EFFECT OF ICT USE ON PERFORMANCE OF AGRIENTERPRISES. A CASE OF SMALLHOLDER PINEAPPLE FARMERS IN KIAMBU COUNTY, KENYA

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A Thesis Submitted to the Graduate School in Partial Fulfillment for the Requirements of the Award of Master of Science Degree in Agri-enterprise Development of Egerton University.

EGERTON UNIVERSITY

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DECLARATION AND RECOMMENDATION

Declaration

I declare that this thesis is my original work and has not been submitted for any award of any degree in any other University.

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DEDICATION

This thesis is dedicated to my lovely parents, siblings and all my friends, especially my late father Mr. Denish Owuor Okello, my dear mother Margaret Amimo Okello for their support and prayers.

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ABSTRACT

Recently, there has been emergence in the use of modern Information Communication Technologies (ICT) in the different operations of agrienterprises. This ranges from the provision of agricultural information to marketing of agricultural products through the use of ICT tools such as mobile phones, television and radio. Despite the potential of ICT tools to enhance efficiency in agrienterprises operations, little is known about the effect of ICT use on performance and farm income of small scale farmers in rural areas. The aim of this study, therefore, was to examine the effect of ICT use on performance of pineapple agrienterprises. Specifically, it sought to: characterize structure of ICT usage among the smallholder agrientrepreneurs; determine factors influencing use of ICT among smallholder agrientrepreneurs and determine effect of ICT use on income of smallholder agrientrepreneurs. The study was based on data collected from a sample of 183 households drawn from Gatundu North Sub-County in Kiambu County. Multistage sampling procedure was used to select the respondents and semi structured questionnaires employed to collect qualitative and quantitative data through face to face interviews. The determinants of ICT use was estimated by multivariate probit model while the effect of ICT use was estimated using endogenous switching regression model. The results show the most commonly used ICT tool to access agricultural information was mobile phones (86%), radio (79%) and then television (59%). Findings revealed that age, education, household size, farm size, group membership, extension contact, credit access, installation of electricity and attributes of ICT tool significantly influenced the usage of ICT tools. Results suggest that optimal users of ICT tools realized more income per acre than they would have had they not used the ICT tools. While, sub-optimal users realized lower household income per acre than they would have had they not decided to use ICT tools in their agrienterprises. Usage of ICT tools is associated with a 98% and 28% gain in average household income for optimal and sub-optimal users, respectively. Hence use of ICT tools leads to increase in income of smallholder agrienterprises. Consequently policies targeting usage of ICT tools in agrienterprises must consider the age and education level of farmers when developing ICT tools for dissemination of agricultural information and should concentrate on improving the extension services, farmer groups and electricity access to rural areas.

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LIST OF ABBREVIATIONS/ACRONYMS

ASDSP -Agricultural Sector Development Support Programme

AR -Average Revenue

ATC -Average Total Cost

ATE -Average Treatment Effect.

ATT -Average Treatment Effect on the Treated.

ATU -Average Treatment Effect on the Untreated.

FAO - Food and Agriculture Organization

GDP - Gross Domestic Product

GIS -Geographic Information System

HCDA -Horticultural Crops Development Authority

ICT - Information Communication Technology

KARI - Kenya Agricultural Research Institute

KHDP -Kenya Horticultural Development Programme

KHCP -Kenya Horticulture Competitiveness Project

KNBS -Kenya National Bureau of Statistics

MVP - Multivariate Probit Model

NAFIS -National Farmers' Information Service

NGO -Non-governmental Organization

SPSS -Statistical Package for Social Sciences

TC -Total Cost

TR -Total Revenue

TV -Television

CHAPTER ONE
INTRODUCTION

1.1 Background of the study

The performance of agrienterprises is of immense importance in most developing countries where agriculture remains the engine of growth. Agricultural sector is still the backbone of majority of sub-Saharan Africa countries economy, providing food, employment, foreign exchange and raw materials for industries (World Bank, 2014). It accounts for 24% of the gross domestic product (GDP) in sub-Saharan Africa states. Recent studies have also shown growth in GDP that originates from agriculture is about four times more effective in raising the incomes of a country's poorest people as opposed to GDP growth derived from other sectors such as manufacturing (Fan *et al.,* 2013).

In Kenya smallholder agrienterprises are the backbone of the economy, employing more than 75% of the total population; contributing about 30% to the GDP; bringing about 60% of the foreign exchange; and providing raw materials for local industries (KNBS, 2013). However, for agrienterprises to sustain sufficient market accessibility, they have to overcome various constraints, such as poor access to high quality seeds, limited knowledge of effective production and marketing practices. Additionally, ineffective pest and disease management practices threaten not only agrienterprises' profitability when their produce is rejected (particularly by export markets), but also the health of farming households, consumers, and the environment (Ministry of Agriculture, 2014). According to Sife *et al.* (2010) to improve opportunities for trade especially at a global level agrienterprises need to continuously improve their competitiveness. They also need to improve their business environment or risk being trapped in producing low-skill, low-value products and services, which will lead to low market access.

The past decade has witnessed a revolution in the use of modern information communication and technology (ICT) tools (mobile telephony, radio and television) in managing agrienterprises. Evidences suggest that the technology is being effectively used in accessing market price information, weather forecasts, transport, storage facilities, crop and livestock diseases and general advice related to agriculture (Kirui *et al.,* 2012). The most commonly used ICT has been mobile telephony which can cause significant benefits to agrienterprises through improved access to information, lower marketing costs, and thus higher profits and incomes. In addition to such direct effects, mobile phones are an enabling technology for

other innovations. One important example is mobile phone based money transfers, which could be very relevant for rural agrienterprises that are often underserved by the formal banking system (Kirui *et al.,* 2013). Again in Kenya, market information is provided through short message service (SMS) so that agrienterprises have access to daily agricultural commodity prices, extension messages and opportunities to sell or bid through text messages and voicemail (Munyegera *et al.,* 2014).

Kenya's agriculture sector comprises five major subsectors: horticulture, industrial crops, food crops, livestock and fisheries. This study focused on the pineapple agrienterprises in Gatundu North sub-County in Kiambu County who were using different ICT tools in running their businesses. The ICT tools that were considered included radio, television and mobile phones. Use of these tools has grown in number especially radio and television programmes which educate farmers on better agricultural practices. Such programmes include *Shamba* shape up, Seeds of Gold, *Mugambo wa Murimi* and *Urimi* (Nyoike, 2015). The integration of information, communication and technology (ICT) into pineapple agrienterprises helps in the transformation of smallholder farmers from their current subsistence level, marked by low productivity and low added-value, to an innovative, commercially-oriented, internationally competitive and modern agricultural sector'. ICT holds the key to this transformation since the use of mobile telephony, radio and TV seems to be an enabler, necessary to spur development of agrienterprises (World Bank, 2014).

Therefore, for these agrienterprises to function effectively and efficiently, they need good information on a variety of subjects such as production, marketing and consumption. It is expected that modern ICT can play a role in bridging the information gap and reduce the information asymmetry that exists between the large and the small agrienterprises by making the content precise, timely and localized and thus will enhance the dissemination of knowledge and information on technologies, inputs, markets and prices. This high use of ICT is likely to stimulate economic development (Mittal, 2012). Hence, use of ICT may contribute to a well-functioning agricultural markets which would lead to increase rural incomes and hence contribution to agrienterprises development. Therefore, this study aimed to examine factors that influencing use of mobile phones, radio and television and effect of their usage on performance of pineapple agrienterprises.

1.2 Statement of the problem

Mobile telephony, radio and television usage is gaining popularity in smallholder pineapple enterprises. Recently, public and private organizations have come up with initiatives that are using these facilities to provide agrienterprises with information they need to be productive and profitable. These ICT facilities such as mobile phones are also used by smallholder farmers to market their produce. Hence, the integration of these ICT facilities in pineapple enterprises is an important factor that may influence their performance. Moreover, their use may affect this enterprises inclusion in profitable commercial supply chains which offer a great driver for the development of vibrant agrienterprises. However, information on the choice of the ICT tools and the degree to which usage of these ICT tools influences the performance of pineapple enterprises is still not clear in empirical literature. Hence, this study sought to bridge this knowledge gap by determining the effect of ICT use specifically mobile telephony, radio and television on performance of pineapple agrienterprises in Kiambu County.

1.3 Objective

1.3.1 General objective

The general objective of this study was to contribute to enhanced ICT tools utilization in agrienterprises for improved livelihood of small-scale pineapple farmers in Gatundu North sub-County, Kenya.

1.3.2 Specific objectives

1. To characterize structure of ICT usage among smallholder pineapple agrienterprises.
2. To determine factors influencing use of ICT among smallholder pineapple agrienterprises.
3. To determine the effect of ICT use on income of smallholder pineapple agrienterprises.

1.4 Research questions

1. What is the structure of ICT usage among smallholder pineapple agrienterprises?
2. What are the factors influencing use of ICT among smallholder pineapple agrienterprises?
3. What is the effect of ICT use on income of smallholder pineapple agrienterprises?

1.5 Justification of the study

The horticultural sector specifically commercial pineapple farming plays a critical role in the social-economic development of Kenya economy. The focus on pineapple farming is an important factor in economic development with a potential for increasing incomes in rural areas, improving living standards and creating employment. This is because it is a high-value crop which is grown for commercial purposes. The agrienterprises' role can only be aptly realized through the adoption of not only efficient and effective technologies but also its profitable systems. Therefore, it requires that the enterprises remains competitive to deliver. It is imperative that the various constraints to the agrienterprises competitiveness especially market access are effectively addressed if the sector is to remain relevant to economic development as envisioned.

ICT is taking centre stage in the growth and competitiveness of all sectors globally and there is need to apply ICT to improve agrienterprises competitiveness. By exploring the effect of ICT use on performance of pineapple agrienterprises, this study provides the necessary knowledge required for improving the sector's competitiveness to enable it deliver to the country's expectations. The findings from this study will help to provide valuable information to service providers, policy and decision makers on how best to develop ICT in order to benefit pineapple enterprises in accessing market information. It will enable these agrienterprises to make an informed choice of the ICT tool to adopt. This might lead to increased adoption and usage of ICT in pineapple agrienterprises, leading to increase on-farm employment and increased yields, increased farm incomes, increased product and process innovation.

1.6 Scope and limitations of the study

This study only focused on effect of mobile telephony, radio and television use on performance of pineapple smallholder agrienterprises in Gatundu North sub-County, Kiambu County. Information on the structure of ICT usage, factors influencing use of ICT and effect of these ICT platforms on income of agrienterprises was collected by use of structured questionnaire. The period of study under consideration was limited to 2015.

1.7 Operational definitions of terms

Agrienterprises – Within the study context is defined as commercially oriented farmers who are engaged in farming as a business for their economic and social development. They are assumed to have land holding between 0.5 – 2 Ha and have between 5-10 employees. They are engaged in mixed cropping including growing of fruits and vegetables for market, fruit and vegetable value addition, fresh fruit venture, and livestock mainly for milk and meat production.

ICT –Entail specific communication devices used by farmers in their enterprises to connect them to Agricultural knowledge, value chain networks and agricultural institutions. The study will mainly focus on mobile telephony and its money transfers, Radio and Television.

ICT Use - refer to adoption and intensity of use of any of the following devices (mobile phones, Radio and Television) for purposes of receiving weather, input and output market information, connect with service providers, customers, and coordinate enterprise day to day logistics.

Income- this refers to revenue that the smallholder farmers received from selling pineapples.

Optimal users – this refers to smallholder agrienterprises who had adopted and were using television, radio and mobile phones for purposes of receiving agricultural and output market information and gets maximum benefits from optimal usage of these tools.

Sub-optimal users – this refers to smallholder agrienterprises who had opted to adopt and use either television, radio, mobile phones or not to use the three ICT tools in their agrienterprises.

Performance: - Measuring the results of an agrienterprises' operations in monetary whose results are reflected in the agrienterprises, return on investment, return on assets and value added.

CHAPTER TWO
LITERATURE REVIEW

2.1 Pineapple production in Kenya

Pineapple farming is practiced in many countries in the world whereby the main producers are Thailand, Philippines, Brazil, China, India, Costa Rica, Nigeria, Kenya, Mexico, and Indonesia (FAO, 2015). There exists several hundred varieties, but the most widely grown are smooth cayenne, Queen and the recently (in the past decade) introduced variety called MD2 which commands 80% of the global trade in pineapples. Pineapple production is concentrated in the tropical regions of the world. It is grown in over 82 countries with over 2.1 million acres under the crop according to FAO, (2009) with a global production of 15,287MT. In Kenya pineapple is predominantly grown by large scale producers and small scale farmers. Large scale production is concentrated in Central Kenya where intensive inputs are used, while the small scale production is concentrated at the Coast, Central and Western Regions of the country which is characterized by small farms with low input use (Chemonics International Inc., 2013). Pineapples are either sold as fresh fruit or are processed into a number of products with pineapple concentrate/juice accounting for 80% of the trade.

Pineapple production in Kenya is dominated by three farms; Delmonte (K) limited based in Thika, Kakuzi Limited based in Muranga, Ndemo farm based in Kilgoris. These large scale producers contribute to close to 90% of all pineapples grown in Kenya. Medium scale and small scale producers account for about 10% of the total pineapple production. Small scale production takes place at the Coast (North of Malindi), the lake basin, (Kisii, Homabay, Kericho, Migori counties) and in Central Kenya (Gatundu and Thika districts) in Kiambu County. The study focused on smallholder farmers in Gatundu North sub-Counnty where farmers are withdrawing from tea and coffee production to pineapple production which seems to be profitable. The study focused on how the smallholder farmers are using ICT tools to access agricultural information and to market their produce. The most common varieties produced by these farms are smooth cayenne, MD2 and Sweet 16. According to Koech *et al.* (2013), the most planted variety is smooth cayenne accounting for 80% of the total pineapple produced, though currently there are efforts to move to MD2 variety due to its superior nutrition qualities.

Pineapple production is under horticulture sector which is the new ground for high value crop enterprises that can propel smallholder farmers from subsistence to commercial farming within short periods of time (Koenig *et al*., 2008). This sector contributes to the country's economy and to achieving food security, creating income and employment, earning foreign exchange, and creating raw materials for agro-processing and poverty reduction. The industry employs six million people through direct and indirect employment, and grew at an average rate of 15.9% between 2001 and 2010, especially in horticultural exports. It is currently the leading foreign exchange earner for the country (KHCP, 2013).

The horticultural industry has overtaken most of the traditional cash crops in terms of foreign exchange earnings, family income, employment creation and other indirect effects which contribute to economic growth. In addition, horticultural production occurs in most regions in Kenya and with a high presence of the private sector. Through its vibrant growth in the last decade, the sub-sector has also been accredited for improved rural incomes hence poverty reduction, both directly and indirectly (Mutuku *et al*., 2004). In recent past, the sector has recorded lower levels of output and export volumes. The quality of production has declined, following a reduction of the role of exporters in supporting production by small-scale farmers. The decline in exports was also associated with lower demand for Kenya's output in the traditional export markets and insufficient rainfall. This has reduced Kenya's competitiveness in the horticultural export market at time when the sector is faced with increased competition from other producer countries (KHCP, 2013).

Pineapple production requires investment in ICT for it to be competitive and to sustain growth. The integration of ICT use in the agrienterprises offers a great opportunity for their commercialization. ICT commercializes agrienterprises in two ways: the first is market orientation, a business approach or propensity for identifying and meeting customer needs and making agricultural production decisions as a result (Gebremedhin and Jaleta, 2010). The second is market participation, which is how much an agri-enterprise actually participates in a market, including how much produce they sell as a proportion of their overall production capability (Wickramasinghe and Weinberger, 2013). Hence, explaining the need to integrate ICT into pineapples value chain to increase their competitiveness in the global market.

2.2 Structure of ICT usage in Kenya agrienterprises

ICT play an important role in the development process. ICTs have revolutionized life whereby the acquisition and usage of ICT applications by actors in the agribusiness sector including producers is increasing very rapidly. The usage of ICT platforms is setting an unprecedented pace despite the poorly developed rural electrification. The most common ICTs used by agrienterprises include computers, radio, television, internet and telecommunication networks (Sife *et al*., 2010).

A Study done in Kenya by Okello *et al*. (2010) indicated radio is mostly used ICT platform due to its wide coverage of frequencies, availability of many vernacular radio stations, and the portability nature of most radio. In fact many NGOs are advocating for radio extension among agrienterprises such as Farmer Voice Radio (FVR) promoted by Jomo Kenyatta University Extension and Production division in collaboration with Food and Agriculture Organizations (FAO). The other ICT gaining popularity currently is television, whereby it is used by almost 65% of Kenyans. This is mainly due to the fact that most rural areas in Kenya are now able to access electricity. This has triggered emergence of TV programmes which broadcast information on agribusiness and how agrientrepreneurs can commercialize their agribusiness. Some of such TV programmes include *Shamba* shape up, Smart Farm, *Mkulima* young and seed of gold (Pauline, 2013).

Another dominantly used ICT tool in Kenya is the mobile phone. An increasing number of people are currently using mobile phones to run their agrienterprises. Several studies have shown that mobile phones can cause significant benefits for agrienterprises through improved access to information, lower marketing costs, and thus higher profits and incomes. Through the use of mobile phones market accessibility has improved, investment promoted, risk from disasters are reduced, and are known to contribute to empowerment of societies through enhancing access to information (Okello *et al*., 2010). In addition to such direct effects, mobile phones are an enabling technology for other innovations. One important example are mobile phone based money transfers such as M-pesa and Airtel Money, which could be very relevant for rural agrienterprises that are often underserved by the formal banking system. So far, little is known about the effect of mobile money on performance of agrienterprises.

The use of mobile money services by agrienterprises provides a unique opportunity for the development of agrienterprises. This is because these services can enable cheap and reliable money transfers between people that have access to a mobile phone. This is especially

important for sending and receiving remittances, which is much more expensive and sometimes risky through traditional formal and informal mechanisms (Morawczynski *et al.,* 2009). In addition, mobile money facilitates transfers between business partners, reducing transaction costs and promoting market exchange. Finally, mobile money services provide relatively secure opportunities for saving even in remote rural areas (Mbiti, 2011).

Lastly, there has been emergence of computer and internet based ICT platforms such as the e-Soko (e-Market) web-based system which offers an agricultural commodity exchange platform. Farmers, buyers, service providers enlisted with the e-Soko system are provided with passwords so that they can send targeted messages via Short Messaging Service (SMS) to their farmers through mobile telephony (Okello *et al*., 2010). There is also NAFIS which is a comprehensive information service, intended to serve farmers' needs throughout the country including the rural areas where internet access is limited. It enables farmers get critical extension information by either browsing through the internet or calling centres. The service comprises of a detailed website that is easily updated by Extension Officers and a Voice-Based Service which contains summarized information which farmers' access using mobile phones. The Voice-Service is available both in English (Kenyan Local dialect) and Kiswahili (Mbiti, 2011).

2.3 Factors influencing use of ICT among smallholder agrienterprises

In agrienterprises, the use of ICT can be influenced by a number of different factors, such as type of agri-enterprise, farmer's permanent characteristics, agri-enterprise characteristics, goals and community culture. These factors have direct and indirect relationships and influence the use of ICT either positively or negatively. In an agri-enterprise, the use of ICT also depends on the perceived value of ICT (Alvarez *et al.,* 2006). According to Taragola *et al.* (2005) the significant factors influencing the use of ICT in dairy industry to include cost of technology, lack of training, lack of technological infrastructures, lack of ICT proficiency, lack of ICT benefit awareness, too hard to use, trust level in the ICT system, system integration and software availability limit the use of ICT by dairy industry stakeholders.

Oduwole *et al.* (2009) used multi regression analysis to evaluate factors that influence ICT use in Nigeria agrienterprises and identified computing knowledge, ICT facility used by respondent, knowledge of how to operate ICT facility, search of business related information and aspect of business operation information being searched all had significant influence on ICT usage in agribusiness. The main significant perception factors that influence the use of

ICT included perceptions on effect of ICT on profitability, level of ICT use, skill on the internet and use of ICT for search (primary) processing record. Hence, these factors are crucial in the use of ICT by produce marketers.

A study conducted by Sabuhoro *et al.* (2003) on factors that influence the use of computers by agrienterprises owners in South Africa. They identified that a large household size was generally associated with a positive influence on ICT use than a smaller household size. Those with less annual /monthly income are often the ones with the least access to ICT. The higher the income levels, the higher the probabilities of ICT use. Use of technology is believed to be positively associated with education. Those farmers with post-high school qualification tend to make up the majority of ICT users.

According to study conducted by Sabuhoro *et al.* (2003) on influence of gender on ICT use, they identified that the probability of ICT use is likely to increase if the owner of the agri-enterprise is male. Therefore, men have more and easier access to ICT and more readily adopt technology. A study conducted by Boadi *et al.* (2007) on the role of m-commerce in Ghana , they identified the factors that have significant effect on the use of ICT were perceptions of the respondents on effect of ICT on profitability, level of ICT use, skill on the internet and use of ICT for search (primary) processing record. Hence, these factors are crucial in the use of ICT by produce marketers.

Agrienterprises owners with off-farm income are likely to use ICT than those in full time farming (Alvarez *et al.*, 2006). The probability of ICT use is expected to increase if the owner has off-farm employment. The anticipated barriers to ICT use such as lack of ICT training, high technology costs, lack of technical know-how and lack of education negatively affect the ICT use. The higher these barriers are, the less the probability of ICT use. The farmer's experience in agriculture is expected to have a positive relationship with ICT use. Those farmers with more farming experience tend to use technology than those with less experience (Hollenstein, 2004). This also depends on other factors such as the age of the farmers. Some experienced farmers are more likely not to be flexible and prefer their own traditional way of practicing farming. Agrienterprises located close to the centres of development are expected to have greater access and use for ICT than those far away (Alampay, 2006). Lastly, agri-enterprise owners with positive attitude towards ICT are likely to generate a positive effect on ICT use and a negative attitude implies otherwise (Xue *et al*., 2007).

2.4 Effect of ICT on performance of agrienterprises

Agricultural information services must be provided to agrienterprises for enhancing agri-entrepreneurs make rational decisions concerning agricultural production and post-harvest practices (Mtega *et al.,* 2009). ICTs facilitate the accessibility of agricultural information services thus it is a channel necessary for building local capabilities, integrating new and traditional knowledge and increasing profits for agrienterprises. Compared to other channels which carry information, ICTs have the potential to increase the speed and ease with which information can be accessed. Some ICTs can enable interactive communication hindered by space, volume, medium or time. Majority of agrienterprises benefit from ICTs use through access to improved agricultural information flows which enhance timely accessibility of needed information thus contributing to improved agricultural practices and performance of the agrienterprises. The suitability of ICTs to sharing agricultural information and provision of several services needed for agricultural production is due to the fact that most ICTs allow a two way communication and can provide more than one service simultaneously (Sife *et al.,* 2010).

For instance, the use of mobile phones has brought a great effect on the performance of agrienterprises. They are used for communication purposes and for provision of financial services (through mobile banking and money transfer). Currently in Kenya, mobile money banking and transfer have spread very rapidly (Dermish *et al.,* 2011; Kirui *et al.,* 2013). The M-Pesa (for Safaricom) and the Airtel money (for Airtel) are the main service providers. M-Pesa now has around 18 million customers and over 85 thousand agents nationwide. Equity bank through its subsidiary Finserve, Mobile pay which has Tangaza and Zioncell have entered the market making competition to increase in mobile banking and money transfer. There has been intense price war between service providers, which to a great extent has helped agrienterprises to transact and access money through mobile networks in a cheaper way. For example, transactions valued at 87% of the country's GDP passed through M-pesa alone in 2013 (CBK, 2013).

In Tanzania Vodacom alone transacted about 35 billion Tanzanian shillings a day by October 2012. This evidences shows how mobile banking has a potential role in facilitating investment opportunities for agrienterprises. They have a positive effect on agrienterprises as they can be able to make appropriate decisions regarding where to sell their produce. Therefore, the use of mobile phones empower agribusiness stakeholders through increased

bargaining power, increased control over external events and increased market opportunities (Myhr *et al*.,2006).

As was observed by the World Bank (2015), a number of farmers reported that ICT has enabled direct marketing by eliminating the middlemen, thereby lowering transaction costs and enhancing profits. A number of farmers communicate directly to their international customers without the need for an agent or middlemen, and this has resulted in effective communication, direct customer service, combating of risk, low transaction costs and better service delivery in the wine industry. In conclusion, ICT applications have the potential of helping agrienterprises to address challenges and improve operations and marketing.

2.5 Theoretical framework

This study was based on utility maximization theory. Utility is determined by a set of exogenous variables which influence the cost of using ICT tools. Therefore, the decision to use ICT or not depends on whether an ICT application gives the agrienterprises higher utility than without using the ICT platform. The key assumption under this methodology was that the agrienterprises owners were faced with only two alternative choices and that any choice an individual chooses depends on their characteristics (Pindyck *et al.*, 1997).

The expected net utility derived from ICT use or not given agri-enterprise's characteristics was determined as follows:

$$EU_iP = f(W_i) + e_i, \quad (1)$$

$$EU_iN = f(X_i) + e_i, \quad (2)$$

Where, EU_iP, was the expected net utility of an agri-enterprise *i* from using ICT tools. EU_iN, was the expected net utility of an agri-enterprise *i* from non-utilization of ICT tools. *P* denoted ICT use while *N* denoted non-use. X_i and W_i, were independent variables denoting socio-economic factors, institutional factors ICT related factors and e_i is an error term. The expected net utility from each of the decisions was then compared (Greene, 2008). To compare, Y_i was used as an indicator of whether agri-enterprise *i* was optimal user ICT or not, so that Y_i=1 if agrienterprises was optimal user of ICT and Y_i= 0 if agrienterprises *i* is sub-optimal users, as indicated in equation (3).

$$\begin{Bmatrix} Y_i = 1 \; if EU_i P - EU_i N > 0 \\ Y_i = 0 \; if EU_i P - EU_i N < 0 \end{Bmatrix}, \quad (3)$$

Equation (3) implies that the probability that the agri-enterprise *i* use of ICT was given by the probability that the expected net utility derived from optimal utilization was greater than the expected net utility derived from sub-optimal usage. While the probability that the agri-enterprise *i* was not an optimal user of ICT was given by the probability that the expected net utility derived from optimal utilization was less than the net utility derived from sub-optimal usage.

2.6 Conceptual framework

In this study, agrienterprises decision to use ICT was assumed to be influenced by socio-economic factors, institutional factors and ICT related factors. It was assumed that these factors would influence the decision of an agri-enterprise to either utilize ICT tools or not. Therefore individuals who utilized ICT in their agrienterprises were expected to benefit from access to Information on market price, weather forecast, best farming practices and agricultural news. They were also able to get input supply from ICT tools such as access to credit through e-banking, mobile banking and money transfers, access to fertilizers, agro-chemicals and seeds. In addition, agrienterprises were able to market their products through ICT platforms. In conclusion, it was assumed that as a result of agrienterprises utilization of ICT tools, they would benefit from reduction of transaction costs, improved supply chain coordination and market access thus improving their productivity and profitability. Hence, leading to the performance of the agrienterprises.

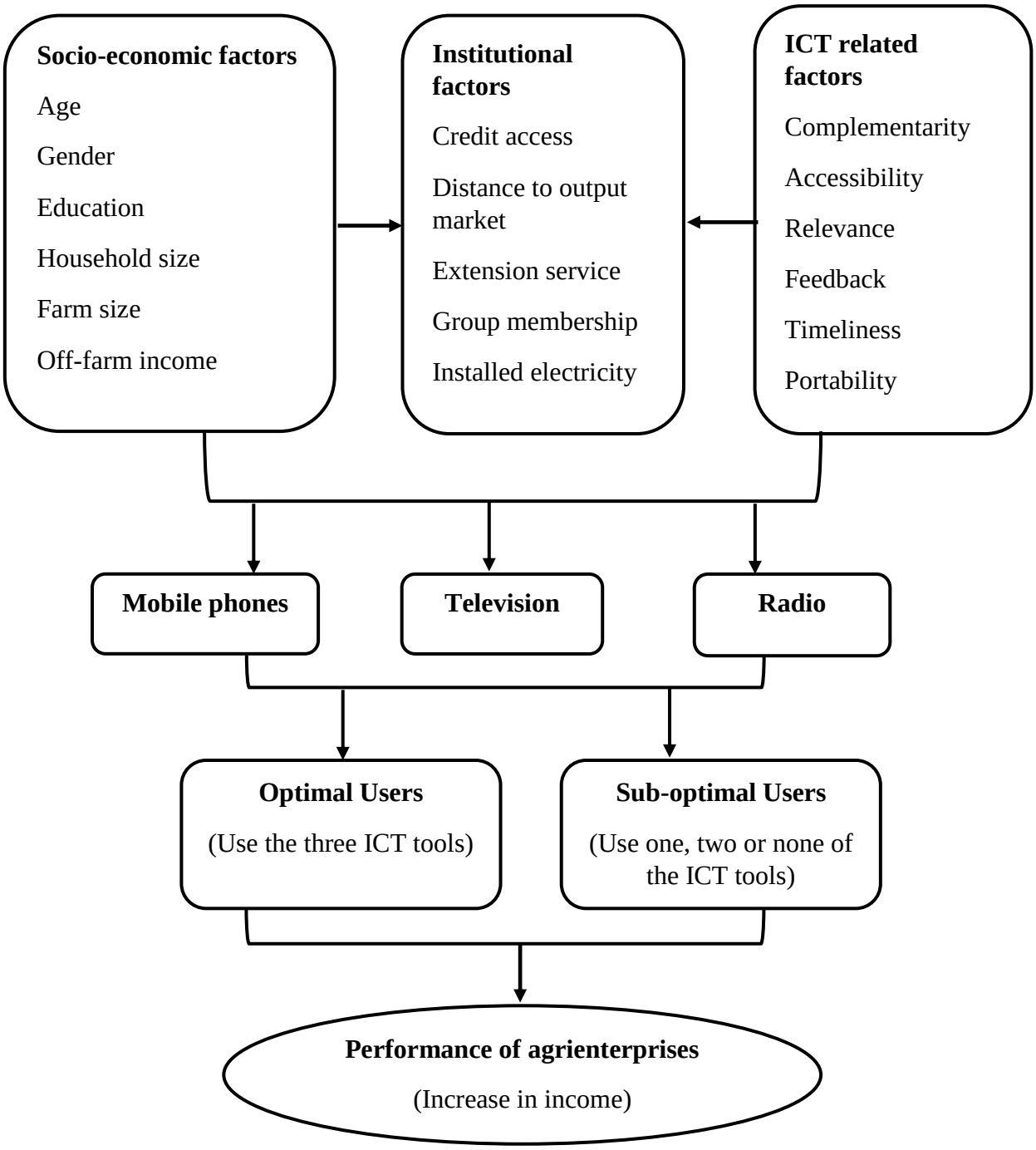

Figure 1: Conceptual Framework (own conceptualization)

CHAPTER THREE
METHODOLOGY

3.1 Study area

The study was conducted in Gatundu North sub-County, Kiambu County. The county borders Nairobi and Kajiado Counties to the south, Machakos to the east, Muranga the to north and north east and Nakuru to west. The sub-County was purposively selected due to increase in smallholder pineapple agrienterprises who are withdrawing from traditional crops (tea and coffee) and venturing into pineapple production for commercial purposes. These farmers were also using ICT tools such television, radio and mobile phones to access agricultural information and to market their produce. Kiambu County is one of the five counties in former Central Province, with a population of approximately 1,766,058 people (KNBS, 2009). It extends between longitude 36° 31′ and 37 ° 15′ east andlatitude 0° 25′ and 1° 20′ south.The county occupies an area of 2,543.5 km^2 of which 1,878 km^2 is arable while 649.7 km^2 is non-arable and 15.5 km^2 is under water mass. It comprises ten sub-counties namely; Gatundu, Gatundu North, Ruiru, Thika East, Thika West, Githunguri, Kiambu, Limuru and Kikuyu.

The county is divided into four topographical regions namely; upper highland (1,800-2,550 metres) above sea level, lower highland (1,500-1,800 metres) above sea level, upper midland (1,300-2,500 metres) above sea level and lower midland zones (1,200-1,360 metres) above sea level. The high potential zone generally receives more rainfall over a longer period of time than the low potential zone. Rainfall ranges from 600 to 1,000 mm in low potential zones and 1,200 mm to 2,000 mm in high potential zones. The average annual rainfall received by the county is 1,200 mm per annum. The change in altitude and factors cause temperature to vary from 7°C to 34°C.

Agriculture is the major economic activity in the county and it contributes 17.4% of the county's population income. Coffee and tea are the main cash crops while the main food crops are maize, beans, pineapples and Irish potatoes. Majority of the farmers in the sub-County are engaged in commercial pineapple production with intense use of ICT tools to market produce and access agricultural information (KHCP, 2013). Limited access to timely and accurate information has been identified as a major hindrance to the development of agrienterprises in Kiambu County. The use of mobile phones has grown as a means of accessing agricultural information and market prices by majority of agrienterprises in the

county. Despite this growth, in the rural areas where agriculture is the main economic activity, digital services do not always reach the communities creating urban/rural digital divide (FAO, 2012).

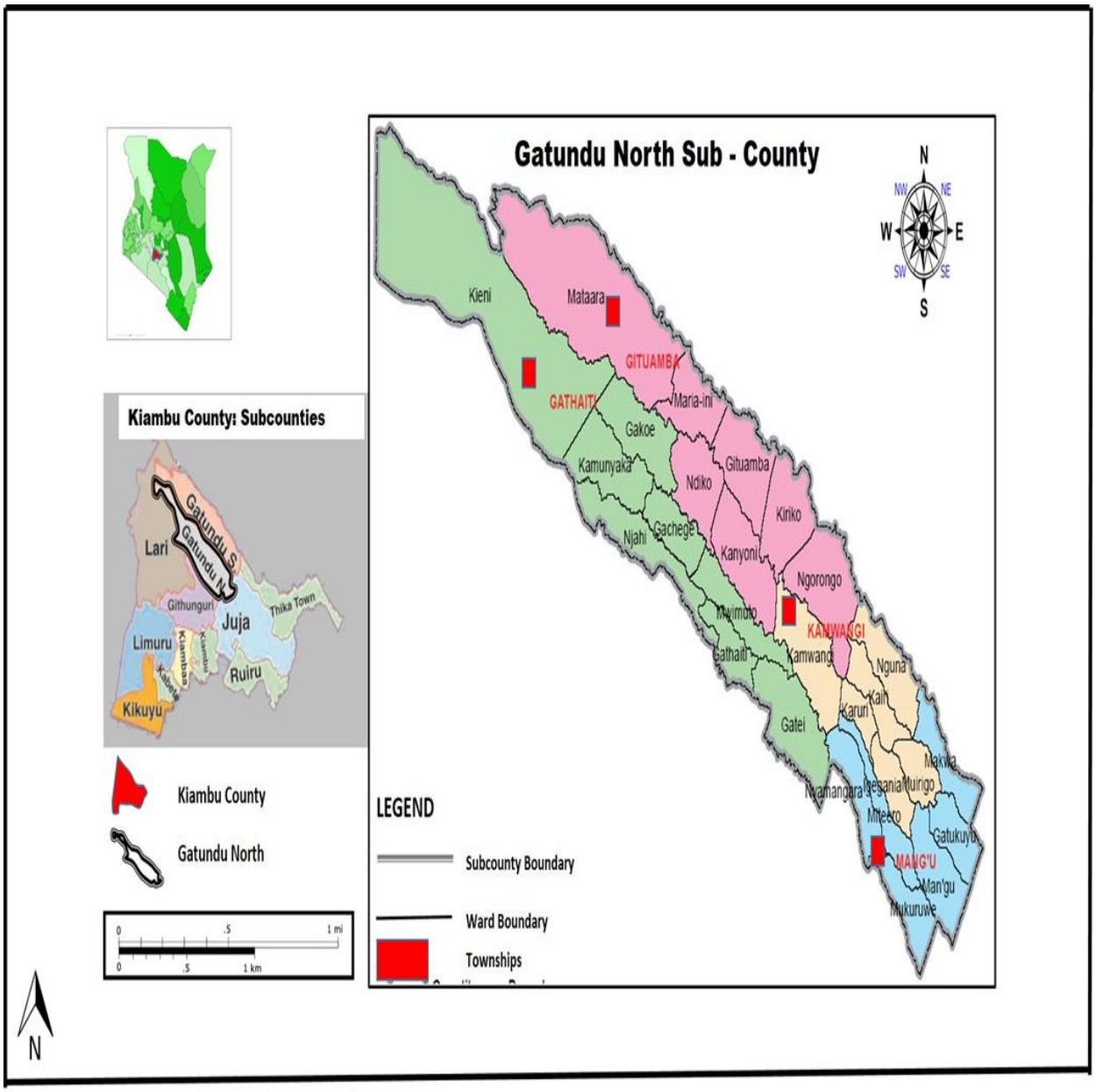

Figure 2: Gatundu North Sub-County map

Source: Ministry of Devolution and Planning, 2013

3.2 Sample and sampling procedure

The sample unit for this study consisted of smallholder pineapple farmers who used ICT in one way or the other along their fruits supply chain in Gatundu North sub-County. The required sample size was determined by proportionate to size sampling methodology (Anderson *et al.,* 2007).

$$n = \frac{pqZ^2}{E^2},$$

$$n = \frac{0.5 \times 0.5 \times 1.96^2}{0.08^2} = 183 \quad (4)$$

Where; n = Sample size; Z= confidence level (α=0.05); p = proportion of the population containing the major interest, q=1-p and E= allowable error. Since the proportion of the population was not known with certainty, it was assumed that p= 0.5, and hence q=1-0.5=0.5, Z= 1.96 and E = 0.08 (acceptable error term). This resulted to a sample of 183 respondents.

Multi-stage sampling procedure was used to select the sample for the study. First, Kiambu County was purposively selected because it was well known for its numerous and diversified commercial agricultural activities. It is also the mainstay of commercial agribusiness in the country. Hence, there was a possibility of a growth in the use of ICT in the day to day business transactions of the agrienterprises.Within Kiambu County, Gatundu North Sub-County was also purposively selected because it was well known for enormous production of pineapples after farmers withdrew from production of coffee and tea. Majority of the farmers in that area were also using ICT tools such as mobile phones to market their produce. Four locations with high number of pineapple agrienterprises were selected purposively which included Gakoe, Kanyoni, Kamwangi and Mangu. Lastly, proportional random sampling was applied to select the respondents from the four locations since they are not equal in size.

3.3 Data collection and data analysis

Data was collected from various sources which included both primary and secondary sources of information. Structured questionnaire was prepared to collect quantitative data for the study.The questionnaires had both open and close-ended questions. Secondary sources were collected publications, journals, relevant websites and books. Different government sources were consulted for information. These included handbooks, policy statements, published statistics, national government sources, planning documents, reports, historical and other

official documents. The data collection methods was aimed at investigating how ICT tools were being used in each stage along the pineapple supply chain, in order to establish the flow of information within the fruit supply chain.

3.4 Analytical framework

3.4.1. Structure of ICT usage among pineapple agrienterprises

Descriptive statistics was used to analyse this objective. This was captured through quantitative and qualitative variables that were important in understanding the socio-economic and institutional factors of pineapple farmers. Mean, percentage and standard deviation of various variables were obtained. The t-test and Chi-square tests were used to compare the selected household and farm characteristics of the two groups of farmers (optimal users and sub-optimal users).

3.4.2 Factors influencing use of ICT among smallholder pineapple agrienterprises

Better understanding of the ICT use in pineapple agrienterprises requires farm household characteristics to be matched with the ICT tools. By identifying the important factors influencing the use of the various ICT tools important policy information on supporting policies for incorporation of ICT in agrienterprises can be obtained. The study focused on three ICT facilities which included mobile phones, radios and TVs. The empirical specification of choice decision over the three ICT facilities can be modeled in three ways, by either univariate, multinomial or multivariate regression analysis. The multivariate probit model was used to analyze the factors influencing the use of ICT in agrienterprises. This model simultaneously models the influence of socio-economic, institutional and ICT related factors on each of the different ICT tools while allowing the unobserved and unmeasured factors (error terms) to be correlated (Lin *et al.*, 2005; Green 2003; Golob and Regan, 2002).

Univariate regression models each of the ICT facilities individually as functions of the common set of explanatory variables. The shortfall of this approach is that it is prone to biases caused by ignoring common factors that might be unobserved and unmeasured and affect the different ICT tools. In addition, Independent estimation of individual discrete choice models fails to take into account the relationships between uses of different ICT tools. Agrienterprises might consider some combinations of ICT tools as complementary and others as competing. By neglecting these common factors the univariate technique ignores potential correlations among the unobserved disturbances in ICT tools, and this may lead to statistical bias and inefficiency in the estimates (Lin *et al*., 2005).

Multinomial regression is another alternative which has one underlying assumptions of independence of error terms of the choice equations are mutually exclusive (Greene, 2003). However, the choices among the ICT tools are not mutually exclusive as agrienterprises are using information from more than one ICT tool at the same time and therefore the random error components of the ICT tools may be correlated. The shortfall of this technique is that all multinomial replications of a multivariate choice system have problems in interpreting the influence of explanatory variables on the original separate ICT tools. Therefore, multivariate probit model seemed to be the best model for this study because it would allow possible contemporaneous correlation in the choice to use the three ICT tools simultaneously.

This estimation procedure has been used in a number of studies that evaluate factors that affect adoption of agricultural technologies (Davis and Rahelizatovo 2004; Jenkins *et al*., 2011). Davis and Rahelizatovo (2004) used this to estimate factors that affect adoption of four breeding technologies in hog production. Moreover, Jenkins *et al*. (2011) used this approach to evaluate factors that affect cotton producers' adoption pattern of different information sources such as private, extension and media. They argue that modeling adoption decisions using a multivariate probit framework allows for increased efficiency in estimation in the case of simultaneity of adoption.

Empirically the model can be specified as follows:

$$Y_{i1} = X'_{ij1}\beta_1 + \varepsilon_{i1}$$

$$Y_{i2} = X'_{ij2}\beta_2 + \varepsilon_{i2}$$

$$Y_{i3} = X'_{ij2}\beta_3 + \varepsilon_{i3}, \quad (5)$$

Where, i = agrienterprises identification, Y_{i1} = 1, if agrienterprises uses radio to access agricultural information (0 = otherwise), Y_{i2} = 1, if agrienterprises uses television to access agricultural information (0 = otherwise), Y_{i3} = 1, if agrienterprises uses mobile telephony to access agricultural information and to undertake transactions such as marketing produce, mobile banking and mobile money transfers (0 = otherwise), X'_i = Vector of factors affecting use of ICT tool, βj = Vector of unknown parameters (j = 1, 2, 3), and ε = is the error term. Factors influencing use of ICT tools can be tested by running three different independent binary probit or logit models by assuming that error terms are mutually exclusive. However, the decision to use different ICT tools may be correlated, thus the elements of error terms might experience stochastic dependence. In this situation, a multivariate probit model of the following form is used to test the hypothesis

$$Y_{i1} = X'_{ij}\beta_j + \varepsilon_{ij}, \quad (6)$$

Where Y_{ij} (j =1….,3) represent the three different ICT tools faced by the i^{th} agrienterprises (i = 1..…150), X'_{ij} is a 1 × k vector of observed variables that affect the choice decision of agrienterprises, β_j is a k × 1 vector of unknown parameters (to be estimated), and ε_{ij} is the unobserved error term. Assuming the error terms (across j = 1… m alternatives) are multivariate and are normally distributed with mean vector equal to zero, the unknown parameters in Equation (6) are estimated using simulated maximum likelihood. The method used Geweke Hajivassiliour-Keane smooth recursive conditioning simulator procedure to evaluate the multivariate normal distribution. Therefore, the implicit functional form estimated to assess the drivers the decision to use ICT tools by owners of agrienterprises was given by:

$$\mathbf{Z_i} = \boldsymbol{\alpha_0} + \boldsymbol{\alpha_1}\text{Age} + \boldsymbol{\alpha_2}\text{Gen} + \boldsymbol{\alpha_3}\text{Educ} + \boldsymbol{\alpha_4}\text{Hhsz} + \boldsymbol{\alpha_5}\text{Fsize} + \boldsymbol{\alpha_6}\text{Occu} + \boldsymbol{\alpha_7}\text{Exp} + \boldsymbol{\alpha_8}\text{Inc} + \boldsymbol{\alpha_9}\text{Acc} + \boldsymbol{\alpha_{10}}\text{Offinc} + \boldsymbol{\alpha_{11}}\text{Mem} + \boldsymbol{\alpha_{12}}\text{Extens} + \boldsymbol{\alpha_{13}}\text{Dist} + \boldsymbol{\alpha_{14}}\text{Affod} + \boldsymbol{\alpha_{15}}\text{ICTtrn} + \boldsymbol{\alpha_{16}}\text{ICTlit} + \boldsymbol{\alpha_{17}}\text{Distelec} + \boldsymbol{\alpha_{18}}\text{Crpent} + \boldsymbol{\alpha_{19}}\text{Areacul} + \varepsilon_1, \quad (7)$$

Where: **Y** = Use of ICT by the agrienterprises (A binary value of 1 if an agri-enterprise is likely to increase income from use of ICT tools on the business, 0 if otherwise)

$\boldsymbol{\alpha_0}$ = Constant, $\boldsymbol{\alpha_1}$**-** $\boldsymbol{\alpha_{19}}$ **=** Coefficients and ε_1 = Error term

Table 1. Description and expected sign of the variables used in regression models.

List of variables	Descriptions	Measurement	Expected sign
Age	Age of household head	Number of years	+/-
Gen	Gender	Dummy 1=male, 0=female	+/-
Educ	Education level	Number of years	+
Hhsz	Household size	Number of individuals	+/-
Fsize	Farm size	Acres	+/-
Offinc	Off-farm income	Dummy 1=yes, 0=no	+
Grpmember	Group membership	Dummy 1=yes, 0=no	+
Econt	Extension contacts	Dummy 1=yes, 0=no	+
Acc	Credit access	Dummy 1=yes, 0=no	+
Dist	Distance to output market	Distance in kilometers	+/-
Occupation	Off farm occupation	Dummy 1=yes, 0=no	+
Instelec	Installed electricity	Dummy 1=yes, 0=no	+
ICTrn	ICT training	Dummy 1=yes, 0=no	+
Agritrain	Agricultural training	Dummy 1=yes, 0=no	+
ICTafford	Affordability of ICT tool	Dummy 1=yes, 0=no	+/-
Comp	Complementarity	Likert 1=SD, 2=D, 3=N, 4=A, 5=SA	+/-
Access	Accessibility	Likert 1=SD, 2=D, 3=N, 4=A, 5=SA	+/-
Rel	Relevance	Likert 1=SD, 2=D, 3=N, 4=A, 5=SA	+/-
Feed	Feedback	Likert 1=SD, 2=D, 3=N, 4=A, 5=SA	+/-
Time	Timeliness	Likert 1=SD, 2=D, 3=N, 4=A, 5=SA	+/-
Port	Portability	Likert 1=SD, 2=D, 3=N, 4=A, 5=SA	+/-

SD =strongly disagree: D = disagree: N= neutral: A =agree: SA =strongly agree

3.4.3 Effect of ICT use on income of smallholder agrienterprises

To achieve this objective, the study used endogenous switching regression model. The outcome variable for the model was income effects of ICT utilization. Gross margins was calculated by subtracting total variable costs from gross revenue (FAO 1985) and specified in equation 8:

$$GM_i = TR_i - TVC_i, \quad (8)$$

Where, GM is gross margin; TR is Total Revenue; TVC is Total Variable Costs;

(For i = 1, 2) either the ICT optimal users or sub-optimal users.

The total pineapple income was used as a final measure for the effect of ICT tools on pineapple farming. In most of agrienterprises in Kenya, the usage of ICT facilities differs in the level of application of different ICT tools in their business transactions. Some agrientrepreneurs may decide to use any of the three modern ICTs (mobile telephony, TV and radio), while some may decide to use none. In order to determine the counterfactual usage of ICT facilities among agrienterprises, the agrienterprises were divided into optimal and sub-optimal users. Agrienterprises that were using all the three ICT facilities were categorized as optimal user while agrienterprises that were using any of the one, two or or none of the ICT tools was categorized as sub-optimal users.

In order to determine the effect of ICT use on performance of agrienterprises, two methods could be used: an endogenous switching regression model and a propensity score matching model. Both models could predict that sub-optimal users of ICT tools would benefit from optimal usage of ICT tools but they would not be as profitable as the optimal users. However, the decisions for pineapple farming and ICT usage are jointly made. Some unobservable characteristics, such as skills, innovation, ability of the farmer and attitude in farming households may affect not only usage of ICT but also farming decisions, leading to endogeneity and self-selection problems in the model (Di Falco and Veronesi, 2013). Therefore, if we do not take account of the endogeneity that arises in pineapple farming and usage of ICT facilities, the true effect on pineapple farming cannot be estimated.

This motivates an endogenous switching regression model that accounts for both endogeneity and sample selection and allows interactions between usage and other covariates in the effect outcome function (Freeman *et al*., 2001 and Alene and Manyong, 2007). Not distinguishing between the casual effect of technology adoption and the effect of unobserved heterogeneity could, indeed, lead to misleading policy implications. Hence to account for the endogeneity of the usage decision (that is, for the heterogeneity in the decision to use or not to use ICT tools and for unobservable characteristics of farmers and their farm) by estimating a simultaneous equations model with endogenous switching by full information maximum likelihood estimation. Therefore, the study used endogenous switching regression that

enabled the researcher to jointly consider the usage of ICT facilities and pineapple farming within a single framework. The endogenous switching regression model could also be used to compare observed and counterfactual benefits of ICT tools usage. Thus it enables one to compare the expected benefits of the agrienterprises that were optimal users with respect to agrienterprises that were sub-optimal users and to investigate the expected benefits in the counterfactual hypothetical cases that the optimal users were sub-optimal users and that sub-optimal users were optimal users.

Usage of ICT tools decisions of the farmer are assumed to be derived from the maximization of a discounted expected utility of farm profit subjected to imperfect or missing factor market for land, labor, credit and perception of farm households. Human capital variables and/or household specific characteristics like family labor force, education level of household head, age and gender of the household head were also included. Contact with government and non-government extension agents and access to off farm actives were also included as explanatory variables in the model. It was expected that these variables could explain the farmer's awareness about the gains of the ICT tools and hence positively affect the level of usage. Variables capturing access and information such as credit, media, group membership and distance from main market were also included.

This model followed two steps. In the first step, it modeled the decision of whether or not agrienterprises use ICT facilities, and in the second step, it modelled the outcome of pineapple farming depending on agrienterprises are optimal users or sub-optimal users. More specifically, in the first step, the agrienterprises were assumed to decide whether to use all the three ICT facilities based on the expected outcome measure for pineapple farming. The smallholder agrienterprises use the ICT facilities if the expected outcome of usage is greater than that of sub-optimal users. The expected outcomes for agrienterprises i for optimal users and sub-optimal users will be $C^*_{i,ou}$ and $C^*_{i,ou}$ respectively. Agrienterprises are assumed to use ICT facilities if $C^*_{i,ou} > C^*_{i,ou}$ Note that $C^*_{ik,k} = (ou, su)$ are not observable, while whether each agrienterprises is optimal user of ICT facilities or not is observable.

The first-step equation is called "selection equation" and estimated using probit regression as follows:

$C^*_{ik} = Z_i\beta + \varepsilon_i$, k = (ou, su)

C = 1 if $C^*_{i,ou} > C^*_{i,su}$

C = 0 otherwise, (9)

Where C^*_{ik} is a latent variable that captures expected outcomes from usage of ICT facilities by agrienterprises i, vector C_i represents variables that affect usage of ICT facilities such as socio-economic, institutional and ICT related factors for agrienterprises i, β is a vector of parameters to be estimated, and ε_i is a random error term with mean zero and variance σ_ε^2

In the second step, we evaluated the determinants of pineapple income depending on whether agrienterprises are optimal users or sub-optimal users of ICT facilities. These second-step equations are called "regime equations," and the estimation can be made with the following specification: For ICT optimal users, the estimation is specified as

$Y_{i,\,ou} = X_{io}\beta_{ou} + \varepsilon_{io}$, (10)

While for sub-optimal users, it is specified as;

$Y_{i,\,su} = X_{is}\beta_{su} + \varepsilon_{is}$, (11)

Where $Y_{i,\,ou}$ and $Y_{i,\,su}$ are the pineapple incomes for optimal and sub-optima ICT users, X_{io} and X_{is} are set of the explanatory variables for equations (10) and (11), β_{ou} and β_{su} are the parameters to be estimated for optimal and sub-optimal users and ε_{io} and ε_{is} are the random error terms with variances of σ_o^2 and σ_s^2. The variables included in X_{io} and X_{is} should be contained in Z_i in equation (9), implying that Z_i must have at least one more variable that is not included in equations (10) and (11). Access to agricultural training, ICT training and ICT affordability were the additional instrumental variables in Zi. The ε_i, ε_{io} and ε_{is} are error terms of selection and regime equations, espectively and were assumed to have a trivariate normal distribution with zero mean vectors and the following covariance matrix:

$$Cov(\varepsilon_\varepsilon, \varepsilon_{io}, \varepsilon_{is}) = \begin{bmatrix} \sigma_\varepsilon^2 & \sigma_\varepsilon^s & \sigma_\varepsilon o \\ \sigma_\varepsilon s & \sigma_s^2 & \sigma so \\ \sigma_\varepsilon o & \sigma so & \sigma_o^2 \end{bmatrix}, \quad (12)$$

The unobservable characteristics of farm households that determine the choice of ICT tools also affect the pineapple income of the households in each regime. Therefore, full information maximum livelihood (FIML) estimation is applied to simultaneously measure selection and regime equations using the endogenous switching regression model that takes account of sample self-selection problems (Lokshin and Sajaia, 2004). Based on the estimates of β_{ou} and β_{su}, we will calculated both conditional and unconditional expectation of pineapple incomes for both optimal and sub-optimal users of ICT facilities. In this type of research, we cannot observe pineapple incomes in counterfactual situations, such that when optimal ICT tools users do not use all the tools and when sub-optimal users use all the ICT tools. Therefore, we estimated their counterfactual value via estimated β_{ou} and β_{su} by considering optimal users as a treatment.

Table 2 presents the calculation of treatment, heterogeneity and transitional heterogeneity effects. To calculate average treatment on treated (hereafter, ATT), we needed to differentiate the actual pineapple income (observed) and its counterfactual for optimal users (Carter and Milon, 2005). Similarly, average treatment on untreated (hereafter, ATU) was calculated as the difference between the actual (observed) and counterfactual incomes for sub-optimal users. For the calculation of ATT and ATU, the study followed the procedures taken by Di Falco and Veronesi (2013) who compared the performance of climate change adaptation strategies in Ethiopian agriculture via calculating ATT and ATU.

Expected pineapple income of optimal users (observed) of ICT tools is

$$E(Y_{i,\,ou}/\,C=1) = X_{io}\beta_{ou} + \sigma\varepsilon_o\lambda_{ou}\,, \tag{13}$$

Expected pineapple income of optimal users without ICT tools (counterfactual) is

$$E(Y_{i,\,su}/\,C=1) = X_{is}\beta_{su} + \sigma\varepsilon_s\lambda_{ou}\,, \tag{14}$$

Expected pineapple income of sub-optimal users without ICT tools (observed) is

$$E(Y_{i,\,su}/\,C=0) = X_{is}\beta_{su} + \sigma\varepsilon_s\lambda_{su}\,, \tag{15}$$

Expected pineapple income of sub-optimal users with ICT tools (counterfactual) is

$$E(Y_{i,\,ou}/\,C=0) = X_{io}\beta_{ou} + \sigma\varepsilon_o\lambda_{su}\,, \tag{16}$$

Where λ_k, k = (ou, su) are inverse Mills ratios of two regime equations, respectively.

Using equations (12) and (13) yields ATT as follows:

$$ATT = E(Y_{i,ou}/ C=1) - E(Y_{i,su} / C= 1), \quad (17)$$

Likewise, using equations (14) and (15) yields ATU as follows:

$$ATU = E(Y_{i,su} / C= 0) - E(Y_{i,ou} / C= 0), \quad (18)$$

Computation of equations (17) and (18) followed the procedures introduced by Lokshin and Sajaia (2004) and gave us further insight on the effect of ICT usage when sub-optimal users utilize all the three ICT facilities or when optimal users did not use any of three ICT facilities.

Table 2. Treatment, heterogeneity and transitional heterogeneity effects

Sub-sample	Decision stage		Treatment effects
	Optimal users	Sub-optimal users	
Agrienterprises that are optimal users Agrienterprises that are sub-optimal users	a) $E(Y_{1i,ou}/ C_i=1)$ d) $E(Y_{1i,su} / C_i= 0)$	c) $E(Y_{2i,su} /C_i= 1)$ b) $E(Y_{2i,ou} / C_i= 0)$	On the treated (ATT_i) On the untreated (ATU_i)
Heterogeneity effects	**BH_{1i}**	**BH_{2i}**	**TH**

Notes: Outcomes (a) and (b) represents observed agrienterprises income while (c) and (d) represents their respective counterfactual expected agrienterprises incomes. C_i = 1 if smallholder pineapple agrienterprise i is optimal user of ICT tools and equals zero otherwise. Y_{1i} = agrienterprise income if the pineapple agrienterprises i is optimal user of ICT. Y_{2i} = agrienterprise income if the pineapple agrienterprise i is sub-optimal user of ICT. ATT_i = the effect of the treatment (ICT use) on the treated (pineapple agrienterprises who are optimal users). ATU_i = the effect of the treatment (ICT use) on the untreated (pineapple agrienterprises who are sub-optimal users). BHi = the effect of base heterogeneity for agrienterprises that are optimal users (i = 1) and sub-optimal users (i = 2). TH = (ATT_i – ATU_i) is the transitional heterogeneity.

CHAPTER FOUR
RESULTS AND DISCUSSIONS

This chapter presents results and discussion of the findings on effect of ICT use on performance of pineapple agrienterprises in Gatundu North sub-County. The ICT tools considered in the study were mobile phones, television and radio. Smallholder farmers were sub-divided into optimal users and sub-optimal users of ICT tools. Optimal users were those using the three ICT tools while sub-optimal users were those using one, two or none of the tools. The most commonly used ICT tool to access agricultural information was mobile phones (86%), radio (79%) and then television (59%). All the optimal users owned mobile phones, television and radio. Among the sub-optimal users, 95.6% owned mobile phones, 73.3% owned radio and 33.0% owned television. On the usage of ICT to access agricultural information, the optimal users were using all the three ICT tools. Among the sub-optimal users, majority were using mobile phones (71.1%), while 56.7% were using radio and only 14.4% were using television. According to chi square results, there was statistical difference in usage of ICT tools among the two groups at 5% and 10% significant level.

4.1 Descriptive statistics

4.1.1 Farmer characteristics

The results of gender and education level of household head are presented in Table 3. In terms of the gender of the household head of optimal users, 61.3% were male while 38.7% were female. Among the sub-optimal users, the proportion of males were 63.3% while that of females was 36.7%. Hence, majority of the households were male headed. Male headed households, have higher access to productive resources and information that increases chances of using new technologies (Odendo *et al.,* 2009).

Education level of the household head was broken down into six categories, no formal education, adult education, primary, secondary, college education and university education. There was significant differences in education level of the household head of the two groups. Among the optimal users' households, majority (40.9%) of the farmers had attained secondary education compared to 28.9% of the sub-optimal users. Conversely 31.2% of optimal users' household heads had college education compared to only 3.3% of sub-optimal users.

Table 3. Gender and education level of the household head by ICT usage

Variable	Optimal users (N=93)	Sub-optimal users (N=90)	χ^2
Gender (%)			
Male	61.3	63.3	0.081
Female	38.7	36.7	
Education Level (%)			
No formal education	2.1	27.8	53.07***
Adult education	1.1	5.6	
Primary education	13.9	30.0	
Secondary education	40.9	28.9	
College education	31.2	3.3	
University education	10.8	4.4	

*** = significant at 1% level.

Generally, the level of education of the household head for optimal users was significantly higher than sub-optimal users. This may make them able to understand the importance of using modern agricultural technologies. Education level influences farmers to comprehend information from any ICT source. Therefore, better educated farmers are likely to be innovative and highly skilled to use new technologies such as ICT. Teklewold *et al.* (2013) found that higher level of education empowers farmers in usage of new technologies in their agrienterprises.

Table 4. Mean of household characteristics by ICT usage

	Optimal user (N=93)		Sub-optimal user (N=90)		
Variable	Mean	Std. dev	Mean	Std. dev	*t*-test
Age	36.7	9.64	46.6	13.52	5.692***
Household size	4.1	1.55	4.6	1.84	1.953*
Farm size	2.0	1.41	1.4	0.95	-3.682***
Income (Annual)	128,388.5	165,040	92,455.9	77,451	-1.875*

* and *** = significant at 10% and 1% level, respectively

The mean differences of household characteristics by ICT usage are presented in Table 4. Concerning the age of the household heads of the two groups, optimal users had a mean age

of 36.7 years while sub-optimal users had a mean age of 46.6 years. The association between ICT usage and age of the household heads was statistically significant at 1%. Age of the household head plays an important role in usage of new technologies. Optimal users were younger than the sub-optimal users possibly because young farmers tend to be innovative and risk takers thus would try technologies than older household heads. Okello *et al.* (2010) argued that younger farmers are more literate and able to use modern ICT tools.

The mean household size of optimal users and sub-optimal users was 4.1 and 4.6 persons respectively. The association between ICT usage and household size was statistically significant at 10%. These findings show farmers with small household size were more likely to seek agricultural information from technologies compared to those who have large household size. This can be due to many mouths to feed in large household which may hinder them from using technologies in their agrienterprises. This results are in conformity with Sekabira (2012) who found for every one person increase in family size, decreases the probability to using ICT tools by farmers.

The farm size was statistically different at 1% significance level with optimal and sub-optimal users owning 2.0 and 1.4 acres of land respectively. The optimal users had the largest land holdings possibly because use of ICT tools enables them to access agricultural information which facilitates them to maximize their outputs from their large land size. Land size is a critical production asset which have a bearing on production of a marketable surplus. This results are in conformity with Mwombe *et al.* (2014) who found that increase in farm size leads to increase in the intensity of ICT tools usage as a source of agricultural information for smallholder farmers.

Income is crucial in agricultural information use because the higher the income of the farmer, the more likely he would seek and obtain information for use. The mean annual income from pineapple production was statistically different at 10% significance level with optimal and sub-optimal users getting KES. 128,388.5 and KES. 92,454.9 respectively. The optimal users had higher income possibly because with improved income, the farmer will be better disposed to spend more on recommended farm practices that would further increase his farm earnings. ICT tools also improve market transparency and reduce transaction costs thus improving market access for small-scale farmers thereby increasing their farm income. This results are in conformity with Obiechina, (2006)) who found that usage of ICT tools increases

market access of smallholder farmers which leads to increase in returns from agricultural production.

4.1.2 Institutional characteristics

Table 5 presents the institutional characteristics for discrete dummy variables. Credit is necessary for enhanced expansion of business activities and agrienterprises development. Among the optimal user households, 76.3% had access to credit whereas among the sub-optimal users, 45.6% had access to credit. Access to credit is better for the optimal users' households than the sub-optimal users. The association between ICT usage and access to credit is statistically significant at 1%. Access to credit can help farmers to purchase modern ICT tools which they can use to run their agrienterprises. They can also use the credit they receive from financial institutions to implement the information they receive from ICT tools. Mutai *et al.* (2013) postulated that access to credit gives the farmer more cash resources hence it has an effect on their adoption of technologies. Feder *et al.* (1990) also stated that household heads that has access to credit increases their likelihood of using modern ICT tools in their agrienterprises.

Table 5. Institutional characteristics for discrete dummy variables

Variable		Optimal user (N=93) %	Sub-optimal user (N=90) %	χ^2
Credit access	Yes	76.3	45.6	18.2590***
	No	23.7	54.4	
Group membership	Yes	79.6	54.4	13.1023***
	No	20.4	45.6	
Installed electricity	Yes	84.9	55.6	18.9938***
	No	15.1	44.4	
Agricultural training	Yes	76.3	54.4	9.7169***
	No	23.7	45.6	

*** Significant at 1% level

Group membership can play a significant role in facilitating farmers' use of services provided by modern ICT tools. Among optimal users 79.6% of the respondents involved themselves in group activities in contrast to 54.4% of sub-optimal users. The association between ICT usage and group membership is statistically significant at 1%. It is thus evident that usage of ICT tools in the households is influenced by membership to a farmers' group. This can be

due to farmers in groups are able to learn new technologies and have external support which can help them in using ICT tools in their agrienterprises. This finding is in conformity to Barret (2008) who found group membership acts as a means to access information, secure market opportunities, exchange price information, obtain credit, reduce information asymmetries and enforce contracts.

Access to electricity plays a key role in the use of ICT tools by smallholder farmers. Among the optimal users 84.9% of the respondents had installed electricity in their homes in contrary to 55.6% of sub-optimal users. The association between ICT usage and installation of electricity is statistically significant at 1%. Most ICT tools are electricity dependent therefore for effective use of these tools, households should have access to electricity. Samuel *et al.* (2005) found a positive correlation between mobile phones and television ownership and access to electricity which is in conformity to the findings of the study.

Agrienterprises can benefit from agricultural training in terms of enhancing access to better technologies and improved inputs. Among the optimal users' households, 76.3% had access to agricultural training whereas among the sub-optimal users' households, 54.4% had access to agricultural trainings. Many optimal users had access to agricultural training than sub-optimal users. The association between ICT usage and agricultural training was statistically significant at 1%. Access to trainings acts as an important factor in the usage of technologies among farmers. Higher number of agricultural training was important in increasing the likelihood of using ICT tools since it exposes them to new technologies which they can use to run their agrienterprises. Mwaura *et al.* (2014) found agricultural trainings facilitates usage of ICT tools which enhances agricultural productivity.

Access to extension services facilitates in dissemination of new knowledge and information to smallholder farmers. Among the optimal users' households, they had a mean of 2 extension contacts within the last 12 months while sub-optimal users' household had a mean of 1 contact. Optimal users had higher extension contacts possibly because they could use ICT tools to communicate with extension agents. The association between ICT usage and extension contacts was statistically significant at 1%. Extension services provides farmers with agricultural information they need in usage of technologies. They are also important in the dissemination of new technologies and consequently affect their effect on household welfare (Mwaura *et al.*, 2014).

Table 6. Household distance to market and extension contacts

	Optimal user (N=93)		Sub-optimal user (N=90)		
Variable	Mean	Std. dev	Mean	Std. dev	*t*-test
Distance to market	9.37	12.55	8.04	10.27	-0.7811
Extension contacts	1.37	1.19	0.51	0.72	-5.859***

*** Significant at 1% level

Distance from the household to output market is often used to proxy for the ease of access to market and hence the transaction cost. The mean distance of the households to the output market was longer for optimal users at 9.37 kilometers whereas for the sub-optimal users it was 8.04 kilometers. Usage of ICT tools increases as the households are far away from output markets. This results are in conformity with Sekabira (2012) who found households that were constraint to market access due to distance and transportation cost, had adopted the usage of ICT tools to access agricultural markets.

4.2 Structure of ICT usage

Figure 3 presents the results on television programmes that were disseminating agricultural information. The most viewed television programmes were NTV-Seeds of Gold (17%), *Utugi* TV-*Kilimo na Faida* (10%), Inooro TV-*Mugambo wa Murimi* (9%), QTv-*Mkulima ni Ujuzi* (8.7%) and Citizen TV-Shamba Shape Up (8.2%). Conversely, the findings show emergence of several new TV stations which were also disseminating agricultural information to agrienterprises. These TV stations included *Utugi* TV-*Kilimo na Faida*, QTv-*Mkulima ni Ujuzi*, Signet Farmer and Njata TV-*Urimi.* High usage of television to access agricultural information is due to a good number of vernucular stations and appropriate airing time. Further, households were also using radio to access agricultural information. Majority of the respondents (68%) were listening Inooro FM, 30% were listening *Kameme* FM, 11% were listening *Milele* FM while 4.9% were listening to Utugi FM and Citizen FM respectively. Studies conducted by Sife *et al.* (2010) in Tanzania established that dependence on radio by rural people is mostly due to the wide coverage of radio frequencies and availability of many radio stations.

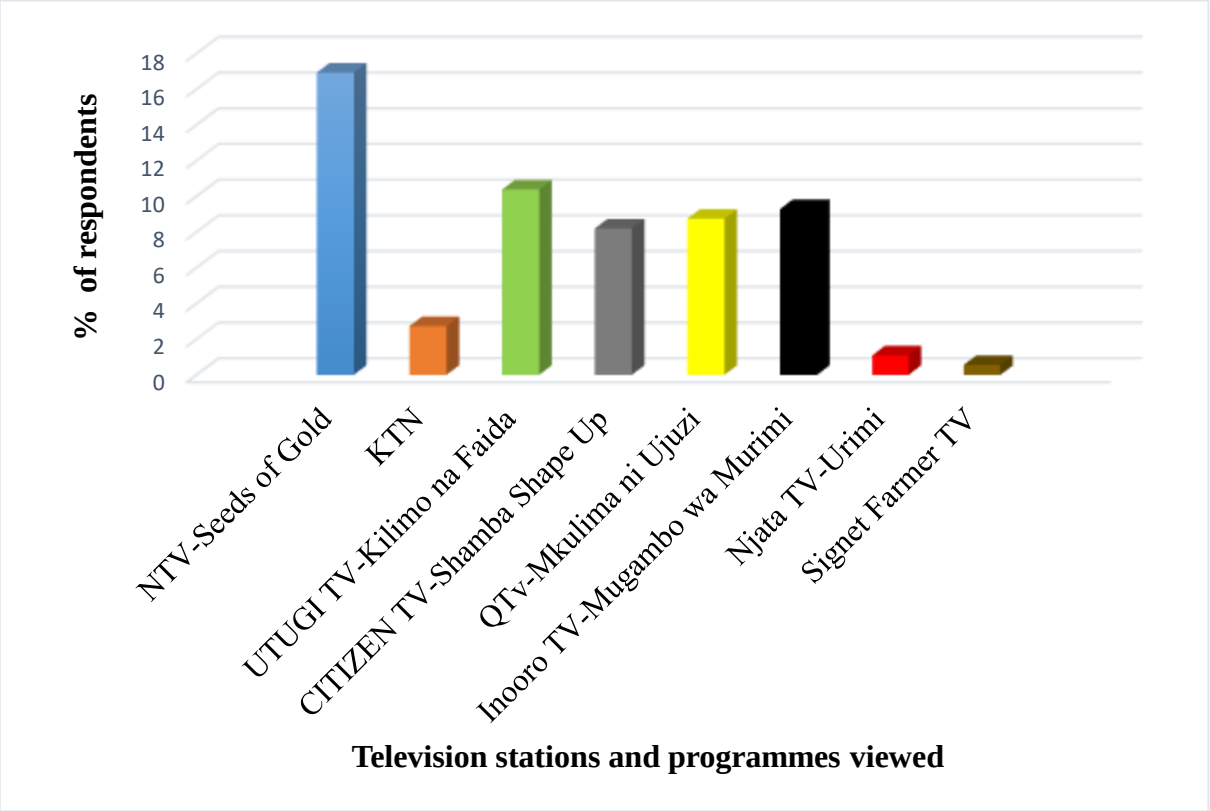

Figure 3. Television stations and programmes disseminating agricultural information

Table 7 shows the main type of information disseminated from mobile phones were market information (67%) and input information (49%). The households consider market and input information as very important agricultural information that can help them secure a reliable market to sell their agricultural produce and gain more income that will help them to improve farming activities and their living standard. These information were disseminated through phone calls and text messages or SMS. The SMS or text message was a low-cost mechanism for disseminating price information that can reach a significant portion of the smallholder farmers. SMS is the one with the versatility to be sustainable for commercial firms that could provide the service, thereby meeting the demand for market prices from Kenyan pineapple farmers.

The respondents were asked other uses of mobile phones apart from accessing agricultural information. Majority of the farmers (47%) used mobile phones to communicate with input suppliers, 36% used mobile phones for mobile banking and money transfer. Conversely, 15% and 6% of the farmers used mobile phones for communication with customers and marketing

of products respectively. The use of mobile phones enables smallholder farmers to market their produce directly to their trusted buyers thus maximizing their profits. Through direct marketing, remote rural-based agribusinesses are able to lower transaction costs and enhance profits by eliminating the middlemen (World Bank, 2002). Also online platforms in which private enterprises such *M-Farm*, *M-Shamba* provides information for a fee to farmers who obtain market, price, crop, and weather information via their mobile phones. In addition, these firms offer farmers the chance to sell their crops collectively and to buy their seed, fertilizers and other inputs by simply using their mobile phones. This business model reduces the burden on the public sector while increasing the abilities of brokers and farmers to profit from information sharing through ICT.

Table 7. Type of information accessed from ICT tools

Type of information	Mobile phone (%)	Television (%)	Radio (%)
Market information	67.2	11.5	21.3
Input information	49.2	9.8	18.6
Weather forecast	15.3	5.5	13.1
Diseases information	19.1	8.2	14.8
Good agricultural practice	14.2	33.9	38.8
Value addition information	5.5	9.3	5.5

On the use of television, majority of the farmers received information on good agricultural practice (33%) and input information (12%). The good agricultural practice disseminated by television included sustainable agriculture techniques to achieve key goals of weed control, pest control, disease control, erosion control and high soil quality to improve productivity of their enterprises. On the use of radio to access agricultural information, good agricultural practice (39%) and input information (21%) were also the main information accessed from radio. Dissemination of input information over the radio meets the requirements for being medium for mass dissemination, with broad coverage of the entire country at a low cost. However, an evaluation of the way the information is received shows that its efficiency depends on whether the person receiving the message is present during the broadcast; otherwise, the message is lost.

4.2.1 Patterns of mobile money usage

Table 8 presents how mobile phone and mobile money was used by the households in 2015 production seasons. In 2015, 97% of all sample households were using mobile money services in their enterprises. The two main mobile money accounts owned by the households were *M-pesa* (94%) and Artel money (6%). The results show Safaricom's *M-pesa*, a mobile money transfer system is the most preferred by the respondents and it has been at the forefront of Kenya's agri-technological innovations. Not only can smallholder farmers make and receive payments for inputs and outputs, but financial institutions, such as banks, SACCOs and microfinance schemes can disburse loans and collect payments. Respondents were asked if they had borrowed money through mobile bank account and 67% had borrowed while 33% had not borrowed. Majority of the respondents (59%) had borrowed from *M-Shwari*, 37% borrowed from Equitel (Equity Bank mobile application), 16% borrowed from Kenya Commercial Bank (KCB) mobile account and 13% borrowed from Co-operative bank mobile account. These findings show how mobile phones are bringing farmers into the formal banking system as was observed by Owuor (2014) on the trajectory of financial inclusion among smallholders in Kenya.

Table 8. Usage of mobile money and mobile banking

Usage of mobile money services	Percentage (%)
Yes	96.7
No	3.3
Mobile money account owned	
M-pesa	94.3
Artel money	5.7
Mobile bank account	
M-Shwari	58.5
Equitel	37.2
KCB mobile account	16.4
Co-op mobile account	12.6

Figure 4 presents the different activities sample households used mobile money services in 2015. Around 67% of the households stated that they borrowed money from their mobile bank account, which may be money from remittances, payments by traders, or also from previous own saving deposits. The major mobile bank account used by the households included *Mshwari,* Equitel, KCB mobi Bank and Coop-mobi bank. Over 50% of the

households stated that they use their mobile money to run their agrienterprises. In addition, 38% and 36% of the households used mobile money to pay school fees and payment of bills such as water and electricity bills. Twenty-three percent used mobile money to specifically purchase farm inputs while 14% transfer money to business partners, such as input dealers or farm laborers. Only 12% of the households saved money in mobile accounts, 4% used mobile money services as a means of transferring money to their formal bank account and 4% also used mobile money services to buy airtime. While the concrete numbers vary, the overall use patterns are similar to those reported in earlier research in Kenya (Mbiti *et al.*, 2011). Especially the payment of bills and school fees. Interestingly, it emerged from the study that households were borrowing money from mobile bank accounts to run agrienterprises. Figure 4 shows the general structure of ICT usage in Kiambu County as par the findings of the study.

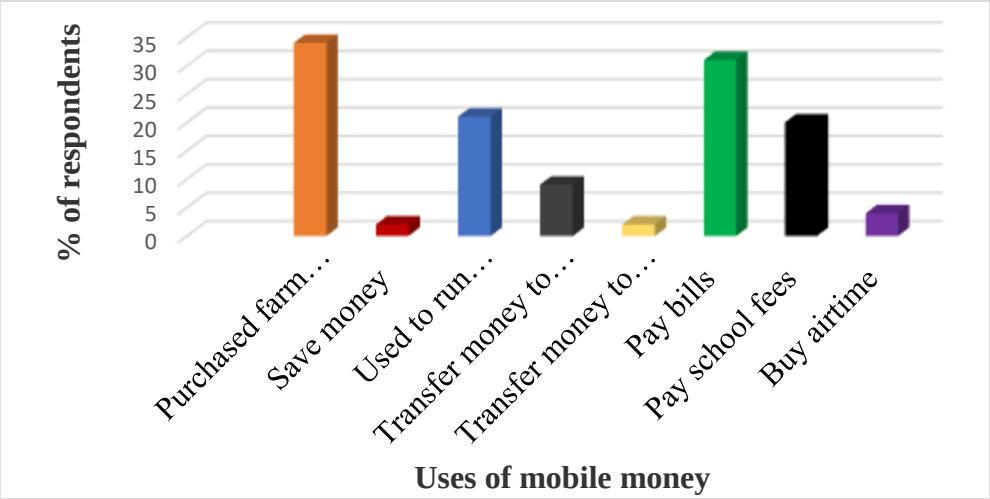

Figure 4. Types of activities performed with mobile money among sample households

Figure 5 presents structure of ICT usage in Gatundu North sub-County. The results shows the majority of smallholder agrienterprises were using the three ICT tools (television, mobile phones and radio).

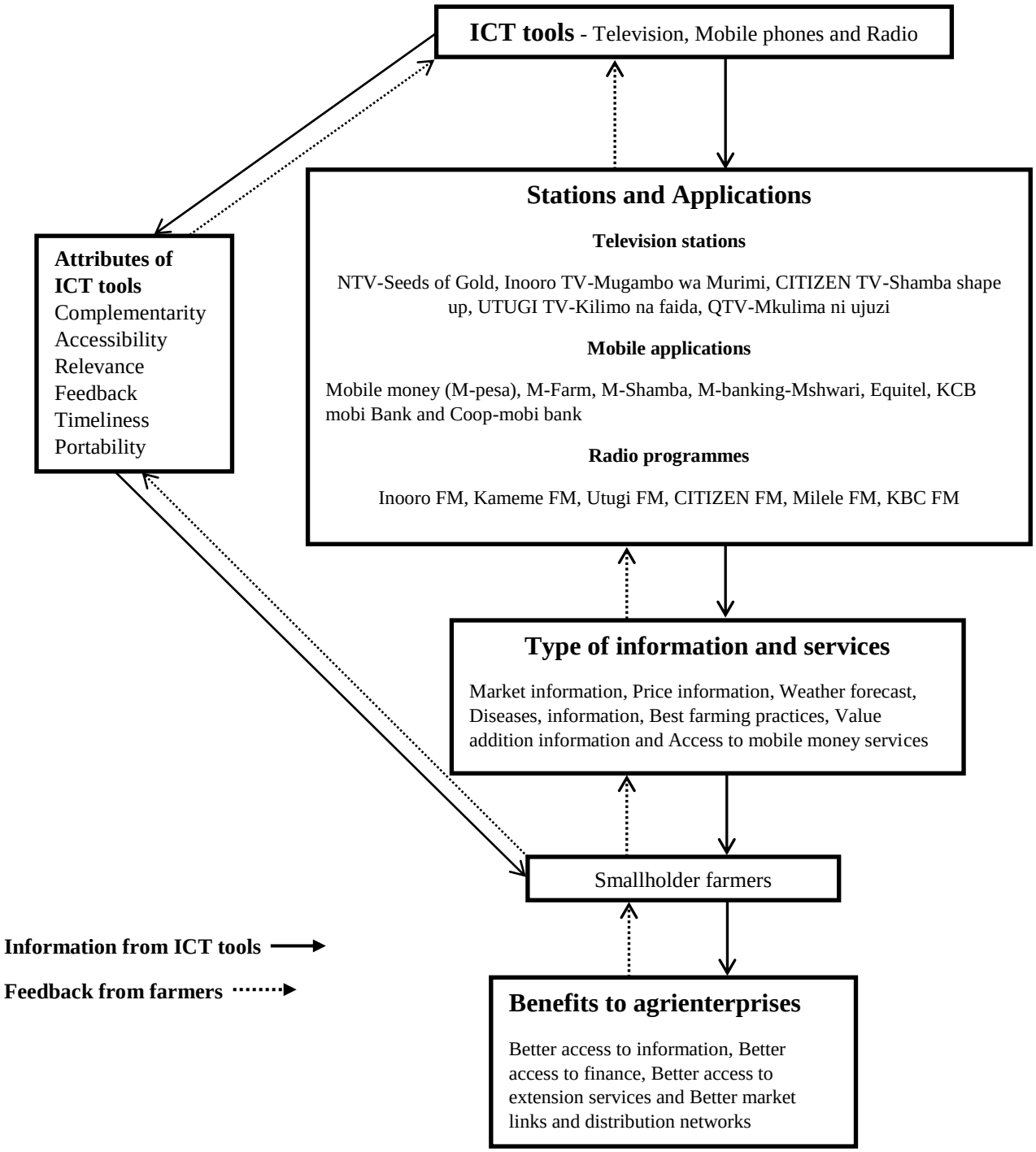

Figure 5. Structure of ICT usage in Gatundu North sub-County

The main television programmes viewed included NTV-Seeds of Gold, Inooro TV-*Mugambo wa Murimi*, CITIZEN TV-*Shamba shape up*, UTUGI TV-Kilimo na faida, QTV-*Mkulima ni ujuzi* while the radio stations that disseminated agricultural information included *Inooro* FM,

Kameme FM, Utugi FM, CITIZEN FM, *Milele* FM, KBC FM. It was also observed that the agrienterprises were using mobile based applications such as Mobile money (*M-pesa*), *M-Farm*, *M-Shamba* and M-banking such as use of *Mshwari*, Equitel, KCB mobi Bank and Coop-mobi bank. The key information and services received from the use of these tools included market information, price information, weather forecast, diseases information, better farming practices, value addition information and access to mobile money services. Due to the use of these information and services, farmers were able to get the following benefits better access to information, finance, extension services and market links and distribution networks. The smallholder farmers preferred the use of these ICT tools due to the following key attributes complementarity, accessibility, relevance, feedback, timeliness and portability.

4.2.2 Smallholder farmers' perception of ICT tools attributes

Table 9 presents the scores of the smallholder agrientrepreneurs perceptions in relation to the attributes of the different ICT tools which were on a scale of 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree and 5 = strongly agree.

Table 9. The average scores of farmers' perceptions of ICT tools attributes

ICT attributes	Radio	Television	Mobile phones
Complementarity	2.5	1.7	4.5
Accessibility	3.6	3.4	3.7
Relevance	2.8	4.2	2.7
Feedback	2.2	1.8	3.9
Timeliness	3.3	3.3	3.7
Portability	3.9	1.2	4.8

Regarding the complementarity of ICT tools, mobile phone had the highest score (4.5). This meant it could easily be combined with other ICT tools to access agricultural information. With regard to easy accessibility of information through the ICT tools, mobile phone and radio had the highest score which were 3.7 and 3.6 respectively. This shows majority of the farmers preferred using these tools to access agricultural information. In relation to the relevance of information disseminated by the ICT tools, television had the highest score (4.2). This meant that the smallholder farmers preferred television because of its attribute of disseminating relevant information which could bring positive changes in their agrienterprises hence performance of their enterprises. This could be because of the broadcasting of agricultural programs that are tailored to the needs of the farmers.

The ability of the ICT tools to give quick feedback to the smallholder farmers is an important attribute. Among the three ICT tools considered, mobile phones had the highest score (3.9) whereas television scored the least (1.8). The findings shows mobile phones offers smallholder farmers and their buyers' one to one communication and quick feedback in relation to agricultural transactions. Moreover, mobile phone had the highest score regarding timeliness and portability attributes which were 3.7 and 4.8 respectively. Overall, mobile phone scored highly with regard to the six attributes of the ICT tools.

4.3 Factors influencing use of ICT tools among smallholder pineapple farmers (multivariate probit estimates)

MVP model was used to determine the factors influencing use of ICT tools among smallholder pineapple farmers. Table 10 shows the pairwise correlation coefficients between the error terms of the three equations of ICT tools usage. All the three pairs of the estimated correlation coefficients were statistically significant from zero implying a strong interdependence among the three ICT tools in usage to access agricultural information.

Table 10. Correlation coefficients for MVP regression equations

	Use TV	Use Radio	Use Phone
Use TV	1.000		
Use Radio	0.367***	1.000	
Use Phone	0.256***	-0.100***	1.000

*** represents significance at 1%

Table 11 presents the MVP model results which revealed significant variables that influenced the use of ICT tools among households. The Wald test $\left[\chi^2(54) = 124.98, \quad p \prec 0.0001\right]$ implied that the data was fit for MVP model and the likelihood ratio test $\left[\chi^2(3) = 36.94, \quad p \prec 0001\right]$ of the independence of multiple usage of various ICT tools was strongly rejected. This indicates that multiple use of different ICT tools among households is not mutually independent.

Table 11. Multivariate probit results for factors influencing use of ICT tools among smallholder pineapple farmers

ICT tools	Mobile phones		Television		Radio	
Variable	Coeff.	Std. Err	Coeff.	Std. Err	Coeff.	Std. Err
Sex (male=1)	0.207	0.423	-0.062	0.276	-0.324	0.263
Age (years)	-0.028*	0.016	-0.027**	0.013	-0.011	0.012
Education (years)	0.144	0.170	0.338***	0.097	0.214**	0.095
Household size (members)	0.373**	0.152	-0.033	0.080	-0.043	0.077
Farm size (acres)	-0.005	0.158	0.291***	0.108	0.213*	0.116
Off farm income (KES)	-0.012	0.431	-0.350	0.264	-0.019	0.241
ICT training (yes=1)	-0.341	0.982	-0.465	0.488	-0.160	0.505
Group membership (yes=1)	1.928***	0.606	-0.219	0.271	-0.256	0.275
Extension contact(number)	0.619	0.613	0.633**	0.271	0.338	0.265
Credit access	0.219	0.467	0.528*	0.271	-0.390	0.277
Distance to market (km)	-0.015	0.018	-0.019*	0.010	-0.017*	0.009
Installed electricity (yes=1)	1.692***	0.532	0.715***	0.249	-0.568**	0.285
ICT related factors						
Complementarity	-0.177	0.297	0.223*	0.120	0.115*	0.088
Accessibility	0.943**	0.369	0.141	0.110	-0.148	0.135
Relevance	-0.113	0.174	0.117	0.098	0.201**	0.123
Feedback	0.579***	0.178	-0.057	0.108	-0.135	0.101
Timeliness	0.675**	0.291	-0.104	0.098	-0.028	0.095
Portability	0.014	0.346	-0.353	0.320	0.215**	0.101
Constant	3.438	2.646	-1.305	0.932	2.387**	1.089
∂ i	-1.094**	0.486	-1.771***	0.280	0.776	0.201
ρ j	-0.798***	0.176	-0.647***	0.163	0.650***	0.116
Lr. Test for indep. Eqns. Rho21=rho31=rho32=0			Chi2(3) = 36.943		prob > chi2 = 0.0000	

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

Age of the key decision maker had a negative effect on mobile phone and television usage with an additional age reducing their usage by 2.8% and 2.7% respectively. These results show that an additional year to the age of the household head is associated with less probability of that household to use mobile phones and television as sources of agricultural information. Older household heads perhaps would be less likely to adopt modern ICT tools such as mobile applications because they would believe that conventional sources of information are still the best. Jenkins *et al.* (2011) and Okello *et al.* (2010) found age had significant influence on usage of modern ICT facilities.

The education level of the household head had significant effect on television and radio usage as sources of agricultural information. An increase in education by one year enhanced

television and radio usage by about 0.34 units and 0.21 units respectively. The results show exposure to education permits an individual farmer to control the rate of message input and develop the ability to store and retrieve information from television and radio usage. Education enables the individual farmers to know how to seek for and apply information on improved farm practices. This is because as the individual gained the ability to read, he is able to extend the scope of his experience through the audio-visual media. This is consistent with results of previous studies which showed education to be a catalyst of modernization by giving the individual access to information through modern technologies (Jenkins *et al.,* 2011).

Household size had a significant and positive effect on mobile phone usage with an additional family member increasing its usage by 37.3%. This could be due to households with large family size are likely to be under pressure to produce more, not only for family consumption but also for sale. The desire to produce more could lead to agricultural information seeking and usage of mobile phones. The findings were in conformity with Sekabira (2012) who found for every one person increase in family size, probability to adopt ICTs-based MIS by traders increased by 3.3%.

Farm size had a significant and positive effect on television and radio usage, with an additional acre increasing their usage by 29.1% and 21.3%, respectively. Therefore, farmers with larger land size are more likely to produce more leading to higher income. The higher income and desire to produce more could lead to agricultural information seeking through usage of television and radio. Olaleye *et al.* (2009) also found that increase in farm size increases the probability of a household in using agricultural technologies.

Group membership had a positive significant effect on use of mobile phones. The probability of using mobile phones as a source of information and for agricultural purposes is positive and significantly affected by a households' participation in a rural groups. Membership to group was expected a priori to contribute positively on ICT tools usage due to access and sharing of information among the members even without physical meeting. This is because farmers find it convenient to use mobile phone to share information, particularly if they are far apart. Further, this could be due to the relatively cheaper cost of calling and short media short message service (SMS). Barret (2008) found group membership influences farmers in the usage of modern technologies. With scarce or inadequate information sources and

imperfect markets, groups such as traders and farmers' groups facilitate the exchange of information, and enable farmers to access inputs on schedule and overcome credit constraints.

The number of contact with extension service providers was significant and had a positive effect on usage of television as a source of agricultural information. An increase in extension contact by one enhanced television usage by 63%. Extension agents popularizes innovation by making farmers exchange ideas, experiences and makes it cheaper to source information. During survey, it was observed that farmers who had frequent contacts with extension agents had a higher probability of using television as a source of information. This is especially the fact that staff of some local television stations such as *Inooro* TV, *Njata* TV and *Utugi* TV were visiting farmers and offering them one to one extension services and encourage them to watch agricultural programmes they broadcast. Hence, farmers who are regularly visited by extension workers and those who attended field days were likely to use television as source of agricultural information due to their increased exposure and awareness. Mwaura *et al.* (2014) found that extension services helps farmers to adopt modern agricultural technologies, since it makes them aware of the availability and benefits of these technologies and their inherent characteristics.

Access to credit was significant and had a positive effect on television usage with an additional access to credit increasing its usage by 53%. It was observed that the move to digital broadcasting from analogue broadcasting brought several challenges to rural community in accessing agricultural information through television. Majority of rural farmers were not able to buy the digital set-top boxes thereby hindering them to use television as a source of agricultural information. Feder *et al.* (1990) found that household heads that have access to credit increases their likelihood of using modern ICT tools.

Distance to the nearest market place determines the ease at which commodities are accessible to consumers. This variable was significant and had a negative effect on television and radio usage with an additional distance to output market reducing the use of television and radio by 1.9% and 1.7% for a kilometer increase. This variable was found to be statistically different at 10% significance level. This was intriguing since distance to the nearest market, was expected to play an imperative role in increasing the likelihood of households in using ICT tools to access agricultural information. This is possibly due to smallholder farmers were mainly interested in making more profits, therefore they could not be interested in accessing information or marketing their produce through expensive ICT tools. Further, they would

prefer selling their produce at farm gate which is cheaper than incur cost of using ICT tools in marketing. Sekabira (2012) found that with increasing distance to town centers farmers were less likely to use expensive ICT tools to market their produce.

Household electricity installation was significant and had a positive effect on usage of mobile phones and television but negative effect on use of radio as a source of agricultural information. Farmers who had installed electricity at their homes had a higher probability of using mobile phones and television by proportion of 1.69 and 0.72 respectively. However, it was unexpectedly observed installation of electricity reduced use of radio by 1.7%. This can be due to farmers have been using it for a number of years without the dependence of electricity because they could manage to buy dry cells. Electricity for powering ICT tools is the primary constraint to using ICT in their agrienterprises. Although generators and dry cells can be used as alternative sources of power, these alternatives were found to expensive and unaffordable by the rural majority of poor rural farmers. Since access to television requires electricity, it is difficult for the farmers to access information through this information communication tool. Samuel *et al.* (2005) found a positive correlation between mobile phones and television ownership and access to electricity. This is possibly because ICT tools are electricity dependent.

The ICT tools could be combined in different ways to deliver agricultural information. Such as some individuals would prefer combination of television and radio usage, mobile phones and radio usage, television and mobile usage or mobile phone and television usage. The different ways in which the ICT tools were combined was known as complementarity of the ICTs tools. This variable was significant and had a positive effect on use of television and radio by a proportion of 0.22 and 1.12 respectively. Complementary between television and radio has always been observed where radio and television stations are broadcasting same programs at different times. During a focus group discussion it was observed that Citizen TV-*Shamba Shape* and *Inooro* TV-*Mugambo wa Murimi*, were repeating the programmes they had broadcasted in their radio stations. This enabled farmers to have a chance to listen to their radio and those with TV sets can listen and watch directly. The television program were held in the afternoon and radio repeated the same program/content in the evening. This allowed one ICT to supplement another ICT in terms of utilization of the content. These results can be supported from some earlier studies which had shown that radio and television operate in complementary manner with television showing the same program in the evening hours whereas radio in the early hours of the day (Dia, 2002).

Accessibility of information through the ICT tool had significant and positive effect on mobile phone usage with an increase in accessibility leading to increase in usage by a proportion of 0.94. Mobile phone offers easy accessibility of information to the users. Majority of the respondents (86%) were using mobile phones to access agricultural information. Hence there was widespread use of mobile phones by farmers in Gatundu North sub-County during information exchange which was very useful to both parties in improving the agricultural activities. Farmers were mainly accessing market information (67%) and price information (49%) through phone calls and text messages or SMS. The SMS or text message was a low-cost mechanism for disseminating price information that could reach a significant portion of the smallholder farmers. These findings are consistent with previous findings which indicated usage of mobile phones increased accessibility of information thereby led to agrienterprises development (Jensen, 2007; Kwadwo and Ayalew, 2011).

The ability to bring changes in agrienterprises is the indicator used in this study to measure relevance of agricultural information conveyed to farmers through ICTs. Relevance of the ICT tool had significant and positive effect on radio use with an increase in relevance leading to increase in use of radio by a proportion of 0.20. Availability and use of radio in delivering agricultural information help farmers to improve production with quality in order to acquire more profit. It was observed that 79% of the respondents were using radio to access agricultural information. It was also found that radio was one of the effective ICT tool of communicating agricultural messages such as technologies and best practices that can help farmers improve production. This was achieved through different programs like radio forums tailored to local communities. The information provided by radio can easily be understood by all the farmers as most of the radio programs are in Gikuyu and Kiswahili language which is spoken by almost all the respondents. There are different innovations made on the different radio programs which have contributed to its increasing relevance. For example radio Inooro FM through a program called '*Mugambo Wa Murimii*' involves both experts and the local people in development of content such as various methods of adding value to products as well as improving crop productivity. Djankov *et al.* (2001) found that independent radio broadcasting services have been found to be positive about agrienterprises development.

The ability for the ICT tools to give quick feedback to the respondents was significant and had positive effect of use of mobile phones. An increase in this attribute by one enhanced

mobile phone usage by proportion of about 0.58. The findings suggest that mobile phones offer farmers, suppliers and buyers with ability to have one to one communication and there is easy follow up when conducting agricultural transactions. Presence of the mobile phone makes it easier for smallholder farmers to communicate with their customers by informing them on the availability and quantities of agricultural produce especially pineapples which is the major cash crop in the area. Through this communication, the real tradable quantities of produce were ascertained and farmers were able to mobilize themselves to bulk their produce and sell as a group. Phones also enabled farmers to know the prevailing market prices of agricultural commodities in various markets in study area and elsewhere, which enabled them to negotiate and sell produce at competitive prices. Study by de Silva (2008) assert that mobile phones ability for quick feedback can facilitate a greater export orientation in agricultural practices and marketing, potentially bringing higher incomes for farmers.

The farmer perception on the timeliness of ICT tools was significant and positive effect on mobile phone use with an increase in timeliness leading to increase in use of mobile phone by a proportion of 0.68. Timeliness of agricultural information is very crucial to farmers' success and agrienterprises development. Farmers need to be provided with the information at the right time so as to apply that information in their farming activities for better farm productivity. It is clearly from the results that mobile phones offer timely information and farmers prefer using this tool because they find it easy to move with because they are light and thus can access the information at their time of convenience at home or on their farms. They can also seek the information when they need it. The farmers usually use mobile phones to communicate with a friend or an expert at right time or using programs from mobile service providers such as *M-Farm* and *M-Shamba*. Mittal *et al.* (2010), argued out that timeliness is one of the important features that enable farmers to use mobile-enabled agricultural information effectively.

The ability move easily from place to another using the ICT tool was considered as ICT tool portability. This variable was significant and positive effect on radio use with an increase in portability leading to increase in use of radio by a proportion of 0.22. The results show portability of radio makes it to have more strength as a medium of communication since it is cost effective in terms of usage among smallholder agrienterprises. Further, radio has been proved as the important tool for the enhancement of agriculture in the rural area. Therefore, farmers prefer this tool because they can move with it and it can give them an opportunity to interact with each other and other relevant authorities such as extension workers, crop and

animal experts through format like live talk shows, phone in programs and radio stations visiting them in the farms. The findings were in conformity with Shephard (2000), who found the strength of radio as the medium of communication is its portability nature.

4.4 Effect of ICT Use on Performance Agrienterprises

4.4.1 Gross Margin Analysis

Gross margin analysis was done to provide a comparison of the net returns between the optimal and sub-optimal users and the results are presented in Table 12. The mean prices were KES. 554 and KES. 536 per dozen of pineapples for optimal and sub-optimal users, respectively. The price differences between the two groups were statistically significant at 1% significance level. Optimal users therefore fetch a higher average price per dozen than sub-optimal users. This may be attributed to better market visibility due to use of ICT tools, better communication with buyers, market timing, and selling to regular markets among other advantages. The mean yields were 289 dozen/acre and 217 dozen/acre for optimal and sub-optimal users, respectively. The yield differences between the two groups were statistically significant at 5% significance level. Thus the optimal users' yields were higher than sub-optimal users possibly because with improved income, the farmer will be better disposed to spend more on recommended farm practices that would further increase his farm earnings. ICT tools also improve market transparency and reduce transaction costs thus improving market access for small-scale farmers thereby increasing their farm income.

The mean variable costs were KES. 29, 917 per acre and KES. 23,287 per acre for optimal and sub-optimal users, respectively. The optimal users had higher mean variable costs possibly because they were using better seeds which were more expensive. The variable costs differences between the two groups were statistically significant at 1% significance level. The bulk of viable costs for the two groups, was taken by seed costs which averaged KES. 18,942 per acre and KES. 12,945 per acre for optimal and sub-optimal users respectively. The mean gross margins were KES. 128,389/acre and KES. 92,455/acre for optimal and sub-optimal users respectively. The differences between the gross margins were statistically significant, at 10% significance level. This means that the use of ICT tools helps farmers to increase their incomes in their agrienterprises. These results are consistent with various past studies which found that usage of ICT tools increases market access of smallholder farmers which leads to increase in returns from agricultural production (Ali *et al*., 2010).

Table 12. Gross margin differences between ICT optimal users and sub-optimal users

Variables	Optimal users (N =93)		Sub-optimal users (N = 90)		*t*-value
	Mean	SD	Mean	SD	
Price (KES/dozen)	554	47	536	49	-2.5999***
Yield (dozen/acre)	289	313	217	166	-1.9261**
Gross revenue (KES/acre)	158,305	170,552	115,743	87,335	-2.114**
Seed cost (KES/acre)	18,942	14,422	12,945	87,335	-3.2981***
Total labour cost (KES/acre)	5,844	3,107	5,369	3,544	-0.965
Fertilizer cost (KES/acre)	4,216	3,430	4,205	3,041	-0.022
Other cost (KES/acre)	915	405	768	342	-2.636***
Total variable cost (KES/acre)	29,917	17,499	23,287	14,205	-2.808***
Gross margin (KES/acre)	128,389	165,040	92,456	77,451	-1.875*

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

4.4.2 Estimation of Effect of ICT use on performance of agrienterprises

To determine the effect of ICT use on the performance of agrienterprises (measured as income from pineapple farming), the endogenous switching regression model was used for analysis. The income equations were estimated jointly with the selection equation that explains farmers' usage of ICT tools. Diagnostic tests confirmed that the estimated coefficients of the three instrumental variables (ICT training, agricultural training and ICT affordability) were jointly insignificant (F3, 2456, p-value= 0.431) in the income equation while they are in fact individually significant in the ICT use equation. This supports their use to identify the outcome equations since they do not affect household income directly. The likelihood-ratio test for the joint independence of the equations was significant in both groups. The Wald test $\left[\chi^2(11) = 34.35, \quad p \prec 0.001\right]$ also indicated a joint significance of the instruments excluded helping in testing the hypothesis of weak instruments. Hemce, we fail to reject the hypothesis of weak instruments. Estimation results of the endogenous switching regression model for ICT use are presented in Table 13.

Table 13 column (1) presents the estimated coefficients of the selection equation on determinants of ICT use. Use of ICT tools significantly depends on the level of education and age of the farmer. Better educated farmers are more likely to use ICT tools in their agrienterprises. This is plausible, because education helps farmers to better adjust to the modern agricultural technologies. In general, better educated farmers tend to be more innovative and therefore more likely to use ICT tools to access agricultural information

(Okello *et al.,* 2010). Young farmers are also more likely to use ICT tools, which is probably related to them being highly innovative and more enterprising.

Farm size has a positive and significant influence on ICT use. Households with bigger land size have higher chance to take up an additional agrienterprises or increase acreage under production. Larger farmers are at a certain advantage, which may be due to fixed transaction costs, such as transportation and information search costs. This may lead to high production which may trigger them to adopt and use ICT tools to search for markets for their produce. This is supported by Olaleye *et al.* (2009) who observed resource rich farmers depended on mobile phones, radio and television as sources of information and market access. Farmers who are engaged in off-farm employment are more likely to ICT tools. This could be due to certain capital investments necessary for purchasing the ICT tools, which are facilitated through off-farm earnings, especially when there are credit constraints. Furthermore, off-farm income helps to ensure short-term liquidity against the background of lagged payment schedules.

In a similar fashion, household electricity installation increase the likelihood of ICT use. This is plausible because – unless there is electricity to power ICT tools, farmers are not able to use these tools in their agrienterprises. Electricity for powering ICT tools is the primary constraint to using ICT in their agrienterprises. These results underscore that infrastructure, which is key for linking farmers to markets in general, is equally important in the context of emerging modern technologies. Samuel *et al*. (2003) argued that, despite the positive effects associated with the use of ICTs tools for enhancing livelihood opportunities, electric power and cost are hindering factors.

Extension contacts and group membership had positive and significant influence on ICT use. Extension service and group membership can be powerful tools that can be used to transfer new technologies to farmers and means of fixing challenges in the agrienterprises through information sharing. It would be expected thus that the more enhanced access to extension services, the higher the probability to use ICT tools in agrienterprises (Mwaura *et al.,* 2014). Group membership is also an important factor influencing use of ICT tools hence it is important that if farmers are to be introduced to new technologies, the promotion needs to be done in farmer groups. Finally, ICT training, agricultural training and ICT affordability had positive and significant influence on ICT use. Training empowers farmers by helping them to gain skills and knowledge which facilitates them to access better technologies and acquisition

of farm inputs. Through trainings and affordability of ICT tools, household heads are able to purchase and use ICT tools in the agrienterprises.

Columns (2) and (3) presents results of the outcome equations (household income) for optimal users and sub-optimal users respectively. To properly identify the model, three variables in the probit model – namely ICT training, agricultural training and ICT affordability – are excluded from the income function. It was tested that these variables did not affect household income directly.

Farm size and household electricity installation had a positive and significant influence on household income in both groups. Farm size is a proxy to production scale. When the land size is large, the production scale is also large and vice versa. Large production scale positively influences the farmer to sell their produce at market place mainly because of economies of scale which lower transaction cost (Sigei *et al.,* 2014). Household installation of electricity suggests that electric power is a very important factor in agrienterprises since majority of modern technologies needs electricity accesses.

Household size influenced income positively and significantly only for sub-optimal users. For every one person increase in family size, household income increased by 5.5%. Due to rural to urban migration, different members of households can use ICT tools to send money through mobile money transfers. Households with many relatives in towns have high remittances through mobile money transfers which leads to increase in income. Extension contacts had a positive and significant effect on household income of both optimal users and sub-optimal users. This meant that, additional visit from extension workers would increase household income for both optimal and sub-optimal users by 9% and 10.6% respectively. This suggests access to extension services helps farmers to fix challenges which hinder performance of agrienterprises thus would lead to increase in agricultural income.

Table 13. Full information maximum likelihood estimates of the endogenous switching regression for ICT usage

		Endogenous switching Regression	
Model		Optimal users=1	Sub-optimal users=0
Dependent variables	Selection equation	Log of pineapple income per acre	Log of crop income per acre
Age	-0.052 ***	0.008	-0.002
	(0.016)	(0.008)	(0.004)
Gender	0.182	-0.150	-0.0755
	(0.284)	(0.111)	(0.093)
Education	0.386***	-0.017	-0.026
	(0.118)	(0.057)	(0.039)
Household size	-0.018	0.040	0.055**
	(0.090)	(0.037)	(0.028)
Farm size	0.429***	0.212***	0.724***
	(0.116)	(0.047)	(0.046)
Occupation	0.440***	0.015	0.084*
	(0.152)	(0.055)	(0.050)
Distance to output market	-0.001	-0.007	-0.004
	(0.012)	(0.004)	(0.004)
Installed electricity	0.500*	0.319**	0.310***
	(0.293)	(0.159)	(0.099)
Access to credit	0.261	0.012	-0.084
	(0.294)	(0.152)	(0.101)
Extension contacts	0.819***	0.090*	0.106*
	(0.273)	(0.051)	(0.061)
Group membership	0.405***	-0.071	0.023
	(0.273)	(0.141)	(0.096)
ICT training	1.149**		
	(0.513)		
Agricultural training	0.507*		
	(0.266)		
ICT affordability	0.221*		
	(0.293)		
Constant	-0.114	11.653***	12.011***
	(1.020)	(0.454)	(.349)
∂_i		0.492	0.405
		(0.042)	(0.043)
ρ_j		-0.343***	0.680***
		(0.327)	(0.240)
LR test of independent. eqns. :	rho 1 = rho 0	chi2(1) = 3.70	Prob > chi2 = 0.0546**

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

The last two rows under endogenous switching regression results in table 13 show estimated correlation coefficients ρ_j for optimal users and sub-optimal users of ICT tools and are both not statistically different from zero. Therefore, even if it were unknown a priori, this

implies that the null hypothesis of absence of sample selectivity bias may not be rejected. As expected, results of the outcome equations (last two columns of table 13 suggest that many factors significantly affect the pineapple incomes for both optimal users and sub-optimal users of ICT tools. It is found that field size, installation of electricity and extension contacts positively and significantly influenced expected pineapples incomes per acre for both groups. Furthermore, household size and occupation of the household head was found to positively affect expected crop incomes per acre for sub-optimal users.

Table 14. Conditional Expectations, Treatment, and Heterogeneity

Sub-samples	Decision stage		Treatment effects
	Optimal users (N=93)	Sub-optimal users (N =90)	
Optimal users	a) 11.54	c) 10.56	**TT** = 0.98***
Sub-optimal users	d) 11.41	b) 11.13	**TU** = 0.28***
Heterogeneity effects	$\mathbf{BH_1}$ = 0.13	$\mathbf{BH_2}$ = -0.57	**TH** = 0.70

***Significant at 1%.

Table 14 presents the expected results of pineapples incomes for both smallholder farm households that were optimal users and sub-optimal users of ICT tools in Gatundu North County. Cells (a) and (b) represent observed outcomes for optimal users and sub-optimal users of ICT tools respectively. Case (c) represents the income outcome for optimal users would realize if they had decided not to use ICT tools while cell (d) represents the income outcome for sub-optimal users would realize if they had decided to use ICT tools.

From the results (Table 14) the observed outcomes of optimal users and sub-optimal users of ICT tools are 11.54 and 11.13 respectively. Comparison of the observed outcomes for the optimal users and sub-optimal users of ICT tools would mean that optimal users would realize 41 percent more pineapple incomes than sub-optimal users (case (a) minus case (b). Doing so would be erroneous because these groups have unobserved heterogeneous characteristics between them. From the last column of Table 14, comparing (a) and (c), clearly shows smallholder farm households that were optimal users would have had a significantly lower counterfactual income levels had they not used ICT tools. Conversely, the

treatment (ICT use) has increased expected income by 0.98. On the other hand, sub-optimal users would have increased the expected income by 0.28 if they had used ICT tools.

The last row of table 14 adjusts for potential heterogeneity effects between the optimal users and sub-optimal users of ICT tools. If sub-optimal users of ICT tools had decided to be optimal users, they would be expected to have realized lower crop income per acre by 13 percent than the optimal users. This implies that smallholder farm households that were optimal users of ICT tools would still be better off compared to sub-optimal users of ICT. This implies that perhaps new optimal users would have to get established in order to have similar returns as their counterparts. Column (2) shows that if optimal users of ICT tools had decided to be sub-optimal users, they would be expected to realize lower crop income per acre by 57 percent than sub-optimal users. Transitional heterogeneity is 70 percent implying that optimal users of ICT tools are expected to have more pineapple income per acre, the reason being that there are important sources of heterogeneity (for example information access and farming skills and in) within them that enable them realize more crop income per acre than their counterparts. The findings are in conformity with previous studies results (Negash *et al.*, 2013; Sekabira, 2012) that indicated that smallholder farmers with low net returns, have low usage of ICT tools compared to those with higher net returns.

CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

The overall objective of this study was to determine the effect of ICT use on performance of agrienterprises farm household incomes in Gatundu North sub-County. The specific objectives of the study included; to characterize structure of ICT usage among smallholder pineapple agrienterprises, to determine factors influencing use of ICT among smallholder pineapple agrienterprises and to determine the effect of ICT use on income of smallholder pineapple agrienterprises. To achieve these objectives, data was collected through the use of questionnaire. Furthermore, to estimate the effect of ICT use, a simultaneous equations model with endogenous switching to account for unobservable factors that influence household incomes and the decision to use ICT tools was employed. The following are the key conclusions of the study according to the objectives.

The first objective of this study was to determine the structure of ICT usage among smallholder pineapple agrienterprises and the results of the study show the main ICT tool used to access agricultural information was mobile phone, followed by radio then television. Despite television being the least preferred ICT tool, the rise of many agriculture related television programmes has promoted dissemination of agricultural information to agrienterprises in the county. The main information accessed from these ICT tools were market information, price information and best farming practices. Further, the results show usage of mobile phones has facilitated financial inclusion of smallholder farmers through the use of mobile money transfers such as *M-pesa*. Farmers are also able to access loans through mobile bank accounts such as *Mshwari*, Equitel, KBC Mobi Cash and Co-op Mobi Cash.

In relation to factors influencing usage of ICT tools, it can be concluded that age, distance to market negatively influenced the probability of usage of these tools while education, household size, farm size, group membership, extension contact, credit access and installation of electricity positively influenced the probability of usage of ICT tools. While among the ICT attributes, results show complementarity, accessibility, relevance, feedback, timeliness and portability positively influenced the probability of usage of Mobile phones, Television and Radio. The key attributes that positively influenced use of mobile phones were accessibility, feedback and timeliness while complementarity, relevance and portability positively influenced the use of radio. However, only complementarity positively influenced

the use of television. This rises policy concern on importance of ICT attributes in dissemination of agricultural information. This is because some agricultural technologies are complicated, hence there is need to disseminate these information in a manner that agrientrepreneurs can be able to understand and apply the knowledge in their agrienterprises.

Finally, the findings on effect of ICT use indicates both optimal users and sub-optimal users would realize more household income per acre had both decided to use ICT tools than they would if they had not used them. However, a comparison between the two groups of households showed that smallholder farm households that were optimal users would realize more crop income per acre than sub-optimal users had they both used the ICT tools. Had both not used ICT sub-optimal users would realize more household incomes per acre than the optimal users. This proves existence of unobserved heterogeneity characteristics such as farming skills between the two groups of farmers. Hence it can be concluded that use of ICT leads to increase in income of smallholder farmers' agrienterprises.

5.2 Recommendations

The public and private extension agents should consider age and education level of smallholder farmers when developing ICT tools to be used to disseminate agricultural information. Findings were that households with younger and highly educated chief decision makers were more likely to use ICT tools in their agrienterprises. Therefore, it is imperative to do proper planning and thorough need assessment when coming up with different programs that involve radio, television and mobile phone in provision of agricultural information to farmers by considering age and education level. These will ensure farmers are getting relevant, timely and the right type of ICT tool is used to a particular group of farmers.

Contacts with extension agents and membership to group was found to significantly influence usage of ICT tools in agrienterprises. These findings underpin the importance of encouraging re-investment in agricultural extension services through use of ICT tools and need for strengthening farmers groups which could provide avenues for attitude and perception change while engineering information and knowledge transfer important for adoption of new agricultural technologies in agrienterprises. Also there is need to sensitize the smallholder farmers regarding modern ICTs tools which can help them in the development of agrienterprises such as the mobile phone applications (*M-Farm, M-shamba, M-soko*). The sensitization will increase awareness and accessing of information using them for their farming activities.

There is need to enhance rural electrification in order to increase usage of ICT tools in agrienterprises. Therefore, policy makers should focus on infrastructural developments by ensuring smallholder farmers have access to electricity which will help them to use ICT tools in their farms. Hence for farmers to benefit from positive effects associated with the use of ICTs tools such as enhancing livelihood opportunities and market access, electric power has to be provided at minimal cost.

Lastly, both private and public information providers through ICT tools should keenly consider the different attributes of ICT tools (complementarity, accessibility, relevance, feedback timeliness and portability) which influence their usage in agrienterprises. This will ensure smallholder farmers get the right information and at the right time which can help in improving the performance of their agrienterprises.

5.3 Further research

This study only focused on three ICT tools (mobile phones, radio and television), from the results, it emerged that some farmers were using mobile applications such as *M-farm* and *M-Shamba* while others were not using. Therefore, there is need to undertake a study on effect of mobile applications on performance of agrienterprises. In addition, since the study found that ICT tools were effective in delivering agricultural information to smallholder farmers, therefore another study can be conducted to assess the relationship between technology use and agripreneurship.

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APPENDICES

APPENDIX 1: QUESTIONNAIRE

The purpose of this study is to assess the **Effect of ICT use on performance of Pineapple Agri-enterprises in Kiambu County.** You have been identified as a useful informant to assist us (Egerton University) to achieve this mission. Your participation is voluntary and you are assured that the information you provide will be treated with confidentiality and used for the sole purpose of research. Kindly respond to the queries below. If you need more writing space you can attach more paper.

Questionnaire identification

Questionnaire Number _____

Sub-County _____ Ward _____

Name of Enumerator_____

Name of Respondent_____

Date_____ Starting time_____ Finishing time_____

A: DEMOGRAPHIC INFORMATION

A1: **Provide the following details about the household head**

Gender 1 = Male 2 = Female	Age (years)	Highest education level (years)	Three primary livelihood source
[___]	[__ _]	[___]	First [___] Second [___] Third [___]

Livelihood
1 = Livestock keeping 2= Crop production 3= Permanent employment 4= Business 5= Temporary employment 6= Remittances

Education Level
1=No formal education 2= Adult education 3= Primary education 4= Secondary education 5= College education 6= University education

A2: **Provide the following details about the household size**

Number of people that usually live in the household	Number of children attending school
Male [__] Females [__] Total [___]	Males [__] Females [__]

SECTION B: PRODUCTION RESOURCES

B1: What total land size in acres that is:

1. Total owned [___] 2. Renting out [___ _] 3. Renting in [___ ___]

4. Under pineapple [___] 5. Under other crops [_____]

B2: Variable costs

a) Please provide information on the main variable costs you incur in your agrienterprise?

No	Type of variable cost	Unit of measurement	Quantity used	Price per specified unit (KES)	Transport cost per unit of inputs (KES)	Total cost per unit of inputs
	Seeds	Kg				
	Seedlings	Number				
	Land preparation	Man-days				
	Planting	Man-days				
	Fertilizer	Kg/lt				
	Manure	Kg/lt				
	Fungicides	Kg/lt				
	Insecticides	Kg/lt				
	Weeding	Man-days				
	Harvesting	Man-days				
	Transportation	Large box				
	Other (specify)					

SECTION C: PINEAPPLES YIELD LEVELS

C1: How long have you been growing and selling pineapples? .....

C2: How often do you harvest your pineapples? ..... (weekly, monthly)

C3: What was your yield per harvest in the last month harvest? …… (Number of dozen)

C4: What was the price of pineapples per dozen in the last month harvest (*in Ksh*)?

……

C5: What is the distance to the nearest shopping centre/market and how much do you spend if you travel by matatu?

i. Distance……..km

ii. Transportation cost Ksh…….

iii. What is the state of the road to the market?

1= Tarmac ☐ 2= Murrum ☐ 3= Other (specify)…….

C6: What was the estimated amount of income in your enterprise for the last season (*in Ksh*)?

a) From farm production Ksh …….

b) From off-farm Ksh ……

c) Total income (a + b) Ksh ……

C7: Apart from fruit production, which other agri-enterprises do you have on your farm?.....

1 = Vegetables 2 = Dairy 3 =Poultry 4 = Others, Specify……..

SECTION D: STRUCTURE OF ICT USE

D1: Do you have a mobile phone? **[If no skip to D5]**

1) Yes [__ _] 2) No [__ _]

D2: Use of mobile phone

Do you access agricultural information from your mobile phone?	What kind of information do you access from your mobile phone?
1. Yes [__ _] 2. No [__ _]	1. Market information [__ _] 2. Price information [__ _] 3. Weather forecast [__ _] 4. Diseases information [__ _] 5. Best farming practices [__ _] 6. Others (Specify)……

D3: Apart from accessing agricultural information from your mobile phone, how else do you use mobile phones?

1. Communication with input suppliers
2. Communication with customers

3. Marketing of products (e-commerce)
4. Mobile banking and money transfer (M-pesa)
5. Others (Specify) ……..

D4: Mobile money services

a) Do you use mobile money services in your business? **[If no skip to D5]**

1) Yes [__ _] 2) No [__ _]

b) Do you own a mobile money account (registered with mobile money)?

1) Yes [__ _] 2) No [__ _]

c) Which mobile money account does hhold own? MMA_____

1= M-Pesa 2 = Airtel Money 3 = Orange Money 4= Other (specify)……

NOTE: If more than one account, obtain answers for the mostly actively used account

d) In which year was this account opened? _____

e) How many times did you receive money via the mobile money from your buyers during the last 12 months? _____

1 = Once 2 = Twice 3 = Thrice 4 = Four times 5 = Five and above

f) On average how much did you receive for each transactions via mobile money? _____Ksh

g) How many times did you send money or make payment via the mobile money during the last 12 months? _____

1 = Once 2 = Twice 3 = Thrice 4 = Four times 5 = Five and above

h) On average how much did you send for each transaction via mobile money? SEN _____Ksh

D4: Mobile bank account credit access

a) Do you have access and use to mobile bank account credit facilities? **[If no skip to D5]**

1) Yes [__ _] 2) No [__ _]

b) Have you ever borrowed money to use in the farming business? 1) Yes [__ _] 2) No [__ _]

c) If yes, name the source of the credit and the amount outstanding by 1/3/2016?

Source of credit…… Amount outstanding…….

Source of credit
1 = Mshwari 2= Equitel 3= KCB mobile money 4= Others (specify)……

d) Which activities did this household perform with mobile money?
AC1_____AC2_____AC3_____AC4_____AC5_____

1=Purchased farm inputs 2= Save money 3=Used to run agrienterprise
4=Transfer money to business partners 5=Transfer money to own bank account
6=Pay bills 7=Pay school fees 8=Buy airtime 9=Other specify……..

D5: USE OF TELEVISION (TV)

a) Do you own a TV? **[If no skip to D6]**

1) Yes [__ _] 2) No [__ _]

If yes, do you use your TV to access agricultural information?

1) Yes [__ _] 2) No [__ _]

b) If yes, how often do use your TV to access agricultural information?

1. Regularly
2. Occasionally
3. Rarely
4. Never

c) Explain the type of agricultural information you access from watching TV programmes?

……
……

d) Which agricultural programmes do you watch?

Agricultural progamme	Tv station
Seeds of gold	
Shamba shape up	
The entrepreneur	
Others (specify)……..	

e) In your own opinion, do you think the information provided by the TV programmes help in improving the performance of your agribusiness?

1) Yes [__ _] 2) No [__ _]

Explain……
……..

…….

D6: USE OF RADIO

a) Do you own a radio? **[If no skip to E1]**

1) Yes [__ _] 2) No [__ _]

b) Do you listen to information on agriculture from the radio?

1) Yes [__ _] 2) No [__ _]

If yes, which kind of information do you access from radio?
……
…

c) Which radio station do you use to access agricultural information?

……
…

d) Why do you prefer to listen to the radio? (Select more than one if necessary).

1. Able to listen to best agricultural practices
2. Able to get market prices for agricultural products
3. Affordable/cost
4. Vernacular Language
5. Effective Interact with programme' presenters through phone
6. Portability
7. No training is required in accessing
8. Others specify ……..

e) How often does the radio present programs on agriculture that you listen to?

1. Regularly
2. Occasionally
3. Rarely
4. Never

f) Do you think agricultural information aired in the radio programmes help in improving performance of your agrienterprise?

1) Yes [__ _] 2) No [__ _]

If yes, please explain how it has helped in your pineapple farming.

……

SECTION E: GROUP MEMBERSHIP

E1 a) Are you a member of any group? **[If no skip to F1]**

1) Yes [__ _] 2) No [__ _]

If '**Yes'**, which type(s) of group?

1. Self Help group ☐ 2. Cooperative Society ☐ 3. Welfare ☐ group

4. Farmer group ☐ 5**.** Other (Specify) ……

c) If yes, does your group use any form of ICT (Radio, Mobile Phone, TV, Internet etc.) to conduct its activities?

Explain……

……

d) Is membership to this group influenced your decision to use ICT in your agri-enterprise?

1) Yes [__ _] 2) No [__ _]

Explain…….

…….

SECTION F: ACCESS TO EXTENSION SERVICES

F1: a) Do you receive **extension services** in the farm last year? [**If no skip to G1]**

1) Yes [__ _] 2) No [__ _]

b) How many times in the last one year and from which extension providers?

Number of times in a year……. Extension agent……..

Extension agents

1= Government extension workers [ ] 2= private extension workers [ ] 3=NGOs/

developmental agencies [ ] 4= Others (*specify*)……

c) Have you ever received any formal training to use of any ICT tools in your agribusiness?

1) Yes ☐ 2) No ☐

If yes, did it influence your decision to adopt usage of ICT in your agricultural transactions?

1) Yes ☐ 2) No ☐

Explain……

d) Do you know how to operate these ICT tools (Mobile phones, TV and Radio)?

1) Yes ☐ 2) No ☐

e) In your own opinion, do you think these ICT tools (Mobile phones, TV and Radio) are affordable to farmers in your area?

1) Yes ☐ 2) No ☐

Explain……

SECTION G: ACCESS TO ELECTRICITY

G1: a) Do you have access to electricity in your farm?

1) Yes ☐ 2) No ☐

b) Do you think access to electricity has contributed to use of ICT tools in your agri-enterprises?

1) Yes ☐ 2) No ☐

Explain…….

End.

Thank you for your cooperation!!!!!

APPENDIX 2: MULTIVARIATE PROBIT REGRESSION RESULTS

```
. mvprobit( Usephone= Gen Age Educ THhsz lsize Workoff ICTtrn Grpmember Econt Acc Dist
Instelec Mobcomp Mobacc Mobrel Mobfeed Mobtim Mobport)( UseTV= Gen Age Educ THhsz lsize
Workoff ICTtrn Grpmember Econt Acc Dist Instelec  Tvcomp Tvacc Tvrel Tvfeed Tvtim Tvport)(
UseRadio=Gen Age Educ THhsz lsize Workoff ICTtrn Grpmember Econt Acc Dist Instelec Radcomp
Radacc Radrel Radfeed Radtim Radport),nolog

Multivariate probit (SML, # draws = 5)             Number of obs   =        183
                                                   Wald chi2(54)   =     124.98
Log likelihood = -168.17653                        Prob > chi2     =     0.0000
```

	Coef.	Std. Err.	z	P>z	[95% Conf.	Interval]
Usephone						
Sex	.2073447	0.422827	0.54	0.593	-.6010209	1.05251
Age	-.0277823	0.0155975	-1.78	0.075	-.0583527	.0027882
Educ	.1443048	0.1701858	0.85	0.396	-.1892533	.4778629
THhsz	.372907	0.1517947	2.45	0.014	.0741788	.6676353
Lsize	-.0052108	0.1584031	-0.03	0.979	-.3146752	.3062535
Workoff	-.0120829	0.4310555	-0.05	0.961	-.8638761	.8219103
ICTtrn	-.340999	0.9817135	-0.36	0.722	-2.281002	1.579004
Grpmember	1.928028	0.6057974	3.19	0.001	.7466472	3.117409
Econt	.6192169	0.6129223	1.02	0.309	-.5800086	1.830443
Acc	.2194108	0.4665079	0.47	0.638	-.6949278	1.133749
Dist	-.0150926	0.0178181	-0.85	0.397	-.0500154	.0198302
Instelec	1.691753	0.5321682	3.19	0.001	.6546428	2.732864
Mobcomp	-.1769415	0.2967027	-0.59	0.558	-.7554682	.4075852
Mobacc	.943483	0.3687183	-2.57	0.010	-1.667198	-.2257683
Mobrel	-.1129586	0.1743066	-0.65	0.517	-.4545934	.2286761
Mobfeed	.5785337	0.1777743	3.24	0.001	.2291426	.9299248
Mobtim	.6749796	0.2913269	-2.33	0.020	-1.24601	-.1079493
Mobport	.0135424	0.3464997	0.04	0.971	-.6667804	.6918653
_cons	3.437831	2.646034	1.30	0.194	-1.752221	8.627883
UseTV						
Sex	-.0624364	.2760563	-0.27	0.786	-.6204167	.4695438
Age	-.0274525	.0125673	-2.13	0.033	-.051384	-.0021211
Educ	.3383767	.0970727	3.49	0.000	.1481178	.5286357
THhsz	-.0325167	.0804529	-0.40	0.686	-.1902015	.1251681
lsize	.2914137	.1078263	2.70	0.007	.0801781	.5028493
Workoff	-.3535641	.2639862	-1.33	0.184	-.8748875	.1677594
ICTtrn	-.4749071	.4878872	-0.97	0.332	-1.435068	.4852542
Grpmember	-.2193835	.2709067	-0.80	0.424	-.747351	.3145839
Econt	.6329458	.271139	2.34	0.019	.1045631	1.171328
Acc	.5279914	.2711524	1.92	0.055	-.0104175	1.0564
Dist	-.018673	.0098935	-1.89	0.059	-.0380639	.0007179
Instelec	.7147822	.2496867	2.85	0.004	.2224452	1.205119
Tvcomp	.2231532	.1204607	1.83	0.068	-.0161414	.4564478
Tvacc	.1406991	.1104808	1.26	0.206	-.0768393	.3562376
Tvrel	.1171155	.0982532	1.21	0.225	-.0734572	.3116883
Tvfeed	-.0566756	.1081766	-0.51	0.607	-.2676978	.1563465
Tvtim	-.1038424	.0980059	-1.05	0.294	-.2978903	.0902056
Tvport	-.3534628	.3204614	-1.10	0.270	-.9823436	.275018
_cons	-1.305321	.9319758	-1.40	0.161	-3.13196	.5213178
UseRadio						
Sex	-.3236912	.2627054	-1.51	0.131	-.9046644	.1172819
Age	-.010542	.0115219	-0.91	0.360	-.0331246	.0120405
Educ	.2135175	.0948452	2.24	0.025	.0266244	.3984106
THhsz	-.0432395	.0767126	-0.51	0.609	-.1895934	.1111145
lsize	.2126064	.1162079	1.86	0.062	-.011157	.4443697
Workoff	-.0191415	.2414916	-0.03	0.976	-.4810443	.4667613
ICTtrn	-.1601467	.5048832	-0.31	0.756	-1.14178	.8294862
Grpmember	-.2560243	.2751495	-0.93	0.350	-.7963074	.2822588
Econt	.3375536	.2652202	1.29	0.197	-.1763484	.8554557
Acc	-.3900813	.276833	-1.48	0.138	-.9497041	.1315415
Dist	-.017187	.0091901	-1.87	0.061	-.0351992	.0008252
Instelec	-.5680699	.2854564	-1.98	0.048	-1.124946	-.0051938
Radcomp	.1152616	.0882128	-1.30	0.092	-.2845956	.0572724
Radacc	-.147584	.1349424	-1.09	0.274	-.4091063	.1159383
Radrel	.201415	.1234466	-1.71	0.048	-.4532578	.0314279
Radfeed	-.1351693	.1013661	-1.40	0.162	-.3403431	.0570045
Radtim	-.0276293	.0947141	-0.27	0.787	-.2112654	.1600069
Radport	.2146833	.1006841	2.15	0.031	.019346	.4140205
_cons	2.387453	1.089129	2.19	0.028	.2528003	4.522106

/atrho21	-1.093827	.4858863	-2.25	0.024	-2.046147	-.1415072
/atrho31	-.7704701	.2801159	-2.75	0.006	-1.319487	-.2214531
/atrho32	.7757641	.2006237	3.87	0.000	.3825489	1.168979
rho21	-.7982707	.176262	-4.53	0.000	-.9671469	-.1405702
rho31	-.6472027	.1627834	-3.98	0.000	-.8666563	-.2179026
rho32	.6502687	.1157901	5.62	0.000	.364919	.8239447

Likelihood ratio test of rho21 = rho31 = rho32 = 0:
chi2(3) = 36.9426 Prob > chi2 = 0.0000

APPENDIX 3: ENDOGENOUS SWITCHING REGRESSION RESULTS

```
. movestay lngrossmar gen age educ thhsz instelec dist fsize acc occu econt grpmember, select
(ictuse=icttrn agritrain ictafford)
Fitting initial values .....
Iteration 0:   log likelihood = -171.75974
Iteration 1:   log likelihood = -171.64689
Iteration 2:   log likelihood = -171.47712
Iteration 3:   log likelihood = -171.47659
Iteration 4:   log likelihood = -171.47659

Endogenous switching regression model Number of obs   =        183
                                                      Wald chi2(11)   =      34.35
Log likelihood = -171.47659                           Prob > chi2     =     0.0003
------------------------------------------------------------------------------
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
lngrossmar_1 |
         gen |  -.1495754   .1109088    -1.35   0.177    -.3669527    .0678019
         age |   .0082581    .007889     1.05   0.295     -.007204    .0237203
        educ |  -.0167351   .0570172    -0.29   0.769    -.1284867    .0950165
       thhsz |   .0399573   .0371628     1.08   0.282    -.0328805    .1127951
    instelec |   .3188642   .1593498     2.00   0.045     .0065443     .631184
        dist |  -.0065119   .0042374    -1.54   0.124    -.0148171    .0017932
       fsize |    -.21164   .0474017    -4.46   0.000    -.3045455   -.1187344
         acc |    .011817   .1524525     0.08   0.938    -.2869843    .3106184
        occu |     .01546   .0547529     0.28   0.778    -.0918538    .1227737
       econt |  -.0904484   .0508903    -1.78   0.076    -.1901916    .0092948
   grpmember |   -.070666   .1413152    -0.50   0.617    -.3476387    .2063068
       _cons |   11.65286   .4542007    25.66   0.000     10.76264    12.54307
-------------+----------------------------------------------------------------
lngrossmar_0 |
         gen |  -.0755246   .0934685    -0.81   0.419    -.2587194    .1076702
         age |  -.0021639    .004345    -0.50   0.618    -.0106799    .0063521
        educ |  -.0262756   .0391165    -0.67   0.502    -.1029424    .0503913
       thhsz |   .0545029   .0276531     1.97   0.049     .0003039    .1087019
    instelec |   .3098024   .0990272    -3.13   0.002    -.5038922   -.1157125
        dist |   -.004381   .0044501    -0.98   0.325    -.0131031    .0043411
       fsize |   .7241955   .0460249   -15.73   0.000    -.8144027   -.6339884
         acc |  -.0838744   .1013807    -0.83   0.408    -.2825769    .1148281
        occu |   .0842809   .0496427     1.70   0.090     -.013017    .1815788
       econt |   .1055897   .0611972    -1.73   0.084     -.225534    .0143547
   grpmember |   .0231878   .0960457     0.24   0.809    -.1650583    .2114339
       _cons |   12.01132   .3487241    34.44   0.000     11.32783    12.69481
-------------+----------------------------------------------------------------
ictuse       |
         gen |   .1817178   .2842275     0.64   0.523    -.3753578    .7387935
         age |   -.051772   .0158405    -3.27   0.001    -.0828188   -.0207251
        educ |   .3855783   .1175122     3.28   0.001     .1552587     .615898
       thhsz |   -.018129   .0900606    -0.20   0.840    -.1946445    .1583866
    instelec |   .4997919   .2934007     1.70   0.088    -.0752628    1.074847
```

```
        dist |  -.0009402   .0119089    -0.08   0.937    -.0242812    .0224009
       fsize |   .4286056   .1162012     3.69   0.000     .2008555    .6563558
         acc |   .2606838   .2944456     0.89   0.376     -.316419    .8377866
        occu |  -.4397993   .1518311    -2.90   0.004    -.7373828   -.1422158
       econt |   .8191317   .2725699     3.01   0.003     .2849045    1.353359
   grpmember |   .4047717   .2727016     1.48   0.138    -.1297135    .9392569
      icttrn |   1.148591    .513402    -2.24   0.025     -2.15484    -.142341
   agritrain |   .5073391   .2659444     1.91   0.051    -.0139023    1.028581
   ictafford |   .2209609   .2934891     0.75   0.042    -.3542671    .7961889
       _cons |  -.1144514   1.019718    -0.11   0.911    -2.113061    1.884159
-------------+----------------------------------------------------------------
       /lns1 |  -.7084598   .0858432    -8.25   0.000    -.8767093   -.5402102
       /lns2 |  -.9043632    .106627    -8.48   0.000    -1.113348   -.6953781
         /r1 |  -.3576439    .370125    -0.97   0.334    -1.083076    .3677879
         /r2 |  -.8286712   .4456951    -1.86   0.063    -1.702218    .0448752
-------------+----------------------------------------------------------------
     sigma_1 |    .492402   .0422694                      .4161501    .5826258
     sigma_2 |   .4047996   .0431626                      .3284573    .4988858
       rho_1 |   -.343137   .3265454                     -.7943369    .3520553
       rho_2 |   .6797619     .23975                     -.9356857    .0448451
------------------------------------------------------------------------------
LR test of indep. eqns. :            chi2(1) =     3.70   Prob > chi2 = 0.0546
```