *Journal of Agricultural Economics*, *61*(1), 175-192.

Ali, S., Jabeen, U. A., Nikhitha, M., & INDIA, Z. (2016). Impact of ICT on Agricultural Productivity. *European Journal of Business, Economics, and Accountancy*, *4*(5), 82-92.

Alonge, J. A. (2003). Integrating farmers, their local level institutions, and social capital into extension delivery systems in Sub-Saharan Africa: Issues, challenges, and implications. *Proceedings of the 19th annual conference of the Association of International Agricultural and Extension Education, USA, 19–31*

Andam, K., Makhija, S., & Spielman, D (2019). Evaluation of the impacts of a soil fertility training project on farm productivity in the Volta region of Ghana.

Ashimwe, O. (2016). *An economic analysis of impact of weather index-based crop Insurance on household income in Huye District of Rwanda* (No. 634-2017-5863).

Baumüller, H. (2012). Facilitating agricultural technology adoption among the poor: The role of service delivery through mobile phones.

Bernoulli, D. (1738). Hydrodynamica. *Dulsecker. Consultable en ligne http://imgbase-scd-ulp. u-strasbg. fr/displayimage. php*.

Birmingham, D. M. (1999). Revisiting agricultural extension: Experiences in less industrialized countries. (Invited panel presentation). *Journal of International Agricultural and Extension Education.*

Blomley, T., & Namara, A. (2003). Devolving rights or shedding responsibilities?—Community Conservation in Uganda over the last decade. *Section I: The complexities of governing protected areas, 283*.

Blundell, R. and M. Costa Dias (2000), 'Evaluation Methods for Non-Experimental Data', *Fiscal Studies, 21, 427–68*

Bogue, P. (2014). Evaluation of the impact on farmers participating in Teagasc beef discussion groups 2012-2014. *Carlow, Ireland: Teagasc.*

Bonye, S. Z., Alfred, K. B., & Jasaw, G. S. (2012). Promoting community-based extension agents as an alternative approach to formal agricultural extension service delivery in Northern Ghana. *Asian Journal of Agriculture and Rural Development*, *2*(393-2016-23897), 76-95.

Brynjolfsson, E. and Hitt, L. (1995). Information technology as a factor of production: The role of differences among firms in economics of innovation and new technology. *Journal of Economic Perspective*, 3, 4, 83-199

Caliendo, M. & Kopeinig, S. (2008). Some Practical Guidance for the Implementation of

Propensity Score Matching, *Journal of Economic Surveys*, 22 (1), pp. 31-72.

Chaula Hopestone Kayiska (2014): The role of ICTs in Agricultural Production in Africa; *Journal of Development and Agricultural Economics*, Vol. 6 (7), pp. 279-289, July 2014

Chilimo, W. (2008). Information and communication technologies and sustainable livelihoods: a case of selected rural areas of Tanzania (Doctoral dissertation, University of KwaZulu-Natal, Pietermaritzburg, South Africa).

Cole, S., & Fernando, A. N. (2012). The value of advice: Evidence from mobile phone-based agricultural extension. *Harvard Business School working paper# 13-047*.

Das, S., Munshi, M. N., & Kabir, W. (2016). The impact of ICTs on agricultural production in Bangladesh: A study with food crops. *SAARC Journal of Agriculture*, *14*(2), 78-89.

Davis, K. E. (2008). Extension in Sub-Saharan Africa: Overview and assessment of past and current models, and future prospects. *Journal of International Agricultural and Extension*

Education

Davis, K., & Place, N. (2003). Current concepts and approaches in agricultural extension in Kenya. *Proceedings of the 19th annual conference of the Association of International Agricultural and Extension Education*, USA, 745-756

Evans, C. L. (2014). Review of Agricultural Extension Interventions in Unlocking Agriculture Potential through Medium Sized Farms, Kenya. *Nairobi, Kenya*.

Dercon, S., Gilligan, D. O., Hoddinott, J., & Woldehanna, T. (2008, December). The impact of agricultural extension and roads on poverty and consumption growth in fifteen

Ethiopian villages (IFPRI Discussion Paper 00840). *Washington, DC: International Food Policy Research Institute*

FAO. 2011. *Dairy development in Kenya*, by H.G. Muriuki. *Rome.*

FAO. (2002). Food and Agriculture Organization of the United Nations: The State of Food Insecurity in the World 2002. Rome:

Fu, X. and Akter, S. (2010). The Impact of ICT on Agricultural Extension Services Delivery: Evidence from the Rural e-services Project in India. *TMD Working Paper Series. University of Oxford.*

Gabre-Madhin, E., & Haggblade, S. (2001). Successes in African agriculture: Results of an expert survey. Washington, DC: International Food Policy Research Institute.

Gelb, E., Maru, A., Brodgen, J., Dodsworth, E., Samii, R., & Pesce, V. (2008, August). Adoption of ICT enabled information systems for agricultural development and rural viability. In *ICT adoption workshop at the IAALD-AFITA-WCCA conference*.

Gina K., Berardo, A., Papavero, C., Horjus, P., Ballard, T., Dop, M., ... & Brouwer, I. D. (2010). Proxy measures of household food consumption for food security assessment and surveillance: comparison of the household dietary diversity and food consumption scores. *Public health nutrition*, *13*(12).

Gómez-Limón, J. A., & Atance, I. (2004). Identification of public objectives related to agricultural sector support. *Journal of Policy Modeling*, *26*(8-9), 1045-1071.

Greene, W. H. (2002) Econometric Analysis (5th Edition). Upper Saddle River, New Jersey: Prentice-Hall, 784.

Gujarati, D. N. (2009). *Basic econometrics*. Tata McGraw-Hill Education.

Hafeez, S., & Sher, S. W. (Eds.). (2006). *UN Global E-government Readiness Report 2005: From E-government to E-inclusion* (Vol. 2). United Nations Publications.

Hassan, M. S., Hassan, M. A., Samah, B. A., Ismail, N., & Shaffril, H. A. M. (2008). Use of information and communication technology (ICT) among agri-based entrepreneurs in Malaysia. *Agricultural information and it. Iaald afita WCCA.*

Heckman, J. J., Ichimura, H., & Todd, P. (1998). Matching as an econometric evaluation estimator. *The review of economic studies*, *65*(2), 261-294.

Hennessy, D. A., Babcock, B. A., & Fiez, T. E. (1996). Effects of site-specific management on the application of agricultural inputs.

Hill, S. R., & Troshani, I. (2010). Factors influencing the adoption of personalisation mobile services: empirical evidence from young Australians. *International Journal of Mobile Communications*, *8*(2), 150-168.

Hosseini, S. J. F., Niknami, M., & Chizari, M. (2009). To determine the challenges in the application of ICTs by the agricultural extension service in Iran. *Journal of Agricultural Extension and Rural Development*, *1*(1), 27-30.

Hujer, R., Caliendo, M., & Thomsen, S. L. (2004). New evidence on the effects of job creation schemes in Germany: A matching approach with threefold heterogeneity. *Research in Economics*, 58(4), 257–302.

Jensen, R. (2007). The Digital Provide: Information (Technology), Market Performance and Welfare in the South Indian Fisheries Sector. *The Quarterly Journal of Economics*, 122, 3, 879-924

Jones, G. E., & Garforth, C. (1997). *The history, development, and future of agricultural extension. Improving agricultural extension: a reference manual*. FAO, Roma (Italia).

Joseph, O. C., & Polytechn, O. (2017). Effectiveness of Extension Services in Enhancing the Productivity, Income and Welfare of Women Farmers Cooperatives in Kajuru ...,

(November).

Karanja, D. N., Ngatia, T. A., Wabacha, J. K., & Bebora, L. C. (2013). Systemic porcine salmonellosis: A potential zoonosis and cause of mortality in smallholder pig farm in Kenya. *Tanzania Veterinary Journal*, *28*(1), 8-13.

Katungi, E., & Akankwasa, K. (2010). Community-based organizations and their effect on the adoption of agricultural technologies in Uganda: a study of banana (Musa spp.) pest management technology. *Acta horticulturae*, (879), 719-726.

Kaushik, P. D. & Singh, N. (2004) Information Technology and Broad-Based Development: Preliminary Lessons from North India. *World Development*, 32, 591-607

Kenya National Bureau of Statistics. (2016). *Economic Survey: 2016*. https://doi.org/10.1017/CBO9781107415324.004

Kinambuga, D. (2010). *Evaluation of the constraints to profitable smallholder Dairying: A case of Nakuru County, Kenya* (No. 634-2016-41511).

Kraemer, K. L. & Dedrick, J. (1994) Payoffs from investment in information technology: Lessons from the Asia-Pacific region. *World Development*, 22, 1921-1931.

Kwadwo, A. and Ayalew, D. (2011). Opportunities and Challenges for Using ICT for Agricultural Extension and Advisory Services in Africa. A paper presented at the international conference on "Innovative Approaches for Agricultural Knowledge Management: Global Extension Experiences", *New Delhi, India, November* 9-12.

Läpple, D., Hennessy, T. and C. Newman (2013) 'Quantifying the Economic Return to Participatory Extension Programmes in Ireland: an Endogenous Switching Regression Analysis' *Journal of Agricultural Economics* Vol. 64 (2) 467-482.

Lavison, R. K. (2013). *Factors influencing the adoption of organic fertilizers in vegetable production in Accra* (Doctoral dissertation, University of Ghana).

Lechner, M. (1999). Earnings and employment effects of continuous gff-the-job training in east germany after unification. *Journal of Business & Economic Statistics*, *17*(1), 74-90.

Legesse, B., Ayele, Y., & Bewket, W. (2013). Smallholder farmers' perceptions and adaptation to climate variability and climate change in Doba district, west Hararghe, Ethiopia. *Asian Journal of Empirical Research*, *3*(3), 251-265.

Lio, M. and Liu, M.C. (2006). ICT and agricultural productivity: evidence from cross-country Data. *Agricultural Economics,* 34, 3, 221–228

Manfre, C., & Nordehn, C. (2013). Exploring the promise of information and communication technologies for women farmers in Kenya. *Cultural practice, LLC, MEAS Case Study*, *4*.

McKinsey (2013): Lions Go Digital: The Internet's Transformative Potential in Africa, on www.mackinsey.com

Mignouna, D. B., Manyong, V. M., Rusike, J., Mutabazi, K. D. S., & Senkondo, E. M. (2011). Determinants of adopting imazapyr-resistant maize technologies and its impact on household income in Western Kenya.

Mtega, W.P and Msungu, A.C. (2013) Using Information and Communication Technologies for enhancing the accessibility of agricultural information for improved agricultural

production in Tanzania. *The Electronic Journal on Information Systems in Developing Countries* 56 (1):1-14

Mukembo, S., & Edwards, M. C. (2016). Agricultural Extension in Sub-Saharan Africa During and After Its Colonial Era: The Case of Zimbabwe, Uganda, and Kenya. *Journal of International Agricultural and Extension Education*, (December 2015). https://doi.org/10.5191/jiaee.2015.22304

Muriithi, A. G., Eric, B., & Sarah, O. (2012). Information technology for agriculture and rural development in Africa: Experiences from Kenya.

Muyanga, M., & Jayne, T. S. (2006). Agricultural extension in Kenya: Practice and policy lessons (*Tegemeo Working paper 26/2006*). Nairobi, Kenya: Egerton University

Muyanga, M., & Jayne, T. S. (2008). Private agricultural extension services in Kenya: Practice

and policy lessons. *The Journal of Agricultural Education and Extension*

Nambiro, E., Chianu, J., & Murage, A. W. (2010). *The association of agricultural information services and technical efficiency among maize producers in Kakamega, western Kenya* (No. 308-2016-4974).

Nambiro, E., Omiti, J. M., & Mugunieri, G. L. (2006). *Decentralization and access to agricultural extension services in Kenya* (No. 1004-2016-78499).

National Agricultural Sector Extension Policy [NASEP]. (2012). National agricultural sector extension policy. Government of Kenya, Agricultural Sector Coordination Unit (ASCU). Nairobi, Kenya.

Nyaga, E. K. (2012). Is ICT in Agricultural Extension Feasible in Enhancing Marketing of Agricultural Produce in Kenya: A Case of Kiambu District. *Quarterly Journal of International Agriculture,* 51(3), 245–256.

Ogutu, S. O., Okello, J. J., & Otieno, D. J. (2014). Impact of information and communication technology-based market information services on smallholder farm input use and productivity: The case of Kenya. *World Development, 64*, 311-321.

Okello, J. J., Okello, R. M., & Ofwona-Adera, E. (2010). Awareness and the use of mobile phones for market linkage by smallholder farmers in Kenya. In *E-Agriculture and E-Government for Global Policy Development: Implications and Future Directions* (pp. 1-18). IGI Global.

Oluwasusi, J. O., & Akanni, Y. O. (2014). Effectiveness of extension services among food crop farmers in Ekiti State, Nigeria. *Journal of Agricultural & Food Information, 15*(4), 324-341.

Oyeyinka, R.A. and Bello, R.O. (2013) Farmers Use of ICTs for Marketing Information Outlets in Oyo State, Nigeria. *Journal of Agricultural Science*, 5 (11):150-158. ,

Peña-López, I. (2001). Human Development Report 2001. Making New Technologies Work for Human Development.

Perumalpillai-Essex, J. (2005). Impacts of extension services in rural Mozambique. *Report by ECON Analysis for the Environment, Rural and Social Development Department, Africa Region, World Bank.*

Poulton, C., Dorward, A. and Kydd, J. (2010) The future of small farms: New directions for services, institutions and intermediation. *World Development* 38(10): 1413–1428.

Rademaker, C. J., Bebe, B. O., van der Lee, J., Kilelu, C., & Tonui, C. (2016). *Sustainable growth of the Kenyan dairy sector: a quick scan of robustness, reliability and resilience* (No. 979). Wageningen University & Research, Wageningen Livestock Research.

Rafea, A. (2009). Managing agriculture knowledge: role of information and communication technology. In *Think Piece for CGIAR Sci. Forum Workshop on ICTs Transforming Agricultural Science, Research and Technology Generation*.

Ravallion, M. (2008). Bailing out the world's poorest. The World Bank Development Research Group Policy Research Working Paper 4763. *Washington DC: World Bank*.

Rogers, E. M. (1995). Diffusion of Innovations: modifications of a model for telecommunications. In *Die diffusion von innovationen in der telekommunikation* (pp. 25-38). Springer, Berlin, Heidelberg.

Rosenbaum, P. R. (2002). Sensitivity to hidden bias. In *Observational studies* (pp. 105-170). Springer, New York, NY.

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

Rosenbaum, P. R., & Rubin, D. B. (1985). Constructing a control group using multivariate matched sampling methods that incorporate the propensity score. *The American Statistician*, 39(1), 33–38.

Salih, T. M. (2003). Sustainable economic development and the environment. *International journal of social economics*, *30*(1/2), 153-162.

Schwartz, L. A. (1991). *Extension in Africa: An institutional analysis* (No. 11075). Michigan State University, Department of Agricultural, Food, and Resource Economics.

Sife, A. S., Kiondo, E., & Lyimo-Macha, J. G. (2010). Contribution of mobile phones to rural livelihoods and poverty reduction in Morogoro region, Tanzania. *The Electronic Journal of Information Systems in Developing Countries*, *42*(1), 1-15.

Singh, S. (2006). *Selected success stories on agricultural information systems*. APAARI.

Smale, M., Mathenge, M. K., Jayne, T. S., Magalhaes, E. C., Olwande, J., Kirimi, L., ... & Githuku, J. (2012). *Income and poverty impacts of USAID-funded programs to promote maize, horticulture, and dairy enterprises in Kenya, 2004-2010* (No. 1096-2016-88428).

Staal, S.J. (2004a). Competitiveness of the Smallholder Dairy Enterprises in Kenya. The Smallholder Dairy Project, Nairobi.

Stienen, J., Bruinsma, W., and Neuman, F. (2007). How ICT Can Make a Difference in Agricultural Livelihoods. *The Commonwealth Ministers Reference Book.*

Swanson, B. E. (2008). *Global review of good agricultural extension and advisory service practices*. Rome: Food and Agriculture Organization of the United Nations.

Tacken, M. P., Cosyn, J., De Wilde, P., Aerts, J., Govaerts, E., & Vannet, B. V. (2009). Glass fibre reinforced versus multistranded bonded orthodontic retainers: a 2-year prospective multi-centre study. *The European Journal of Orthodontics*, *32*(2), 117-123.

Uaiene, R. N., Arndt, C., & Masters, W. A. (2009). Determinants of agricultural technology adoption in Mozambique. *Discussion papers*, *67*.

UNDP. (2012) Promoting ICT based agricultural knowledge management to increase production and productivity of small holder farmers in Ethiopia.

Venkatesan, V., & Kampen, J. (1998). Evolution of agricultural services in Sub-Saharan Africa

(World Bank Discussion Paper No. 390). Washington, DC: *The World Bank*

Walker, T. S., Tschirley, D. L., Low, J. W., Tanque, M. P., Boughton, D., Payongayong, E. M., & Weber, M. T. (2004). *Determinants of rural income, poverty, and perceived well-being in Mozambique in 2001-2002* (No. 1093-2016-87851).

Wanjala, P. O., Njehia, B. K., & Murithi, F. M. (2015). Important variables influencing milk yields on smallholder farms in western Kenya. *Asian Journal of Agriculture and Food Sciences (ISSN: 2321–1571), 3*(01).

Waswa, F., Shitanda, D., & Akhaukwa, P. (2004). Analysis of remuneration disparities within public universities in Kenya: towards reversal of brain drain and brains in the drain. *Tanzanian J. Popul. Stud. Dev, 11*(1), 79-90.

Wejnert, B. (2006). 'Integrating Models of Diffusion of Innovation: A Conceptual Framework. The Annual Sociology. *Cornel Review Report of Human Department of University, Ithaca, NY. http://soc. annualreveiw. org*.

WFP and FAO. Measures of food consumption—harmonizing methodologies. WFP; 2008 *Rome*

Wfp, V. A. M. (2006). Food consumption analysis: calculation and use of the food consumption score in food security analysis. *Rome: WFP*.

Wickramasinghe, L. (1982)."Toward a new extension strategy-from promotion of innovations to participatory communication [in Sri Lanka]." *FAO Economic and Social Development Series (FAO). no. 24.*

Woodridge, J. M. (2002). Econometric analysis of cross-sectional data and panel data. *Cambridge and London: MIT Press*

Wooldridge, J. M. (2006). Cluster Sample Methods in Applied Econometrics: An Extended Analysis. *Journal of Economic Literature (JEL), JEL Classi* (June), 1–57.

World Bank (2002). Information and Communication Technologies. World Bank Group Support for the Development of Information Infrastructure

World Bank (2010). Handbook on Impact Evaluation: Quantitative Methods and Practices.

World Bank, InfoDev and Agriculture and Rural Development, (2011). ICT in agriculture: Connecting smallholders to knowledge, networks and institutions.

APPENDICES

Annex 1 Checklist for KIIs and FGDs

Introduction

The purpose of this focus group is to gain insights and knowledge on Dairy farming practices and iCow service o Dairy farmers in Sirikwa, Olkalau and Siongirio Dairies in Uasin Gishu, Nyandarua and Bomet counties.

County.....

Date.....

Questions for Discussion:

1. Which land tenure system is mainly embraced in this region?
2. Why do people prefer such system?
3. Do most people have land tittles in the area? And if no why don't they own one?
4. In major households who owns the land?
5. Do the most farmers in the region grow fodder or they buy? If they buy what is the reason?
6. If you grow fodder, in relation to other crops how do you prioritize fodder in land allocation?

Husbandry practices

7. Which type of the Dairy breed is mostly kept in this region?
8. Why do you prefer the said breed in this region?
9. What is the feeding system that is mainly used in this region?
10. Why do you prefer the said feeding system in this region?
11. What kind of fodder type that is mainly used to feed dairy cattle in this region
12. Why do you prefer the said type of fodder in dairy production?
13. Do you do the following practices: Deworming, tick control, Vaccination or curative treatment?
14. Among the above practices, which one do you do regularly, and why?
15. Who is the main service provider of the above services? And why do you prefer the said provider?
16. For those who vaccinate their cows, which vaccine do they administer frequently? And why?

Dairy cooperative membership

17. As a member of the Dairy cooperative, what are the benefits you get?
18. What are the challenges do you face being a member?
19. What solutions do you think can address the stated challenges?
20. Are you members of other groups that are important in dairy farming?

Extension Services

21. Do you access to extension services? If yes, what kind of services do you receive?
22. Who are the main providers of the extension services stated above?
23. Which breeding method do you use in this region? Why do they prefer the method? Provider?

iCow service (users of the iCow only)

24. What was the motivation behind adopting the iCow technology? What has icow done to you ?(services)
25. What changes have you noticed/experienced as a result of using the iCow technology?
26. What challenges/costs have you experienced in adopting the iCow technology?
27. What do you think can be done to address the challenges stated?
28. Which people are involved in buying milk?
29. Who the main buyers and why do you prefer selling to this particular buyer?
30. **Dairy cooperatives (Leadership of the dairy copoperative)**
31. How does one become a member to the cooperative?
32. Is membership seasonal or lifetime?
33. What are the benefits that members get from the cooperative?
34. What is the structure of the cooperative/ how do leadership change?
35. What are the main challenges in running the activities of the cooperative

Annex 2 Research household survey Questionnaire

UNIVERSITY OF NAIROBI

Determining the Impact of ICT based extension services on Dairy Production in Kenya: A case of iCow service in selected dairy cooperatives

HOUSEHOLD SURVEY QUESTIONNAIRE HHD NO: [ ]

SECTION A: INTRODUCTION

The Department of Agricultural Economics, University of Nairobi in collaboration with International Livestock Research Institute (ILRI) and Green Dream TECH (GDT) are conducting a research on dairy production in Kenya. The reason for undertaking this study is to gain insights and knowledge on iCow service that was introduced last year (2017) to Dairy farmers in Kenya. The study will focus on the benefits and challenges of iCow service, its impact on Milk yield, income and food security. Your response will be analyzed to inform policy makers on the potential of ICT services to improve incomes, productivity and food security.

Information obtained is strictly for academic and research purposes only and responses obtained will be treated with confidentiality. This interview is voluntary and will take approximately 1 hour. Your participation will be highly appreciated.

The person to be interviewed will be the household head, spouse or a family member aged 18 years involved in decision making in the household.

1) Name of Enumerator: .....…….2) Date: …… 3) Name of Dairy Cooperative ……

4) County of Residence ……..……. 5)Sub-county ……6) Ward…… ….

7) Village…….....8) GPS coordinate …….....

The Respondent agrees to be interviewed? **Yes No,** if no, terminate the interview, if yes move to the next section

SECTION B: DEMOGRAPHIC CHARACTERISTICS:

9) Name of respondent ……. Phone number …….…….

Name of household member	Relationship to household head (code A)	Sex of household member (code B)	Number of years in school	Primary occupation (code C)	Marital status (code D)	Year of birth	Experience in Dairy farming (no. of years)

Code A:*1= household head 2= spouse 3= children 4= relative 5=others (specify)*

Code B:**0= Female [ ] 1= Male [ ]**

Code C: ***1= Farming 2 = Business person 3= Casual Laborer 4 = Salaried Employee 5= students 6= Other (specify)…….***

Code D:*1= single 2= married 3= separated 4= widow/widower 5=none*

SECTION C: FARM CHARACTERISTICS:

10) kindly fill in this table to capture the farm characteristics

Plot ID	Plot Description / Name	Size of this plot (acres)	Tenure system (code)	If plot **is *owned*,** who owns (code**)**	If rented, rent value (Ksh/year)
1					
2					
3					
4					

Plot description code	**Tenure system**	**Plot owner**
0. = Homestead 1. = Cash crop 2. = Food crop 3. = Fodder crop 4. = Grazing land	1. = Owned with title 2. = Owned without title 3. = Communal/public 4. = Rented in 5. = Rented out	1. = HH head 2. = Spouse 3. = Joint (HH head & spouse) 4. = Other male 5. = Other female 6= Others (specify) _____

SECTION D: HUSBANDRY PRACTICES

Feeding system:

11) For cattle type owned, please indicate the feeding system used and how much land was allocated for grazing if animals are grazed (April/2017-May/2018)

Type of cattle	Only grazing (free-range or tethered)	Mainly grazing with some stall feeding	Mainly stall feeding with some grazing	Only stall feeding (zero grazing)
	1 = Yes; 0 = No	1 = Yes; 0 = No	1 = Yes; 0 = No	1 = Yes; 0 =
Local				
Cross				

Grown fodder

12a) besides grazing/harvested grass from forest/roadside/farm, do you also currently grow fodder? [__] 1= Yes; No =0

12b) If yes, have you set aside a plot for growing forages/fodder or you grow on hedges/fence? [__] Plot set aside = 1; On hedges/fence =0

12c) If fodder/forage is grown on plots, please provide the following details for each fodder type grown on plots.

Fodder type	Area of land planted with forage/fodder (acres)			
	Area owned	Area rented		Cattle Fed

Fodder type/pasture	**Cattle fed**
1. = Napier grass	1. = All
2. = Planted grasses e.g. Rhodes grass	2. = Cows only
3. = Fodder maize	3. = Lactating cows only
4. = Fodder shrubs (Calliandra, Sesbania, Lucaenia)	4. = Calves only
5. = Other fodder legumes (Desmodium, lucern, vetch)	5. = Other (specify) _____
6. = Other (specify) _____	
7. = Brachiaria	

Animal health services

13)Kindly fill this table in relation to health services of your cattle.

	Anthelmintic (deworming)	Tick control (spraying/dipping)	Vaccination	Curative treatment	Other (specify)
Can you access and use this service? (0= NO; 1=YES)					
How many times have used this service in the last one (1) year?					
Type of cattle treated/given the service in last one (1) year (code)					
Who provided the service?	Provider 1. [__] Provider 2. [__] Provider 3. [__]	Provider 1. [__] Provider 2. [__] Provider 3. [__]	Provider 1. [__] Provider 2. [__] Provider 3. [__]	Provider 1. [__] Provider 2. [__] Provider 3. [__]	Provider 1. [__] Provider 2. [__] Provider 3. [__]

Type of cattle	**Service provider**
= All = Cows only = Lactating cows only = Calves only = Other (specify)_____	= Self/ Neighbor with professional advice = Self/ Neighbor without professional advice = Animal health service provider/para-vet. = Government veterinarian 5= Project/ NGO staff = Coop/ group staff = Agro-vet shop) = Community dip = Other (specify) _____

14) If you vaccinate your cattle, which are the three most vaccinations that have you done for the past 1 year?

15) Among the listed challenges which **three** are most affecting your production?

Code	**Challenge**	**Rank**		
		R1	**R2**	**R3**

Code	**Vaccination**	**Rank with Reason**		
		Rank 1	**Rank 2**	**Rank 3**
1	Rift Valley Fever	Give Reasons	Give Reasons	Give Reasons
2	East Coast Fever			
3	Foot and Mouth			
4	Lumpy Skin			
5	Brucellosis			
6	Black Quarter			
7	Anthrax			
8	Other, specify			

1	Livestock Pests			
2	Livestock Diseases			
3	No heat signs on cows			
4	AI or Vets are far			
5	Feed Shortages			
6	Poor feed quality			

SECTION E: MARKET INFORMATION AND ACCESS

16) What is the distance to the nearest main market Centre from the farm? (Kms)_____

17) What is the distance from the farm to the road (Kms)_____

18) What is the type of road from the farm to that main market? **[___]** ***(Codes K: 1=Tarmac, 2=All-weather marram road, 3=Seasonal marram road, 4=other (specify)***

SECTION F: GROUP MEMBERSHIP

19) Are you a member of a dairy cooperative? **[__] Yes = 1; No = 0;**

20) If yes, what is the name of the Dairy cooperative? .....

21) If yes, how long have you been a member? ……..

22) Please indicate in the table below the services offered by the cooperative that you have named?

Main services of Dairy cooperative 1=Training/extension 2=Output processing and marketing 3=Input provision 4=A.I/animal health services 5=Financial services 6=Others (specify)	Among the services offered by the cooperative, which one are you using 1=Training/extension 2=Output processing and marketing 3=Input provision 4=A.I/animal health services 5=Financial services 6=Others (specify)	**Who makes the decision to use/ not to use the service?** 1=Head 2=Spouse 3=Joint 4=Other males in hh 5=Other females in hh 6=Others (specify)

23b) Other than membership to the dairy cooperative, are you also currently **a member** of any association/group? [__] Yes = 1; No = 0;

23c) If yes, indicate in the table below the type of association and **main** services offered;

What **type** of association do you belong to? (*multiple response accepted*) ***1 = Production and marketing*** ***2 = Savings and credit*** ***3 = Religious group*** ***4 = Welfare*** ***5 = Other, (specify)***	What are the **three main** services offered by the associations? **1=Production;** **2=transportation;** **3=value-addition;** **4=marketing;** **5=credit;** **6=Others, *(specify)***	Among the offered services by the group, which one are you receiving **1=Production;** **2=transportation;** **3=value-addition;** **4=marketing;** **5=credit;** **6=Others, *(specify)***

SECTION G: EXTENSION SERVICES AND TRAINING

24a) In the last one year, have you received any form of extension service/training on Dairy production? [___]1=Yes; 2=No

25b) If yes, complete the table below.

Source of extension/Training (Code)	Frequency of visits/training (Code)	Had you requested for the service (1= Yes; 0= No)	Level of satisfaction (Code)	Distance to extension office (Kms)	Subjects covered (Code)

Code F: 1=Government, 2=Private, 3=NGO, 4=CBO, 5= other farmers, 6= other (specify)

Code G: 1=Never; 2=fortnightly; 3=Monthly; 4=quarterly; 5=annually

Code H: 1=Very Dissatisfied; 2=Dissatisfied; 3=Neutral; 4=Satisfied; 1=Very Satisfied

Code I: 1=Agronomic practices; 2=Dairy management practices (specify)……; 3=farming as a business (specify)…….

SECTION H: iCow SERVICE

26a) Do you receive any information/advice on **agriculture** via your mobile phone? **Yes No,**

26b) If no skip to the question 34

26c) If yes, what type of information do you receive? **1=Poultry, 2=Crops, 3= Dairy, 4=Soil management, 5=Pig Keeping, 6=Agricultural Credit, 7=others, (Specify)**

27a) Do you receive any information/advice on **dairy farming** via your mobile phone? **Yes No,**

227b) If yes, what type of information do you receive? **1=Production; 2=transportation; 3=value-addition; 4=marketing; 5=credit; 6=Others, *(specify)***

27c) If yes, do you know the organization/provider offering this information? **Yes No,**

27d) State the name of the organization

28a) Have you ever heard about iCow? **Yes No,**

28b) If **NO**, terminate this section and move to the next section

28c) If yes, how did you come to know about iCow?

Code		Tick
1	Friend/fellow farmer	
2	Radio	
3	Group/association	
4	Text Message	
5	Newspaper	
6	Tv	

29a) Have you started receiving cow tips from iCow? **Yes No,**

29b) If **NO** terminate this section and move to the next section

29c) If yes, then fill this table?

Code	**Topic**	**Which one have you received? (Tick)**	**Which ones have you put into practice most? (Choose the most 3 important and give reason)**		
			R1	**R2**	**R3**
1	Fodder Management		Give reason	Give reason	Give reason
2	Proper Feeding				
3	Hygiene				
4	Mastitis Prevention				
5	Disease Prevention				
6	Vaccination				
7	Deworming				
8	Calf rearing				
9	Others (specify)				

30) Apart from the information you receive on dairy farming, what other kind of information do you receive from iCow?

1=Poultry, 2=Crops, 3=Soil management, 4=Pig Keeping, 5=Agricultural Credit, 6=Marketing, 7=others, (Specify)

31) When did you start receiving information from iCow? .....

32a) Are you still using iCow service? **Yes No,**

32b) If no, when did you stop using iCow services? …….

32c) If no, why did you stop using the iCow service…….

33a) Did you write down the iCow messages? **Yes No**

33b) If yes, where did you write them? **1) Book 2) Phone**

32b) From the messages you received from iCow, which are the 3 significant and important changes have you noticed?

	Changes	**R1**	**R2**	**R3**
1	Improved Hygiene			
2	Improved Feeding			
3	Mastitis Control			
4	Regular Deworming			
5	Regular Spraying			
6	Vaccination			
7	Improved Fodder Management			
8	Reduced tick infestation			

34) Do you access internet? **Yes No**

35) Do you have an email address? **Yes No**

36) Do you use WhatsApp? **Yes No**

37) Do you use face book? **Yes No**

38) Please give your level of satisfaction about iCow services.

1=Very Dissatisfied; 2=Dissatisfied; 3=Neutral; 4=Satisfied; 1=Very Satisfied

SECTION I: MILK PRODUCTION AND SALES

39a) Have you been milking any cows in the last one year (April/2017-May/2018)? [__] 1=Yes; 0 = No

39b) If yes, please enter the following details on milk production for **all cows milked** during the last one (1) year

40) Number of lactating cows: _____ (record up to a maximum of 10 cows)

	cow	**Cow2**	**cow**	**cow**	**cow**
Breed of cow (1 = local; 2 = cross bred; 3 = pure exotic)					
Average milk production per day (in Litres)					
Milk production per day (*morning and evening milk*) at calving					
Milk production per day (*morning and evening milk*) at peak (if					
Milk production yesterday (*morning and evening milk*)					
Milk production per day (*morning and evening milk*) at late lactation					
Milk production per day in **late May 2018**					
Lactation length (**number of months** cow is milked between 2					
Calving interval (time between one calving (cow) to the next in					
When did the cow calve down (give birth)? *(MM/YY) (99/9999 if*					
Breeding method used for the last calving [1=Own bull 2=Other bull					
Number of services (repeats) before conception for this service					
Price paid for the last breeding service (Ksh)					

40)Milk sales: For milk produced yesterday or the last day milking was done, please provide details of milk sales.

	Morning milk			**Evening milk**		
	Buyer	**Buyer**	**Buyer**	**Buyer 1**	**Buyer 2**	**Buyer 3**
Type of buyer (code)						
Quantity sold to buyer (liters)						
Price received (Ksh/liter)						
Milk payment method used by buyer						
Buyer	**Payment**					
1. = Individual consumers 2. = Private milk-traders 3. = Dairy co-op/ group with chilling plants 4. = Dairy co-op/ group without chilling plants 5. = Privatively owned chilling plants = Other (specify)_____	1. = cash, no delay in payment 2. = at end of month, no delay 3. = at end of month, has experienced delay 4. =Bank/Mobile banking 5. =SACCO 6. =Other (specify)_____					

SECTION J: SOURCES OF HOUSEHOLD INCOME

41) Did you receive any cash through any of the following means?

Income Source	Did anyone in the household earn income from source in last the six (6) months? (0 = no, 1 = yes)	Who mainly earns income from this source? (code)	Total HH income in last six (6) months
1. Trading in livestock and livestock products			
2. Trading in milk (not own produce), feeds and other livestock products			
3. Trading in agricultural products (excluding livestock!)			
4. Formal salaried employment (non-farming, e.g. civil servant, private sector employee, domestic work in other home)			
5. Business – Trade or services (non-agricultural)			
6. Working on other farms (including herding)			
7. Sale of products of natural resources (forest and sea/rivers products)			
8. Pensions			
9. Rent out land / sharecropping (cash value of share crop or rent)			
10. Remittances			
11. Other (specify) _____			

Who earns/controls money from this source	
1. HH male 2. HH female 3. Joint HH (male & female)	4. Non-household member 5. Other (specify)_____

SECTION K: ACCESS TO CREDIT/FINANCING

42a) Have you received credit in the last one year…….? ***0= no) 1= yes ()***

42b) If yes, provide the following details

Household member who accessed credit	**Main Source of agricultural loan (Code)**	**Amount borrowed (KES)**	**Satisfaction with credit services *(Code)***	**Purpose of the loan**
CODE: Source of Loan 1. Micro-finance institution (SACCO) 2. Commercial banks 3. Cooperatives 4. NGOs 5. Government credit schemes (Youth Enterprise Fund, Women Enterprise Fund, Constituency Development Fund, Poverty Eradication Fund, Disability Fund) 6. Agricultural Finance Corporation 7. Local money lender 8. Group/Table banking 9. Family and friends 10. Contractual out grower arrangements			**CODE:** **Satisfaction level** 1=Very dissatisfied 2=Dissatisfied 3=Neutral 4=Satisfied 5=Very Satisfied	

43) Please give two main reasons with reference to level of satisfaction with credit services……

44) Who in the household **mainly** makes decision regarding dairy enterprise e.g., on use of breeding services, animal treatment, proceeds from milk sales, etc.? [**]; 1=Male dominated; 2=Female dominated; 3=Jointly owned and managed**

SECTION L: FOOD CONSUMPTION DATA COLLECTION. (FCS)

*I would like to ask you about all the different foods that your household members have eaten in the **last 7 days**. Could you please tell me **how many days** in the past week your household has eaten the following foods? (for each food, ask what the primary source of each food item eaten that week was, as well as the second main source of food, if any.* ***The person to be interviewed in this section is the one who is involved in preparing meals in the household.***

Types of foods	Has the household consumed these food items in the last 7 days? 1=yes, 0=no	In the last7days, in how many days has the household consumed these food items?	Source of food (codes)	
			Primary	Secondary
Millet or food made from millet				
Sorghum or food made from sorghum				
Maize or food made from maize				
Rice or food made from rice				
Wheat or food made from wheat				
Other staples				
Tubers - Potatoes, yams, cassava, other foods made from roots or tuber				
Vegetables (including leaves)				
Fruits				
Beans, peas, lentils, or nuts?				
Red meat beef, pork, lamb, goat, rabbit wild game, liver, kidney, heart, or other organic meats?				

White meat – Poultry including chicken, duck, other poultry				
Eggs				
Fresh or dried fish or shellfish?				
Milk, and dairy products - cheese, yogurt, or other milk product				
Milk in tea				
Vegetable oils and fats				
Sweets, sugar, honey				
Any other foods, such as condiments, coffee, tea including milk in tea?				
Source of food				
1 = Own production 2 = Purchased 3 = Borrowed 4 = Exchange/bartered 4 = Payment in kind for activities 5 = Received as gift				

THANK YOU!!