ANALYSIS OF SMALLHOLDER TOMATO FARMERS AWARENESS AND ADOPTION OF ICT-BASED PEST INFORMATION SERVICES IN THE CENTRAL HIGHLANDS OF KENYA

BY

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DECLARATION

This thesis is my original work and has not been presented for the award of a degree in any other University or any other award.

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Supervisors' Declaration

We confirm that the work reported in this thesis was carried out by the student under our supervision.

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DEDICATION

I dedicate this thesis to my dad Moses and mum Rosemary. I also dedicate it to my friends who helped me in data collection.

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ABSTRACT

Tomato is a widely consumed vegetable in Kenya and globally. It is an essential source of nutrients, income and employment. Pest infestation is one of the major challenges in tomato farming that leads to low- and poor-quality production especially through physical destruction of the products and high production cost due to their control measures. Besides, tomato farmers experience difficulties in accessing timely pest information to enable effective pest management decisions. Use of Information and Communication Technology (ICT) is a novel pathway of helping farmers to access pest information services, particularly in an environment with declining public extension services. However, there is scanty literature on awareness and adoption levels of ICT-based pest information services by farmers, together with the factors that limit adoption of these services by farmers. Available studies give mixed results on factors influencing adoption of ICT-based information services. The main objective of this study was to analyze tomato farmers' awareness and adoption of ICT-based pest information services in tomato production in the Central Highlands of Kenya. Specifically, the study: (i) characterized the current information services for tomato pests and their management, (ii) assessed the farmer awareness and adoption of ICT-based pest information services and (iii) assessed the determinants of and factors limiting the adoption of ICT-based pest information services. The study was conducted in Nyeri and Meru Counties. Data was collected between October and November, 2021, through field surveys using structured questionnaires, which were administered by trained enumerators to a sample of 170 farmers using KoBo Toolkit. The data was analyzed using descriptive statistics, inferential statistics and Logistic Regression. The results indicate that the current sources of agricultural pest information were ICT-based and non-ICT-based. The main non-ICT based sources were; other farmers (82.9%), agro dealers (81%), public extension officers (47%) and agro chemicals' sales agents (30%). The ICT-based sources were radio programs (94%), television programs (90%) and mobile- and internet-based information services (MIBIS) (100%). Farmers reported high awareness of ICT-based information services, with 100% awareness of radio programs, 93% TV programs and 83% MIBIS. However, the adoption rate was low as only 48% of the farmers adopted at least one ICT-based information service. The most adopted service was radio programs (34% adoption rate) followed by television programs (30%) and MIBIS (28%). The study found that the factors that positively influenced adoption of ICT-based pest information services were: gender (male), membership in social groups, off-farm employment, levels of trust on ICT-based information sources, transport costs to nearby market centers and area under tomato production. The factors that had a negative influence on adoption were; the level of education, size of land owned, and the production system, with greenhouse system having lower adoption level than open field system. Factors limiting ICT-based pest information services adoption include: poor timing of the information broadcast by service providers; lack of ownership of ICT tools and high cost of using the services. The results from this study provide unique evidence to inform policymakers on the need to integrate ICT-based tools into strategies and interventions for disseminating pest information services to farmers.

The findings suggest that the radio and television service providers should air information at the most convenient times for farmers, who prefer evening broadcasts. There is also a need to encourage farmers to form and participate in social groups and cooperatives that support adoption of ICT-based pest information services. Further studies can be done to evaluate the impact of ICT-based pest information services on pest management, productivity and profitability of tomato production.

ABBREVIATIONS AND ACRONYMS

AFA	Agriculture and Food Authority
FAO	Food and Agriculture Organization of the United Nations
FPEAK	Fresh Produce Exporters Association of Kenya
GDP	Gross Domestic Product
GoK	Government of Kenya
HCDA	Horticultural Crops Development Authority
ICT	Information and Communication Technology
KALRO	Kenya Agriculture and Livestock Research Organization
KII	Key Informant Interviews
KNBS	Kenya National Bureau of Statistics
MIBIS	Mobile and Internet Based Services
PASGR	Partnership for African Social and Governance Research
SSA	Sub-Saharan Africa
UN-SDGs	United Nations Sustainable Development Goals
USAID	United States Agency on International Development

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Agriculture is among the most powerful avenues for boosting shared prosperity and reducing extreme poverty (World Bank, 2019). Agriculture drives United Nations' Sustainable Development Goals (SDGs) numbers one and two on no poverty and zero hunger respectively (Pandey & Srivastava, 2019). Indeed, agriculture is still the main sector of the majority of sub-Saharan African (SSA) countries' economies through the provision of food, employment, foreign exchange and raw materials for industries (World Bank, 2014). Agriculture is also fundamental to the growth of the economy, as it accounted for 4% of the global gross domestic product (World Bank, 2018). Globally, agriculture sector employs 65% of the population in developing nations and 72% of the population in the least developed countries (UNICEF, 2020).

In Kenya, agriculture is the engine of economic growth. It accounts for 33% of the gross domestic product, with 75% of Kenyans earning all or part of their income from agriculture (UNICEF, 2021). The sector provides raw materials to the manufacturing sector (World Bank, 2014). Agricultural products account for 65% of Kenya's total export. The sector offers employment to more than 80% of Kenyans and it's a source of livelihood for close to 70% of the Kenyan population living in the rural areas (Kavoi *et al*., 2016).

Kenya's agriculture comprises five major subsectors namely: horticultural crops, food crops, industrial crops, livestock and fisheries. Horticulture is the biggest sub-sector, contributing 33% of the agriculture's GDP (AFA, 2017). It is made up of five crops: vegetables, which account for 44% of the total production value; flowers, which contribute 20.3%; fruits 29.6%; and nuts, medicinal and aromatic plants 5.8% (Horticultural Crops Development Authority, 2013). It ranks third in foreign exchange earnings behind tourism and tea and has gone through changes over the last 50 years earning around 150 billion annually and contributing immensely to the Kenyan economy (Sharpley, 2018).

This study focuses on horticulture and specifically tomato (*Solanum lycopersicum*) because of its importance not only nationally but also worldwide. With its origins in Western South America and Central America (Naika *et.al*, 2005), tomato is part of the widely cultivated vegetables, ranking second after potato in terms of value and production (Mitra *et al*., 2018). Tomato is consumed in raw form (salads), processed products for instance tomato sauce or paste, or as an ingredient in many dishes and drinks (Ahmed *et.al*, 2017). The crop is a major source of the antioxidant lycopene whose benefits include reduced risk of heart diseases and cancer (Rao & Agarwal, 2000) In addition; it is a major source of vitamin C, potassium, folate and vitamin K (Ganesan *et al*., 2012). This makes tomato an essential component of nutrition among households (Geoffrey *et al*., 2014). Besides its nutritional value, tomato creates employment and generates income particularly in rural areas (Geoffrey *et al*., 2014). The sub-sector contributes 14% of the aggregate vegetable output and 6.72% to total horticultural output in Kenya (Najjuma *et al*., 2016). Worldwide, China is the leading producer of tomatoes with a tonnage of 59,514,773 per annum, followed by India, United States of America, Turkey, Egypt, Italy, Iran, Spain, Brazil and Mexico (Nicola *et al*., 2018). Africa produces about 11.8% of total global output, with the five main producers being Egypt, Nigeria, Morocco, Tunisia and Cameroon, and Kenya taking the 9th position (Dube *et al*., 2020). Kenya ranks 43rd in tomato production globally, with 410,033 tons of tomatoes annually (Gatahi, 2020). Kenya's tomato sub-sector is dominated by smallholder farmers, with farms that range from 0.2 to 3 hectares and producing over 70% of total tomato output (Ndirangu *et al*., 2018). The major growing zones are Mwea in Kirinyaga County, Ngurumani in Kajiado County, parts of Rift Valley, Western region and Taita Taveta. Tomato is produced under irrigated and rain-fed conditions (HCDA, 2009). The commonly grown varieties are Onyx, Kentom, Cal J, Caltana, Riogrande, Money maker, Zawadi F1 hybrid, Neema 1400, Manset, Neema 1200 (resistant to nematodes), Rotade and Fortune (Wiersinga & de Jager, 2008) with many other varieties continuously being introduced and developed for farmers.

Tomato yields in Kenya remain low due to abiotic factors such as unreliable and inconsistent rainfall, poor soils due to land degradation and soil erosion and biotic factors such as pests and diseases (Ochilo *et al*., 2019). Recently, the Kenyan government has come up with strategies such as integrated pest management strategies to increase smallholder farmers' productivity (Wambua *et al*., 2019), through development of varieties that are resistant to diseases, effective agrochemicals, quality fertilizers and technologies aimed at reducing the production costs (GoK, 2018). However, this has not translated to increased productivity of the crop. Ochilo *et al*. (2019), show that tomato productivity decreased from 22.4 tons per hectare in 2011 to 17.9 tons in 2015 and 16.9 tons in 2016. This trend continued in 2018 with an average yield of 12 tons/ha against a potential yield of 30.7 tons per ha (Ochilo *et al*., 2019), while countries such as Egypt (35 tons/ha) and France (120 tons/ha) exceeded this potential yield (Najjuma *et al*., 2016).

1.2 Tomato Pests and their Management Practices

Pests are one of the main challenges in tomato production in Kenya and globally, with major pests being the leaf miner moth (*Tuta absoluta*) which is causing over 60% of tomato losses globally, whitefly (*Bemisia tabaci*), African bollworm (*Helicoverpa armigera*), thrips (*Ceratothripoides brunneus)*, red spider mite (*Tetranychus spp.*) aphids and grasshoppers (Desneux *et al*., 2011; Santana *et al*., 2019). These pests reduce the productivity of tomatoes as some of them reduce the rates of photosynthesis and also the quality of produce. Low-quality produce will not meet market standards and thus commanding low prices. This implies that pests indirectly affect marketing and profitability of tomatoes.

Farmers mostly use agrochemicals to manage these pests but due to challenge in monitoring the pests, chemical control is ineffective. This is because applications of insecticides are normally done on a calendar program (Nansen & Ridsdill-Smith, 2013). Periodic unpredictability of the populations of pests lead to these calendar programs sometimes being erroneous therefore making the control ineffective (Miller, 2020). This inaccuracy is mainly associated with lack of up-to-date and untimely relay of information on pests (Guedes *et al*., 2019). Therefore, farmers need access to up-to-date and timely information to effectively manage the pests (Mwenda *et al*., 2022).

1.3 Tomato Pests' Information Provision and Access

Farmers have always sought information from each other ever since they started growing crops, caught fish and raised livestock (World Bank, 2017). Due to the reduction in public extension services, there has been reduced access to information by farmers especially those operating at small scale (Kante *et al*., 2017). However, the farmers have opted to other sources of information due to the inadequacy of extension agents.

1.3.1 Non-ICT Sources of Information

The current non-ICT sources of information include; other farmers, agro-dealers, agro-chemical sales agents. A study by Parmar *et al*. (2019), which was aimed at evaluating farmers' access to agricultural information in India, used regression analysis and found out that farmers obtained information more from non-ICT based sources such as agro-dealers, than the ICT-based sources. In another study by Das (2018), that evaluated the sources of technological knowledge and output in agriculture, the author found out that 14% of the farmers access agricultural information from non-ICT based sources as compared to 10% usage of ICT-based sources. In Kenya, farmers get pest information from extension officers, agro-dealers, seed companies, agro-chemical companies, other farmers and NGOs (Mwenda *et al*., 2022). However, farmers do not have adequate information on pests for instance on other methods of pest management besides chemical methods (Vétek *et al*., 2017).

A recent study by Grademba *et al*. (2020), aimed at investigating how extension agents employ ICT in transforming agricultural information services delivery in Kenya, found that 23% of the farmers make use of non-ICT based information services. Famers have been controlling pests' mostly through chemical means using information from non-ICT sources, but some pests such as the leaf miner for instance has been developing resistance to these chemicals (Chhetri, 2018). This has led to unsuccessful control and therefore more reproduction of this dangerous pest. One of the explanations of the pest developing resistance has been because farmers lack timely information on when best and how to control this pest. Thus, there has been information gap concerning the pest, for instance its life cycle, which is vital in successfully controlling it (van den Berg *et al*., 2020). Some farmers also are unable to identify and distinguish between different pests and the existing chemicals for controlling these pests (Roditakis *et al*., 2018). Smallholder farmers in Kenya have traditionally relied on agricultural extension officers for such information. However, there is scarcity of extension officers, with the current ratio of extension workers to farmers being 1:1000 (Muyanga & Jayne, 2016) compared to the Food and Agriculture Organization (FAO) recommendation of 1:400 (Gichamba *et al*., 2017).This presents an information gap where ICT could be applied to help smallholder tomato farmers with the necessary information on pests and their management.

1.3.2 ICT-based Sources of Information

Information and communication technology (ICT) use could alleviate pest information asymmetry. ICT is the new science of collecting, storing, processing and transmitting information (Milovanović, 2014). It could help collect and disseminate data on tomato pests and diseases that could be costly to do manually**.** Through the use of social media platforms, access to information on pests and diseases and the interaction with pest specialists across the globe would offer solutions on pest management. For instance, there is a short message service (SMS) program in Kenya that provides farmers with the information they need on pests by sending any question they have to a toll-free number 40130.

Other technologies such as satellite positioning, novel earth observation technology; on-the-ground real-time observations and plant health modeling could be used to provide science-based pest risk information service to farmers (Beverley & Thakur, 2021). Developed countries have used *Internet of Things* through the application of *in-situ* sensors to predict pest outbreaks (Potamitis *et al*., 2017).

Farmers have been exposed to diverse ICT channels to access and use of agricultural information in developing countries (Kante *et al*., 2017). However, the potential to utilize ICT-based information services in the provision of modified agricultural information and services to facilitate smallholder farmers' performance in sub-Saharan Africa (SSA) remains largely masked (Aker *et al*., 2016). Hence, there is a need to investigate the contribution of ICT-based pest information services to smallholder farmers’ access to and use of pest information to identify and manage tomato pests.

ICT-based sources of information on pests are numerous and because of this, information dissemination channels are also many. In Europe, farmers get pest information by several means, for instance individuals in the private and the public sector employment (Torres & Vargas, 2021). Also, there are extension services in Central and Eastern Europe although the farmers are too poor and don’t see the essence of extension services but the governments are still anxious to increase food production, therefore, doing all they can to implement extension services (Adams, 2000). In Asia, the governments are combining extension services with media to adjust their farming practices in the interests of long-term sustainability. They are training the extension service workers on how to provide farming information to farmers using ICT tools (Baig *et al*., 2013).

In Australia, ICT tools such as webinars, YouTube videos, podcasts and mobile applications are used to disseminate pest information to farmers (Wright *et al*., 2018). However, Dufty and Jackson (2018) report that many farmers grapple with challenges that limit their adoption of new ICT tools, including lack of skills, inadequate internet access, cost associated with the tools, perceived lack of new innovation and new tools in the market, among others. In Africa, pest information is accessible mainly through the pest risk atlas which is a free online mobile platform that assesses potential pests' outbreak under current and potential future climatic conditions (Smith, 2015). However, this atlas is not well known to farmers which make it ineffective in pest control (Kroschel *et al*., 2016). Moreover, information sourcing by farmers in Africa is dependent on the mode of pest management. For instance, conventional pest management information is obtained by farmers from other farmers and agro-dealers. On the other hand, organic pest management information is obtained from non-governmental organizations (NGOs), and it's not easily available whenever the farmers need it (Waage *et al*., 2008).

1.4 Statement of the Problem

The horticultural sub-sector is important to Kenya and the global economy at large, through provision of quality health diet, increased incomes to farmers, provision of raw materials for agro-industries and provision of employment opportunities in rural areas. Among the key horticultural crops in Kenya is tomato, whose farming provides income to many small-scale farmers and other actors along its value chain (Tyce, 2020).

Despite its numerous benefits, tomato production faces many challenges, key among which is high incidences of pests that limit achievement of optimal yield and income by farmers. Further, farmers incur huge losses as a result of the product rejection for failure to meet market standards, owing to pest-related quality deterioration (Karuku *et al*., 2017).

Pest infestation is devastating to farmers and is becoming increasingly unpredictable due to change in climate. This is worsened by inadequate and timely pest information and their management, especially among smallholder farmers. Many smallholder farmers also do not have knowledge on how to differentiate pests as different pests warrant different management practices (Kinuthia, 2019).

Information and Communication Technology (ICT), which is the new science of collecting, storing, processing and transmitting information, could help collect and disseminate data on tomato's pests and diseases that could be costly if done manually. A number of ICT-based pest information services have been developed to assist farmers in accessing information on agricultural pests and their management. Farmers have been exposed to diverse ICT channel that provide agricultural information in developing countries (Ndimbwa *et al*., 2021). However, the potential of these ICT-based innovations in providing customized pest information and services to improve smallholder farmers' performance in sub-Saharan Africa (SSA) remains largely untapped. Moreover, literature and studies on ICT in agriculture have tended to focus on marketing, lowering transactional costs, and value chain development. Although efforts have been made to apply ICTs in agricultural pest management, literature is scanty on use of ICT-based pest information services by smallholder farmers, and factors that would facilitate or constrain farmer adoption of such services. It is therefore imperative for more research to examine the current information services available to farmers, the awareness and adoption of ICT-based information services and the determinants and limiting factors of adoption of the ICT-based pest information services.

1.5 Research Objectives

1.5.1 Main Objective

The general objective of the study was to analyze tomato farmers' awareness and adoption of ICT-based pest information services in tomato production in the Central Highlands of Kenya.

1.5.2 Specific Objectives

i. To characterize the current information services for tomato pests and their management in the Central Highlands of Kenya.

ii. To assess farmer awareness and adoption of ICT-based pest information services in tomato pests and their management in the Central Highlands of Kenya.

iii. To assess the determinants of and factors limiting the adoption of ICT-based pest information services by farmers in the Central Highlands of Kenya.

1.6 Research Questions

i. What are the characteristics of the information services for tomato pests and their management that currently exists in Central Highlands of Kenya?

ii. What are the levels of awareness and adoption of ICT-based pest information services by smallholder tomato farmers in the Central Highlands of Kenya?

iii. What are the determinants of and factors limiting the adoption of ICT-based pest information services by tomato farmers in the Central Highlands of Kenya?

1.7 Scope of the Study

This study was conducted in Meru and Nyeri counties with specific sub-counties being Nyeri Township Sub-County and Imenti Central Sub-County. The study focused on small-scale farmers who were growing tomato and had knowledge and skills in tomato production.

1.8 Significance of the Study

The findings of this study can be used in emphasizing and supporting the achievement of United Nation's – Sustainable Development Goals (UN-SDGs) numbers one and two on no poverty and zero hunger, respectively, through formulation of policies that will boost pest management processes and productivity thereby increasing the income of the farmers.

The two county governments can use the findings of this study in formulation of policies that support efficiency in agricultural production and digitalization of agriculture. This will contribute in the realization of Kenya's Vision 2030 whose aim is to transform Kenya into an industrialized economy through innovations such in ICT, the Big 4 Agenda on food security and agro-manufacturing and implementation of the anchors in Agricultural Sector Transformation and Growth Strategy 2019-2029 which include; increasing the income of small-scale farmers, increasing agricultural output and enhancing household food resilience. The results from this research will inform the challenges smallholder farmers face in accessing essential information on pests and pest management. The findings of this study will also be useful to other researchers because further study recommendations will be made based on the findings.

1.9 Limitations of the Study

The study was limited to Imenti Central and Nyeri Township sub-counties which may not have been fully representative of the country at large on the sample size of the study. However, the results will be largely applicable to the other counties and could be used to inform further research in the country and similar environments. The challenges faced during data collection include: farmers being reluctant in providing personal details such as the amount of tomato produced; the unreliable weather of Nyeri County was very cold.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter reviews the literature on the types of ICT tools already in existence in agriculture. It also presents a review of on factors influencing the awareness of ICT-based information services among farmers and the factors influencing adoption of ICT-based information services in agriculture. Finally, it documents a review of the literature gaps that exist, the theoretical framework and the conceptual framework that guided the study.

2.2 The Concept of ICT

Information and Communication Technology (ICT) is the infrastructure and component that is a modern computing enabler. It entails all networking components**,** applications, devices and systems that combined allow organizations and individuals to have interactions in the digital world (França *et al*., 2020). Encompassed by ICT are the mobile one-powered by wireless networks and an internet-enabled sphere. The list of ICT components is in-exhaustive, and its growth is continuous. Some components such as telephones and computers have been in existence for decades (Chen *et al*., 2015). Others, such as digital TVs, robots and smartphones are more recent entries.

2.3 Types of ICT Tools Already in Existence in Agriculture

Today's agriculture uses some of the most sophisticated technologies which include robots and moisture sensors, aerial images and the Global Positioning System (GPS) technologies (Sivarethinamohan *et al*., 2020). Technological advancements in agriculture have come up with many ICT tools and programs. For instance, Agri-clinics, touch screen kiosks and National e-Governance plan (NeGP-A) (Naika *et al*., 2021). The Kenya Agriculture and Livestock Research Organization (KALRO) have launched over thirty agricultural applications to help farmers in their daily activities. For example, indigenous chicken KALRO application for poultry farmers, Fall Army Worm application, Kenya AgriObservatory Platform and the KALRO GIZ application amongst many and are available in the play store of smart phones. These applications are giving farmers step by step guidelines on agricultural production of different crops. They also inform farmers on how to identify and manage different pests and diseases affecting their crops. Contrastingly, farmers are still battling the effects of many pests in their tomato production which shows that farmers are not effectively getting the necessary information (Gatahi, 2020).

Another ICT tool being used to disseminate agricultural information is the television. Munene & Mberia (2016) in a study of the television program Shamba Shape-up Show explains how TV programs have played a huge role in dissemination of agricultural information and knowledge to small scale farmers in Kenya. Television has been found to increase farmer's knowledge through educational interventions and useful messages (Nazari & Hassan, 2011). The television programs that facilitate agricultural productivity and access to pest information in Kenya include; Shamba Shape-up which provides information on general farming practices of different crops, tomatoes included; Poultry Farming Show and others broadcasted by KTN Farmers TV, Seeds of Gold (NTV) and Mugambo wa Murimi (Voice of Farmers) aired on vernacular TV station (Inooro TV and Inooro FM). Social media platforms such as Facebook have groups where farmers can get information from and interact with specialists in farming.

The Kenya Agricultural Observation Platform, an application from KALRO also provides tomato farmers with rainfall data so that they can be able to plan on the best seasons and months to do their production. However, these applications work in android smart phones and other digital devices which limit their access and use by the local uneducated farmers who are mostly engaged in tomato production because these applications require technical know-how to source information from them. This factor makes adoption by local farmers difficult. These applications also require internet connectivity which might be an issue in the rural areas (Republic of Kenya, 2019). Although, there are other services that are cost free and can be accessed at any time by the farmer for instance the short message service by the Ministry of Agriculture (MoA-INFO), the use is still minimal.

2.4 Factors Influencing the Awareness of IBPIS among Farmers

For any farmer to be able to adopt any ICT-based information service, the farmer must be aware of the service. Mahant *et al*. (2012), in a study aimed at understanding how far the ICT initiatives have the ability of addressing the needs of farmers in their agricultural activities, found that awareness is the key issue in implementation and use of ICT-based pest information services. The awareness of ICT-based information services by farmers has however been constrained by lack of information concerning the available ICT-based pest information services. A study that was aimed at examining the conditioners of awareness and use of ICT-based information services by Okello *et al*. (2014), using a sample of 379 smallholder farmers and regression analysis, found out that awareness of any ICT-based information service is driven by transaction cost of using the information service, the characteristics of the area in which ICT-based information services are being implemented and the farmer's human and financial capital endowment. The study recommended that any strategy of increasing the awareness of ICT-based information services by farmers should put into consideration, the benefits of such services and the capacity of the farmers to use the services.

2.5 Factors Influencing the Adoption of ICT-based Information Services

Information delivered to farmers through ICT-based services has transformative potential to provide information to the rural farmers on different tomato production aspects for instance information on pest management. However, the adoption of these ICT-based information services by farmers is usually influenced by many factors.

Several studies have investigated factors that include age, education level, and income of the farmer, infrastructure and connectivity and gender of the farmer.

Krell *et al*. (2021), in their study on the factors that are likely to affect the likelihood of adopting mobile phone services specifically related to agricultural production in the Central Kenya, found out that age and income do not influence adoption of m-services through a farming household survey of 577 respondents. However, a study conducted by Ali (2012), on the influence of socio-demographic factors, business orientation of farmers, and farm characteristics on adoption of ICT-based information using data collected from 461 farmers in India found out that education, income, and social category of farmers are important sociodemographic factors affecting the adoption of ICT-based information systems after carrying out a Poisson Count Regression Model analysis. Size of the farm was also found to have an influence on the adoption of ICT-based information services and tools. These two studies gave conflicting results and findings.

Wyche and Steinfield (2016) sought to understand factors that impede the adoption of ICT-based services in Bungoma, Homabay, Kakamega and Migori counties in Kenya, using seventy-six rural village farmers. The study applied in-depth surveys and key informant interviews and found that the ICT-based tools such as mobile phones need infrastructure such as electricity for charging and internet coverage which are very poor in rural areas. The cost of accessing the internet and the tools to use was also found to influence the adoption of these ICT-based information services.

Nyamba and Mlozi (2012), investigated factors influencing the use of mobile phones in communicating agricultural information in Rural Tanzania using 384 respondents and 16 key informant interviews, focus group discussions and cross sectional survey. The authors found that information asymmetry generates uncertainties in farming business which eventually limit the economic potential of farmers as market participants. The study also found out that network coverage and connectivity, age, gender and farming system influenced adoption of ICT-based information services negatively in the sense that the uptake of these services was declining.

In a 2015 study, Anoop *et al*. (2015) studied the determinants of adoption of ICT-based market information services in Kerala, India. Through a logistic regression model analysis, the study found out that education, family size and the contact with extension services had a positive influence on adoption of ICT-based information services while income from other sources negatively influenced the adoption. Regression analysis conducted on data collected from the World Bank Database showed that the capacity to adopt by South African farmers in terms of being able to cater for the expenditure and exposure to international environment influenced adoption of any ICT (Kyobe, 2011).

2.6 Factors Limiting the Adoption of IBPIS in Agriculture

In the wake of many ICT-based information services in agriculture from weather services, to information services on new crop varieties to new methods of production, it should be expected obvious that farmers are in the front line to ensure the adoption of these services. However, this has not been the case due to the different factors that limit the adoption by farmers. Aleke *et al*. (2022), studied the adoption of ICT innovations in agriculture in Nigeria using 23 primary studies found out that adoption of the innovations among the Nigerian farmers is being limited by community social imperatives such as land tenure systems. Ali (2012), in his study that aimed at examining the factors that limit the adoption of ICTs for farming decisions found out from a sample of 461 farmers in India that high illiteracy levels limit the adoption of ICT-based information services for all farming decisions that a farmer needs to make such as when to control pest in the farms.

A multivariate Probit analysis conducted on a study by Mittal and Mehar (2016), aimed at evaluating socio-demographic characteristics that influence adoption of modern ICTs by farmers in India using 1,200 farmers found that the availability of non-ICTs among farmers such as other farmers and agrochemical dealers limit the adoption of ICTs because farmers already have readily available information services from the non-ICT sources. Kiiza and Pederson (2012), sought to investigate the effect that knowledge of ICT-based information services has on the adoption of the ICT-based information services in Uganda. The study found out that lack of knowledge concerning any ICT-based information services limited the adoption simply because farmers can’t adopt what they don’t know about.

Feder and Umali (2019) used a sample of 370 farmers and a logistic regression analysis conducted found that high levels of illiteracy among the least developed countries is limiting the adoption and diffusion of any innovation in the agricultural sector. A multiple hurdle Tobit regression analysis conducted on a data of 832 households in Central and Northern Tanzania found that farmers lack the assurance that ICT-based programs can actually alleviate information asymmetry. The results of the study also found that lack of adequate capital limits adoption of any innovation (Kaliba *et al*., 2018). Mtega (2018), in a study of evaluating the usage of radio and television as agricultural information sources found that very low number of radio and television programs in week that focuses on agricultural information provision limits adoption of the programs by farmers. Due to the aspect of language understandability, Bello and Yahia (2021), found that age limits adoption of television agricultural programs because the younger generations of farmers are more willing to watch the programs than the old generation because the younger generation understands the languages and terms used more than the old farmers.

2.7 Literature Gaps

The challenge that farmers are experiencing in effectively controlling tomato pests is lack of timely and up-to-date information concerning the best time and best methods to control certain pests. There is scanty literature on the level of awareness and adoption of ICT-based information services by farmers, together with the factors that limit adoption of these ICT-based pest information services by farmers. Although there is strong evidence that ICT has been used in different agricultural activities, none of these was based on tomato pest management. While prior research shows that the use of ICT in agriculture is emerging and rapidly growing in Kenya and Africa at large, the adoption of ICT based information services is still lagging behind. There is inadequate research to try and understand why adoption is lagging behind. Studies are giving mixed results, for instance one study says that age and income level of the farmer does not influence adoption of ICT-based information services while another one says that the two factors influence adoption. This study will help in understanding the factors that influence the adoption of ICT-based information services. The study will also bring out information on the factors limiting the adoption of ICT-based information services by tomato farmers.

2.8 Theoretical Framework

This study was based on the random utility theory.

2.8.1 Random Utility Theory

This theory, developed by Daniel McFadden in the 1920s, postulates that an individual will choose what he or she prefers and in the instance, that they do not choose any option, it can be explained by random factors. For example, one can choose something for four out of five times and choose something else during the fifth time due to some random factors. In this context, farmers might choose to use ICT-based information services that they prefer such as mobile application based information services or print media services such as magazines, sound media such as radio programs or television programs. This theory will help understand the random factors that affect the choice of ICT-based information services by farmers.

The theory assumes that a farmer belongs to a particular population and there are available options of ICT-based information services illustrated as follows:

$$A = A_1 \dots\dots A_n \qquad (2.1)$$

Where the subscripts 1 up to n represent the different kinds of ICT-based pest information services available to tomato farming households, which are affected by internal and external factors;

$$X = (X^I X^E) \qquad (2.2)$$

The model assumes that preference of the farmer making a choice among the available ICT-based pest information services alternatives can be described by a utility function, whereby the farmer will choose the alternative with the highest utility. If the number of alternatives is equated as J, then the utility of alternative j will be:

$$U_j = \beta^! X_j + \varepsilon_j \qquad (2.3)$$

Where X_j is a column vector of observed attributes of alternative j and the individual, β is a conformable vector of constant parameters, and ε_j is a random variable that accounts for the effects on preferences of unobserved attributes of the alternative and individual.

Let ICT_i denote the difference between the utility from adoption ICT-based pest information services (ICT_{iu}) and the utility from non-adoption of ICT-based pest information services (ICT_{iN}) such that an individual *i* will choose to adopt the ICT-based pest information services if;

$$ICT_i = ICT_{iu} - ICT_{iN} > 0 \qquad (2.4)$$

While the utility difference cannot be directly observed, it can be expressed as a function of observable components in the latent model below:

$$ICT_i = \beta_i Z_i + \varepsilon_i \; with \; N_i = \{1 \; if ICT_i > 0, 0 \; otherwise\} \quad (2.5)$$

Where ICT_i represents a propensity of adoption ICT-based pest management by smallholder tomato farmers, and it can be observed by an observed dummy variable ICT_i (1 for adopters and 0 for non-adopters); β_i is a vector of parameters to be estimated; Z_i is a vector of explanatory variables (e.g., age, gender, education, household size and employment) and ε_i is a random error term, which is assumed to be normally distributed with equal variance.

2.9 Conceptual Framework

Figure 2.1 below represents the conceptual framework that guided the study. Adoption of any ICT-based pest information service, whether mobile and internet-based pest information services, radio-based pest information services, or television-based pest information services, can be influenced by either the farmer's demographic characteristics, such as age and level of education, or the farmer's social characteristics, such as membership in a social group, or farm characteristics, such as size of land under tomato production. Demographic characteristics such as age might negatively influence the adoption of MIBIS because as farmers become older, they are more likely to listen to radios than watching television or using mobile phones. Wawire et al. (2017), found that gender of the farmer influences adoption of ICT with male gender likely to adopt more than female gender. This can be explained by the fact that most women have other responsibilities such as taking care of the family and when some of the programs are being aired on the television or radio, the women might be cooking thereby failing to get the information. The level of education of the farmer is also likely to influence the adoption of the services. The higher the level of education, the higher the income of the farmer and with enough income, the farmer can easily own any ICT tool (Nwokoye et al., 2019)

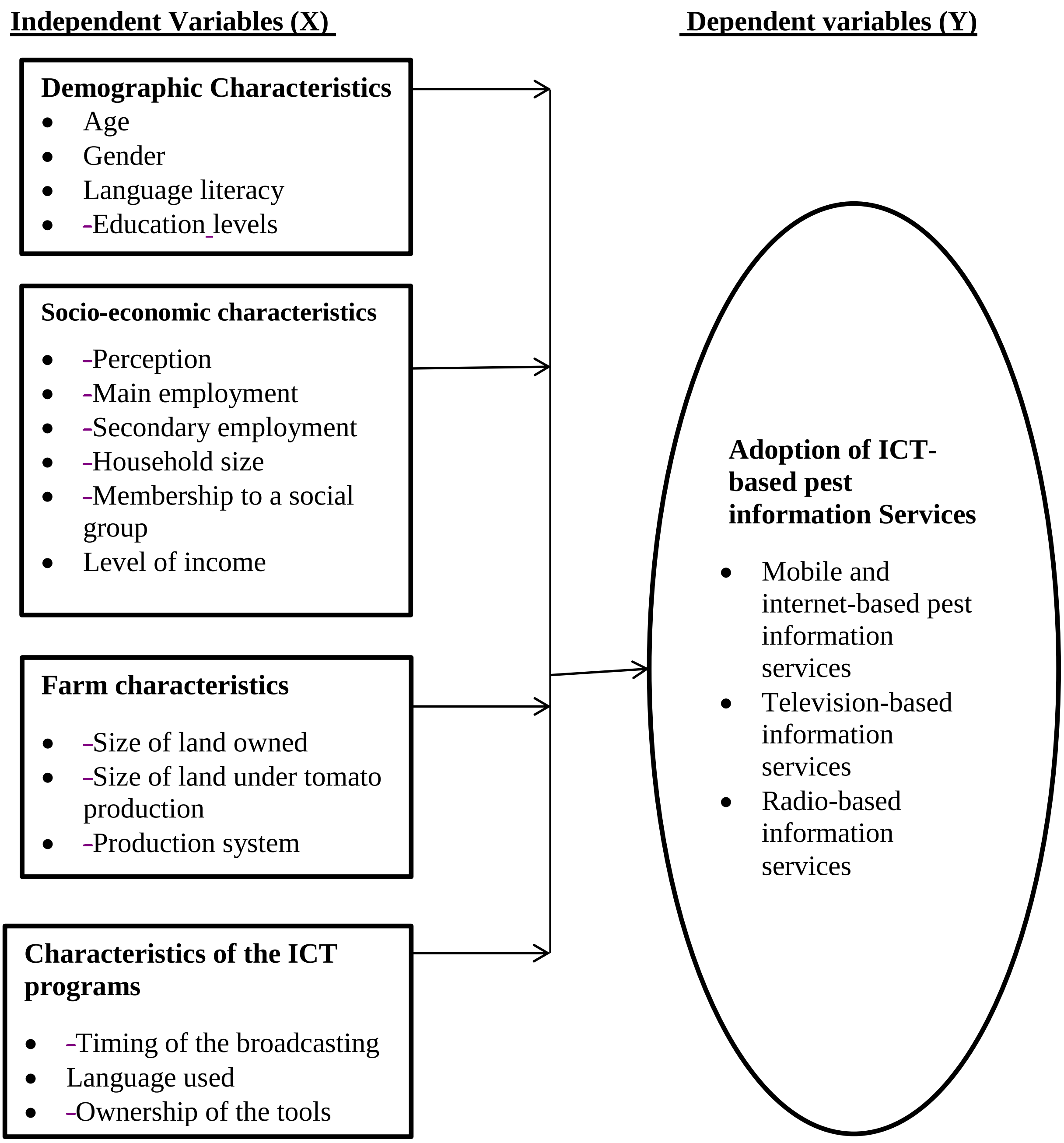

Figure 2.1: Adoption of ICT-based pest information Services

Source: Researcher 2022

Farm characteristics such as the production system might influence adoption. This is because, when a farmer is using greenhouse production system, it is believed that the system prevents entry of pests into the production area and as such, the family is not likely to need any pest management information. A study by Bucci et al., (2019) found out that farmers who adopt field production system are likely to adopt ICT-based pest information system than farmers who adopt greenhouse production system. Also, the size of land can influence the adoption because a farmer with a small piece of land will not need any specialized information for control of the pests which tend to be minimal.

The reliability of air the information is also likely to influence adoption. Mwenda et al. (2022), found that the timeliness and reliability of the airing the information will positively or negatively influence depending on the needs of the farmers and the perception they develop towards the information. Also, ownership of the ICT tools will definitely influence the adoption of the services because a farmer will not adopt what they don't have and can access easily. A farmer who is actively using social media will most likely adopt the services because; he/she will be more exposed to the services.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter brings out the research design of the study, the description of the study area, the target population and the sample size and the sampling method for the study. The chapter also explains the instrumentation of the study that guides data collection, entry, cleaning and analysis are also covered together with the validity and reliability of the data collection instruments; measurement of the research variables and ethical considerations are also covered.

3.2 Research Design

This study employed a descriptive research design as to answer the research questions. Field surveys were used to collect data from the farmers. This design allowed the collection of all the required information from the farmers who filled the questionnaires with the help of the enumerator. A sample of the questionnaire is annexed in Appendix 2. Further, the design ensured a wide coverage, put less pressure on the respondents and described the demographic characteristics of a large population.

3.3 Study Area

The study was conducted in Meru and Nyeri counties, which are located in the Central Highlands of Kenya. The two counties were purposively selected based on their agricultural potential, rich in fertile agricultural soils and reliable rainfall which are conducive for tomato production.

3.3.1 Meru County

The main economic activity in Meru County is agriculture due to the rich volcanic soils and the high altitude with coffee, tea, French-beans and dairy products as primary produce. Tomato is among the main horticultural crops produced in the county and many farmers are making a living from its production. The fertile, well-drained soils and reliable rainfall foster tomato production. Its height above sea level is 1660 meters and receives 1436mm of rainfall annually. The County comprises of nine sub-counties namely Buuri, Imenti Central, Imenti South, Imenti North, Igembe Central, Igembe South, Igembe North, Tigania West and Tigania East (Miriti, 2017). The target sub county which is Imenti Central sub-county, has a population of 133 813 people. The poverty rate of the county is 15.5% (Tyson *et al*., 2020). The sub county was selected due to its vast agricultural potential as compared to the other sub counties.

3.3.2 Nyeri County

The main economic activity of Nyeri County is agriculture with coffee as the primary cash crop, while tomato is the main horticultural crop. Nyeri County also produces food crops such as maize, beans, potatoes and other food crops. It is comprised of ten sub-counties: Tetu, Kieni East, Kieni West, Mathira East, Mathira West, Nyeri South, Nyeri Central, Mukurwe-ini, Mt. Kenya Forest and Aberdare Forest (Njoroge, 2015).

The County receives average rainfall of 1581mm annually and the height above sea level averages 1750m.The population of the target sub-county which is Nyeri Township is 101,238 people (KNBS, 2019). The poverty level of the county is currently at 19.3% (Tyson *et al*., 2020)**.** The sub county was randomly selected.

3.4. Target Population and Sample Size

This study sampled small-scale tomato farmers in the two sub-counties. The target population was all the smallholder tomato farmers in the two counties. The sample size of 195 farmers and was determined using the sampling formula below (Cochran, 1963):

$$n = p\% * q\% * \left(\frac{z}{\varepsilon\%}\right)^2 \quad (3.1)$$

Where, n is the minimum sample required, $p\%$ is the proportion of population of people who have been doing tomato farming (if unknown, 50% is assumed). $q\%$ Is the proportion of population not practicing tomato farming($100\% - p\%$), while z is the Z-score corresponding to the level of confidence required. The confidence level in this study was 95%, hence the corresponding Z-score was 1.96. The ϵ is error margin and for this study was 5%. The assumed p was 15% and q was 85%. Hence, using the above equation, the sample size was 195 tomato producing households.

$$n = 15\% * 85\% * \left(\frac{1.96}{5\%}\right)^2 \quad (3.2)$$

$$n = 195$$

3.5 Sampling Method

A multi-stage sampling method was used to select the sample for the study. The counties were selected purposively because they are well known for their numerous and diversified commercial agricultural activities and are representative of the Central Highlands of Kenya. The two sub-counties were also purposively selected due to their infrastructural accessibility, good agricultural weather conditions and fertile soils for agriculture and farming activities. Three wards were purposively selected per sub-county based on the number of tomato producers. The Wards in Nyeri were Kamakwa, Rware and Gatitu; while in Meru, the Wards were Kariene, Gatimbi and Katheri. The list of the tomato farmers was obtained from the Horticultural Crops Directorate offices. Farmers were randomly selected from the list and proportionate distribution of the farmers in all the locations was done to make a total of 31 respondents from every Ward.

3.6 Instrumentation and Data Collection

Data was collected using a structured questionnaire with both closed and open-ended questions (Appendix 2). Items in the data collection tool were developed based on the objectives of the study. The first part of the questionnaire was used to collect basic information on the socio-demographic characteristics of the population for example the respondent's age, education, gender and household size, membership in any farmer group, employment and land size, tomato production details such the varieties grown, pest and pest management, the quantity of inputs used, the quantity of produce harvested and the quantity sold and the prices sold at and the revenue generated. The second part was used to collect information on ICT awareness and use and the farmers' sources of pest and pest management information. Part three was used to collect tomato production information.

During the actual data collection, each household in the sample was visited to administer the questionnaire with Kiswahili used as the language of communication but in case the farmer did not understand Kiswahili, local language was used to further foster the understanding of the information sought. Respondents were contacted in person to give and foster the acquisition of more accurate responses. The questionnaires were administered by one enumerator in Nyeri County and two in Meru County using the KoBo Toolkit which is an android application.

3.7 Validity and Reliability of Data Collection Instruments

Validity and Reliability of data collection instruments are both about how well the instruments will collect the required data. Validity measures how well the results represent what they are supposed to measure while reliability whether results can be produced under the same conditions (Taherdoost, 2016). The enumerators underwent training on how to use the data collection toolkit and on the collection of the data. The tool was carefully pretested in a ward which had similar tomato production potential and social economic conditions as the targeted study areas. The tools were carefully pretested in a ward which had similar tomato production potential and social economic conditions as the targeted study areas. The tools were revised accordingly before the actual data collection. To measure the reliability of the questionnaire, Cronbach's alpha was run on 20 pilot questionnaires using SPSS. The results presented an internal consistency of 0.8 meaning that the research instruments were reliable.

3.8 Data Analysis

Data collected was entered into the Statistical Package for Social Sciences (SPSS) computer program. SPSS and STATA were used to analyse data as elaborated below:

Objective 1: To characterize the current information services for tomato pests and their management in the Central Highlands of Kenya

Qualitative and quantitative methods of data analysis were used with both descriptive as well as inferential statistics. Descriptive statistics helped the researcher to meaningfully describe the current pest information services, while inferential statistics was appropriate because they enabled the researcher to make inferences about the types of information services for instance ICT or non-ICT based, kind of information channeled through the services, language used, who passes the information through the services and if free or farmers are charged, based on the results of the representative sample. The descriptive statistics used were the frequencies, percentages, means and standard deviations. These statistics were presented in tables.

Objective 2: To assess farmer awareness and adoption of ICT-based pest information services in tomato pests and their management in the Central Highlands of Kenya

To handle data on this objective, descriptive statistics were used to evaluate the level of awareness of the ICT based pest information services, the perceptions that farmers have concerning these ICT based pest information services and the level of adoption of the ICT based pest information services by tomato farmers in tomato pest management.

Objective 3: To assess the determinants of and factors limiting the adoption of ICT-based pest information services by farmers in the Central Highlands of Kenya.

For this objective, binary dependent variable model approach was adopted to assess the determinants of adoption of ICT-based pest information services by farmers, in the first step. This was because adoption was measured as a binary variable with the values 1 (where the farmer adopted pest information service) and zero (where the farmer did not adopt the service). A Logit model was deemed appropriate to assess factors influencing adoption of ICT based tomato pest information services. A Logit model is specified as follows:

$$Pr(Y_i = 1|X_i) = \Phi(\beta_0 + X'_i\beta) \tag{3.3}$$

Where; $Pr(Y_i = 1|X_i)$ is the probability that a farmer (i) adopts ICT-based pest information services, given their characteristics (X); Y_i is a binary dependent variable with a value of 1 if a farmer adopts ICT-based pest information services and 0 otherwise. $\boldsymbol{X'_i}$ Is a vector of explanatory variables that include social-economic factors such as membership to groups and distance to nearest market, demographics, such as education levels. β_0 is the model intercept, while $\boldsymbol{\beta}$ is a vector of parameters to be estimated, measuring the effect of independent variables on awareness; and Φ is the logistic distribution function that ensures estimated probabilities range between 0 and 1. The Logit model assumes all independent variables are exogenous and follow a logistic distribution.

The second step adopted descriptive statistics to assess factors limiting adoption of ICT-based pest information services in tomato pest management as reported by farmers who did not adopt the services. The qualitative data used in the second stage was grouped into themes, analyzed descriptively and presented in a bar chart.

From the logistic model above, the following empirical models were derived;

$$Y_{ji} = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \cdots \beta_n X_{ni} + \varepsilon_i \qquad (3.4)$$

Where; for each farmer, i, $Y_j$is adoption of radio-based television-based, or mobile and internet-based pest information services, X_1 is the education level of the farmer, X_2 is gender, X_3 is age, X_4 is occupation, X_5 is language literacy, X_6 is distance to the nearest market, X_7 is access to nearest market, X_8 is household size, X_9 is membership to social group, X_{10} is perception of farmers towards radio-based information service, X_{11} is production system, X_{12} is the size of land, X_{13} is the tomato production area, X_{14} is a County dummy, β_0 to β_n are the coefficients to be estimated and ϵ is the random error term that is assumed to be symmetrically distributed about zero, independent of X follow logistic distribution.

$$Y_{ki} = \alpha_0 + \alpha_1 X_{1i} + \alpha_2 X_{2i} + \cdots \alpha_n X_{ni} + \varepsilon_i \qquad (3.5)$$

Where; for each farmer i, $Y_k$is the adoption of at least one pest information service, X_1 is the education level of the farmer, X_2 is gender, X_3 is age, X_4 is occupation, X_5 is language literacy, X_6 is distance to the nearest market, X_7 is household size, X_8 is membership to social group, X_9 is number of ICT tools owned, X_{10} is the perception of farmers towards radio-based information service, X_{11} is a County dummy, α_0 to α_n are the coefficient, ϵ is the random error term that is assumed to be symmetrically distributed about zero, independent of X follow the logistic distribution. The empirical models were estimated using Stata software, with robust standard errors to correct for possible heteroscedasticity.

3.9 Measurement of Key Variables

Table 3.1: Measurement and Description of Key Variables

Variables	**Description and/or measurement**
Dependent Variables (Y)	
Pest information service	Any agricultural service delivering information on pests and their management only or embedded in general crop production information package, through any information channel.
ICT-based pest information service	Agricultural service delivering information on pests and their management only or embedded in general crop production information package, through TV or radio programs/adverts, internet or mobile phone-based applications, online platforms (YouTube, WhatsApp, Facebook or Twitter) or digital storage devices such as CDs and flash disks.
Awareness of ICT-based pest information services	This was captured as a binary variable measured with a value of 1 for those farmers who are aware and 0 for those not aware.
Adoption of ICT-based pest information services	This is a binary variable that took a value of 1 for farmers who used an ICT-based pest information service in tomato production the season preceding the study, and 0 for those who did not use.

Independent/ explanatory variables	
Formal education	This will be measured by asking respondents their highest level of education i.e. none, primary, secondary, college and university.
Age	This is a continuous variable that gives the age of the respondent in years.
Household size	This is a continuous variable that gives the number of people living in the household
Gender of household head	Gender of the person most responsible for household decisions especially those relating to farming. The variable takes value of zero if household head is female and 1 if male.
Gender	If respondent is male=1 and 0= female.
Member to social group	Captured membership to any social group and took a value of 1 if respondent or any household member is a member to any social group
Distance to market	Distance to nearest agricultural market in km
Adopted any ICT-based pest information service	1= if a farmer adopted ICT-based pest information service 0= otherwise

3.10 Ethical Considerations

An introductory letter was obtained from the Graduate School of the Machakos University to facilitate acquisition of a research permit from the National Commission for Science, Technology and Innovation (NACOSTI) (Appendix 1). The permit enabled the researcher to carry out the study among farmers in Nyeri Township and Imenti Central sub-counties. In the study areas, authority to conduct research was sought from the local chiefs and the assistant chiefs. At the household level, the enumerators sought the consent of the farmers to interview them through explaining the purpose of research and assuring them that the information would be treated with utmost confidentiality.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the results of the study and discussions. It starts with the description of the sample which includes the description of the demographic and household characteristics of the sampled farmers. The chapter also describes the characteristics of the existing information services for tomato pests and their management, including the non-ICT service providers and ICT-based services that are known by the farmers. The awareness and use of the non-ICT and ICT tools in tomato pest management is assessed and presented. Lastly, the chapter presents the adoption of ICT-based pest information services together with the factors influencing and those limiting the adoption of the ICT-based pest information services tomato farmers.

4.2 Description of the Sample

Table 4.1 presents a description of the variables used in the study and descriptive statistics of the sample. The study targeted a sample size of 195 tomato farmers across the Meru and Nyeri counties. Out of this target, 170 farmers filled the questionnaire fully, which represent 87% response rate. Of total sample, 97 farmers were from Meru County, representing 57% of the total sample, while 73 farmers were from Nyeri County which represents 43%.

About 54% of the sampled farmers were male while 46% were female. The average age of the farmers was 37 years, implying that tomato farmers were relatively youthful. The farmers were fairly literate, with 15.3% having attained university education, 27% other tertiary/vocational education, 29.4% secondary education, and 27% primary education. Only 1.1% of farmers had no formal education. In Meru County, respondents mainly had tertiary and university education while in Nyeri, majority had secondary education. The differences in university education level were significant between the two counties at a p-value of 5%. The other levels of education had no significant difference between the two counties at 5% significance level. The data also shows that tomato farmers participated in farmers' associations.

Table 4.1: Descriptive Statistics of the Sample (N=170)

Variable	Description	Statistics	
		Mean	*Standard Deviation*
Age	Age of a farmer in years	37.08	9.95
Hhsize	Number of household members	5.13	4.52
Distroad	Distance to the nearest all weather road(km)	4.11	3.31
Distmkt	Distance to market (km)	5.84	5.55
Distxt	Distance to the nearest extension office (km)	8.81	3.65
Landfull	Full land size	2.25	1.72
Landtom	Land under tomato production	1.33	1.15
ICT tools	Number of ICT tools owned	3.66	1.02
		Frequency	*%*
Male	Farmer is male (0=No; 1=Yes)	91	53.5
Female	Farmer is female (0=No; 1=Yes)	79	46.5
Membfarm	Farmer is a member of a farming group	49	28.8
Membtom	Farmer is a member of tomato farming group	31	18.2
Membvirt	Farmer is a member of a virtual farming group	133	78.2
Electricity	Household is connected to electricity	159	93.5
Formal education level			
Noeduc	No formal education	2	1.1
Primary	Up to primary level	46	27.0
Secondary	Up to secondary level	50	29.4
Tertiary	Up to tertiary/vocational level	46	27.0
University	Up to university level	26	15.3
Main occupation			
Nowork	Farmer has no occupation	6	3.5
Farming	Main occupation is farming	68	40.0
Formal emp.	Main occupation is formal employment	53	31.7
Self emp.	Main occupation is self-employment	27	15.9
Casual emp.	Main occupation is casual employment	16	9.4

About 18.2% belonged to a farmer group dealing with tomato farming and 78.2% in a virtual group dealing with farming in general. The sampled farmers owned an average of 2.25 acres of which 1.33 acres were put under tomato production. Forty percent of the respondents have farming as their main occupation while 31.7% are in formal employment. However, more than 52% of the respondents have farming as their secondary occupation. Ownership of ICT tools was fairly high. More than 90% of the respondents reported to own television and radio while around 64% and 57% owned smart phones and feature phones respectively. On average, a household owned about four ICT tools.

Farmer ability to communicate in languages commonly used by ICT-based pest information services (local language, Kiswahili and English) was assessed by asking the farmers how well they could understand, read, write or speak the languages. Results from analysis of this data are presented in Table 4.2. The results show that all tomato farmers in Nyeri understand local language well while 98% of Meru farmers understand local language. More than 70% of the farmers in Meru County understand Kiswahili very well while less than half of the farmers in Nyeri County understand Kiswahili very well. In Meru County, 44% of the tomato farmers understand English very well while just 15% understand English very well in Nyeri. More than 60% of tomato farmers in Meru are able to read and write fluently in local language while slightly more than 90% can fluently read and write in local language in Nyeri.

All farmers in Nyeri can speak the local language very fluently compared to 97% in Meru. Conversely, in Meru, 44% can speak English very fluently compared to just

15% in Nyeri. The differences in language literacy between farmers from Nyeri and Meru can be largely attributed to the education status of these farmers. This is because, 25% of the farmers in Meru attained University education compared to 1.4% of Nyeri. Also, 28% attained vocational/college education as compared to 24% in Nyeri. These differences also imply that farmer preference for different ICT-based pest information services could differ since different information services use different languages. Overall, more than 44% of farmers have little or no understanding of English, implying that information services using English as the language of service delivery may not benefit a large proportion of farmers.

Table 4.2: Farmer Ability to Communicate in Local Languages, Kiswahili and English (% of farmers)

Understanding, reading, writing, speaking	County/Language								
	Nyeri			Meru			Sample		
	Local	Kiswahili	English	Local	Kisw	Eng.	Local	Kisw.	Eng.
Level of understanding									
Zero	0.0	0.0	0.0	0.0	2.1	8.2	0.0	1.2	4.7
A little	0.0	4.1	39.7	0.0	8.2	21.6	0.0	6.3	39.7
Average	0.0	49.3	45.2	2.1	18.6	25.8	1.2	31.8	45.2
Very well	100	46.6	15.1	97.9	71.1	44.3	98.8	60.6	15.1
Fluency of Reading/Writing									
Zero	2.7	4.1	21.9	6.2	6.2	16.5	4.7	5.3	18.8
A little	0.0	24.7	19.2	16.5	15.5	15.5	9.4	19.4	17.1
Fluent	6.8	30.1	43.8	9.3	15.5	25.8	8.2	21.8	33.5
Very Fluent	90.4	41.1	15.1	68.0	62.9	42.3	77.6	53.5	30.6
Fluency of Speaking									
Zero	0.0	0.0	9.6	0.0	2.1	16.5	0.0	1.2	13.5
A little	0.0	17.8	30.1	0.0	16.5	13.4	0.0	17.1	20.6
Fluent	0.0	38.4	45.2	2.1	13.4	25.8	1.2	24.1	34.1
Very Fluent	100	43.8	15.1	97.9	68.0	44.3	98.8	57.6	31.8

4.3 Characteristics of Current Information Services for Tomato Pests and their Management

4.3.1 Non-ICT-based Pest Information Services

Tomato farmers were asked if they are aware of any non-ICT-based tomato pest information service providers available in the study area. The findings show that majority of farmers are aware of different providers of agricultural and pest information, whereby this level of awareness differed across the study areas (Table 4.3). The most widely known non-ICT-based pest information service providers were: other farmers (83%), agro-dealers (82%), public agricultural extension officers (47%) and agro-chemical sales representatives (31%). This shows a declining role of public extension services, which have been attributed to inadequate extension officers and low budgetary allocation by the government towards the extension sector (Ali-Olub *et al*., 2011). It also shows the growing prominence of social networks and agro dealers in provision of agricultural information services. This can be explained by the fact that these agro dealers have economic incentive of spreading the information as they stand to reap benefits by interacting and sharing information with farmers (Bold *et al*., 2017).

A higher proportion of famers in Meru were aware of the other farmers, agro dealers and public extension agents as sources of pest information, while a higher proportion of farmers in Nyeri were more aware of agro-chemical sales representatives. Farmers obtained information mostly from other farmers because it is free to talk to a fellow farmer and ask questions concerning the crops. Also, more inclusive, low-cost, effective, and offer a wide-reaching alternative in supporting agricultural innovation (Lukuyu *et al*., 2012). Some of the youthful farmers had up to university education some even specializing in agriculture and as such, they had knowledge that they freely disseminate to other farmers.

Through the agro dealers, farmers ask questions when they go to purchase farming inputs such as pesticides. The agro dealers will educate the farmers on for instance the best chemical to use to control a certain pest or disease. Agrochemical sales representatives, in their quest to make sales, pass information to the farmers concerning their chemicals and the pests or diseases that they control. For the public extension officers, the farmers obtain information through the visits of the officers to their farms and during farmer field days when they get to be educated and enlightened on different aspects of farming. Farmers also get to ask the extension any questions or concerns they have during these visits.

The least known and accessible non-ICT-based sources of pest information were Horticultural Crops Directorate (HCD) officers (18%), private extension (5%), plant clinics (5%) and Non-Governmental Organizations (NGOs) (2.4%). HCD officers, private extension agents and NGOs were better known by tomato farmers in Meru County, while plant clinics were known more by farmers in Nyeri County.

Table 4.3: Non-ICT-based Pest Information Providers Known by Farmers

Pest information service provider	Overall		Nyeri		Meru	
	Frequency	**% of users**	**Frequency**	**% of users**	**Frequency**	**% of users**
Other farmers	141	82.9	54	73.9	87	89.7
Agro dealers	139	81.8	54	73.9	85	87.6
Public extension	90	47.1	17	23.3	73	75.3
Agro-chemical sales representatives	52	30.6	35	47.9	17	17.5
HCD Officer	30	17.6	0	0.0	30	30.9
Private extension	9	5.3	0	0.0	9	9.3
Plant Clinics	9	5.3	7	9.6	2	2.1
NGO Extension Officers	4	2.4	0	0.0	4	4.1
N	170		73		97	

4.3.2 Ownership of ICT-based Tools and Information Services by Farmers

Farmers were asked if they owned the most commonly used ICT tools and the results are shown in Table 4.4. Overall, mobile phone, radio and television were the most owned ICT tools with 100%, 94% and 90% ownership, respectively. More than 63% and 57% farmers reported to own smartphones and feature phones respectively. A higher proportion of farmers own smartphone in Meru County (70.1%) than Nyeri (54.8%), while ownership of feature phones was higher in Nyeri than in Meru, implying regional differences. This implies that mobile-based information services can reach most tomato farmers although this will depend on the language and platform used, given that 36.5% of the farmers did not own a smartphone. Overall ownership of computers, satellite dishes and internet devices were minimal, and differed significantly between the two counties.

Table 4.4: Ownership of ICT-based Tools and Information Services by Farmers

ICT-based Tool	Overall		Nyeri		Meru	
	Frequency	**%**	**Frequency**	**%**	**Frequency**	**%**
Radio	160	94.1	70	95.9	90	92.8
Television	153	90.0	73	100.0	80	82.5
Smart Phone	108	63.5	40	54.8	68	70.1
Feature Phone	97	57.1	57	78.1	40	41.2
Any phone	170	100	97	100	73	100
Laptop computer	39	22.9	2	2.7	37	38.1
Desktop computer	4	2.4	0	0.0	4	4.1
Any computer	39	22.9	2	2.7	37	38.1
DVD/CD Player	51	30.0	22	30.1	29	29.9
Satellite Dish	4	2.4	1	1.4	3	3.1
Internet Device	6	3.5	0	0.0	6	6.2

4.3.3 Use of ICT-based Tools to Access Agricultural Information

Farmers were asked if they used ICT tools to access agricultural information. Results show that overall, 44% of the farmers used radio to access general agricultural information while 35.9% of the farmers used television for accessing the agricultural information they need (Table 4.5). Smartphone and feature phones are respectively used by 35.9% and 21.8% of the farmers. More than a half (54.8%) of farmers in Nyeri use radio with only 36% using radio in Meru, to access agricultural information. Farmers reported to be using both the smart phones and feature phones in different ways to access agricultural information. Farmers sent messages and made calls to other farmers to ask questions and get information from other farmers using both the smart phones and feature phones.

Furthermore, through the use of smart phones, farmers could access the internet and get information from social media platforms such as Facebook, WhatsApp, and Google, for different websites and mobile applications. No farmers used desktops or DVD players to access any agricultural information. These results show lower levels of use of ICT tools in accessing agricultural information, compared to ownership levels, implying that not all farmers who owned ICT tools actually used them to access agricultural information.

Table 4.5: Use of ICT-based Tools to Access Agricultural Information

ICT-Tool	Overall Frequency	%	Nyeri Frequency	%	Meru Frequency	%
Radio	75	44.1	40	54.8	35	36.1
Television	61	35.9	17	23.3	44	45.4
Smart Phone	61	35.9	25	34.2	36	37.1
Feature Phone	37	21.8	28	38.4	9	9.3
Laptop	10	5.9	0	0.0	10	10.3
Desktop	0	0.0	0	0.0	0	0.0
DVD/CD Player	0	0.0	0	0.0	0	0.0
Satellite Dish	1	0.6	0	0.0	1	1.0
Internet Device	2	1.2	0	0.0	2	2.1

4.4 Current ICT-based Pest Information Services

Several ICT-based pest information services existed in the study areas. These included radio programs, television programs, and mobile and internet-based services such as SMS-services, WhatsApp, YouTube, Facebook and the internet as elaborated below;

4.4.1 Radio Programs:

The radio programs that were reported to be used in accessing agricultural pest information include: *Murimi Njorua* (smart farmer), *Kuonjorithia Urimi-ini (*prosperity in farming) and *Mugambo Wa Murimi* (voice of the farmer). Several radio stations usually broadcast different types of agricultural information from land preparation to sale of output, through these programs. Farmer awareness of these radio stations is shown in Table 4.6.

Table 4.6: Farmer Awareness of Different Radio Stations that Air Agricultural Programs

Radio Station	Overall		Nyeri		Meru	
	Frequency	%	Frequency	%	Frequency	%
Inooro FM	116	68.2	73	100	43	44.3
Kameme FM	71	41.8	46	63.0	25	25.8
Rware FM	25	14.7	23	31.5	2	2.1
Muga FM	79	46.5	1	1.4	78	80.4
Thiiri FM	39	22.9	1	1.4	38	39.2
Mwariama FM	7	4.1	0	0.0	7	7.2

Note: *Rware* FM, *Inooro* FM *and Kameme* FM are local radio stations affiliated to Kikuyu language while *Thiiri* FM, *Muga* FM and *Mwariama* FM are affiliated to Meru language. This explains the differences in awareness between the different radio stations between the two counties.

A description of the radio stations and agricultural programs they broadcast is given below:

1. *Rware FM* - this station airs its programs within Nyeri County and its outskirts and has an estimated audience of 35,000 people in the County. The study showed that in overall, 14% of the farmers were aware of this station with 31% in Nyeri and 2% in Meru County. The station airs the *Murimi Njorua* program (Smart Farmer) every Thursday at 8.00pm. The program is aired using the local language

(kikuyu). Besides this program, the radio station has partnered with the Department of Agriculture, Livestock and Fisheries of the Nyeri County Government, with the aim of obtaining the necessary agricultural information from the department and broadcasting it to farmers. This station airs the program with the help of agricultural experts and extension officers in the County who are often brought to the station to answer questions from the farmers and offer the necessary agricultural information, ranging from land preparation to harvesting and all the management practices in between such as pest and pest management. The radio station also partnered with the *Kilimo Media International (KIMI)* which visits farmers and offers necessary training to the farmers in the County. Additionally, the station airs a program known as *Kuonjoithia Urimi-ini* (prosperity in farming) every Thursday at 10.00am, which is replayed the same day after the 7.00pm news. The program aims to address the challenges faced by farmers in their farming activities some of which are pest and diseases; and to boost their income. The program uses farmers to help other farmers with the necessary information.

2. *Inooro FM* - this is also a Kikuyu station located in Nairobi. The word *"inooro*" means to sharpen and as such, the main aim of the station is to sharpen the listeners mind so as to empower them to face their daily challenges. Overall, 68% of the farmers are aware of the station, with all the farmers in Nyeri being aware and 44% in Meru. The station airs an agricultural program known as the *Mugambo Wa Murimi* (voice of the farmer) every Tuesday at 8.20pm. The

program brings on board experts in different areas of agriculture and different agricultural value chains to educate farmers on different management practices.

3. *Muga FM*- this is a radio station in Meru County and broadcasts from Nairobi. The radio station went into a partnership with KIMI with the aim of offering audio training to farmers. The station brings on board speakers who specialize in different agricultural activities to broadcast essential information and answer questions from farmers. However, there is no particular program that is aimed at providing agricultural information.

4. *Thiiri FM* is a local language radio station in Meru County. The station has also partnered with KIMI, whereby the station visits different farmers in the county and conducts interviews with the farmers concerning their agricultural endeavors. Only 22% of the farmers are aware of the station and its programs, with slightly 1% in Nyeri and 39% in Meru.

5. *Kameme FM* is a local language radio station in Kikuyu language. The radio station used to air a program known as *Kayu ka Murimi* which was rival to *Inooro's Mugambo wa Murimi* but unfortunately due to inconsistency of the program, it became defunct. The overall awareness of the radio station is at 41% with Nyeri having the highest awareness of 63% compared to 25% in Meru County.

6. *Mwariama FM* is a Kimeru local radio station based in Meru County. This station doesn't have any agricultural programs; however, it broadcasts adverts of different inputs that can be used to improve farming of different crops. Its awareness level is at 4% with 7% of the farmers in Meru being aware of the station, but no farmer in Nyeri was aware of the station.

4.4.2 Television Programs

The television programs that broadcast agricultural information in the study areas were; Shamba Shape-up, Seeds of Gold, KTN Farmers TV program (Table 4.7). These programs are aired by different television stations that broadcast in the study areas, as described below.

1. *Citizen Television*- this is a national television station which airs programs in the two national languages: Kiswahili and English. Citizen television airs a program known as *Shamba Shape Up* every Saturday and Sunday at 1:30pm. The program is a recorded show, whereby the hosts visit different farmers and help them solve the issues that they may be experiencing in their farms. The show airs in Kiswahili language. This study found that 54.7% of the farmers were aware of the *Shamba Shape Up* program, with Meru having a higher level of awareness (66.0%) than Nyeri (39.7%).

2. *NTV Kenya*- this is a national station that airs the program of *Seeds of Gold*. The program airs at 10:00pm on Wednesdays and it covers different groups of youths

dealing with different agricultural activities and products with the aim of enlightening other people who want to venture into agriculture. Farmer awareness of the *Seeds of Gold* was low at 7.1% of sampled farmers and higher in Nyeri (4.1%) than Meru (9.3%).

3. *KTN Farmers TV*- this is a television station which specializes in agriculture and agribusiness programs. The station broadcasts in Kiswahili and English languages with the aim of bringing to the attention of farmers, the different issues and solutions that farmers face in their daily agricultural activities. Most farmers (58.8%) were aware about the TV Station and the level of awareness was almost the same in both counties as shown in Table 4.7.

Table 4.7: Awareness of TV Stations and Programs that Air Agricultural Information

TV Program	**Overall**		**Nyeri**		**Meru**	
	Frequency	%	Frequency	%	Frequency	%
KTN Farmers TV	100	58.8	42	57.5	58	59.8
Mugambo Wa Murimi	121	71.2	73	100	48	49.5
Shamba Shape-up	93	54.7	29	39.7	64	66.0
Seeds of Gold	12	7.1	3	4.1	9	9.3
TV Adverts	28	16.5	17	23.3	11	11.3

4.4.3 Mobile Phone- and Internet-based Pest Information Services

The study found that farmers know about social media platforms, with WhatsApp being the most widely known (49.4%) followed by Facebook (48.8%), YouTube (22.4%) and Twitter (17.6%). Generally, farmer knowledge of all social media apps was higher in Meru than Nyeri. The farmers were also aware of several mobile phone applications used for dissemination of agricultural information, including MoA-INFO, *iShamba* SMS services and *Ujuzi Kilimo*, which were known by 31.2%, 10.6% and 2.4% of the farmers, respectively. Nyeri farmers reported more knowledge of *Ujuzi Kilimo* and MoA-Info than their Meru counterparts.

Facebook – The use of Facebook by farmers has enabled them to access agricultural information through various groups and links such as Mkulima Young (https://www.mkulimayoung.com/), Young Farmers, Market, Digital Farmers Kenya and Mkulima Hub Kenya. In these groups, farmers get to interact with other farmers and even specialists from all walks of life and exchange agricultural information concerning different aspects of farming. Also, links to new articles, feedback, information and answering of queries are often shared through these Facebook groups. The information can be accessed in English or Kiswahili languages (Rhoades & Aue, 2010). The study revealed that 60% of the farmers who used Facebook to access agricultural information were below the age of 40 years. This shows that young farmers used the platform more because they have knowledge of maneuvering the platform. Rhoades and Hall (2007), noted that there was a large presence of blogs in Facebook covering topics on agriculture.

WhatsApp – the smartphone users spend considerably more time on WhatsApp platform than any other social media platform. In a recent study, Naruka *et al*. (2017), it was noted that more than 70% of the farmers use WhatsApp to get agricultural information from other farmers, connecting with experts, sharing professional agricultural information and finding agriculture related interests. This study shows that 67% of farmers in Meru use WhatsApp as compared to the 26% in Nyeri. All these differences in the use of internet-based platforms between famers in the two counties can be explained by the level of education and the age of the farmers as discussed on the demographic differences. Table 4.8 presents findings on farmers' awareness about mobile-based information sources.

YouTube – With YouTube, farmers get agricultural information by watching videos posted there by different institutions for example the FAO, organizations such as the Consultative Group on International Agricultural Research (CGIAR) and even the Ministry of Agriculture. YouTube uses English language to disseminate information and requires internet connectivity which is usually costly. A study that was aimed at evaluating the impact of social media on agricultural extension in Kenya by Kipkurgat *et al*. (2016), found that many agricultural institutions in Kenya have incorporated social media in their information systems. For instance, the Agricultural Information Resource Center has Facebook and YouTube platforms while the Ministry of Agriculture through the KALRO use YouTube to disseminate videos about any agricultural events at their institutions. However, this study found low awareness of You Tube services as a source of agricultural information, as reported by 35% of farmers in Meru County and 6% in Nyeri County (Table 4.8).

Table 4.8: Farmers' Awareness of Mobile and Internet-Based Information Sources

Platform/Service	**Overall**		**Nyeri**		**Meru**	
	Frequency	%	Frequency	%	Frequency	%
Facebook	83	48.8	15	20.5	68	70.1
WhatsApp	84	49.4	19	26.0	65	67.0
MoA-info Service	53	31.2	31	42.5	22	22.7
You tube	38	22.4	4	5.5	34	35.1
Twitter	30	17.6	0	0.0	30	30.9
iShamba SMS Service	18	10.6	2	2.7	16	16.5
Mobile Application	13	7.6	2	2.7	11	11.3
Online storage	4	2.4	1	1.4	3	3.1
Ujuzi Kilimo	4	2.4	2	2.7	2	2.1

Note: MoA means Ministry of Agriculture, Livestock and Fisheries

MoA-INFO - Ministry of Agriculture SMS Services – the SMS service was launched by the Kenyan Ministry of Agriculture in 2018 with the aim of enabling farmers to access information on fall army worm (*Spodoptera frugipedra*) countrywide directly on their mobile phones without necessarily having to seek for the information from government offices. However, the service is currently used by the farmers to obtain any agricultural information for different value chains, among tomato production. Farmers just need to SMS the word “FARM” or “SHAMBA” to 40130 and get timely information on monitoring, identification, non-chemical and chemical pest control measures in either English or Kiswahili and the service is free of charge. The service is used more in Nyeri than Meru and this can be explained by the fact that in Meru, most of the farmers use the internet-based platforms such as the Facebook and WhatsApp. The use of Twitter, iShamba services, mobile applications, and Ujuzi Kilimo and Online Storage platforms was not significant in both counties as seen on Table 4.8 above.4.4.5

4.5 Farmer Perception on Information from ICT-based Pest Information Services

To assess farmer perception on information disseminated by the various ICT-based pest information services, farmers were asked to state the extent to which they trusted the information acquired through ICT tools. Table 4.9 shows that only 20.6 % of the farmers trusted/strongly trusted the information obtained from ICT-based pest information services while 74.1% did not trust nor distrust the information. According to a study by Aldosari *et al*. (2019) that aimed at identifying the perception of farmers in Pakistan, 37% of the farmers strongly trust information from ICT sources. The findings of this study show that 33% of farmers in Meru had a higher level of trust towards ICT-based information sources, compared to 1.4% farmers in Nyeri. This difference is significant with the comparison made on the basis of the overall statistics. This result implies that farmer adoption of pest information disseminated through ICT-based services may, to a large extent, be constrained by how they perceive or trust the information from such sources. A study focusing on the perception of farmers towards ICT in Nigeria by Ajayi *et al*. (2018), found that only 8% of the farmers had a positive perception towards ICT.

Table 4.9: Perception of Farmers on Information from IBPIS

Level of trust	**Overall**		**Nyeri**		**Meru**	
	Frequency	%	Frequency	%	Frequency	%
Distrust	9	5.3	6	8.2	3	3.1
Neutral	126	74.1	66	90.4	60	61.9
Trust	33	19.4	1	1.4	32	33.0
Strongly Trust	2	1.2	0	0.0	2	2.1

4.6 Awareness and Adoption of IBPIS in Tomato Production

To evaluate the awareness of the farmers towards the ICT-based pest information services, farmers were asked whether they knew any agricultural radio program, TV program or mobile/internet-based information pest services and the results are as shown in Table 4.10. The results show that all the farmers in both Meru and Nyeri were aware of at least one radio program that broadcasts agricultural pest information. All farmers in Nyeri are aware of at least one television program that airs agricultural pest information compared to 86.6% of the farmers in Meru. However, the awareness of mobile and internet-based services was significantly higher ($p<0.05$) in Meru than Nyeri.

Table 4.10 Awareness of at least one IBPIS by Farmers

ICT-based pest information service	Overall Frequency	%	Nyeri Frequency	%	Meru Frequency	%
Radio Programs	170	100	73	100	97	100
TV Programs	157	93.3	73	100	84	86.6
Mobile & internet-based services	142	83.5	48	65.8	94	96.9

For the adoption, farmers were asked whether they had used information from ICT-based pest information services to manage pests in tomato production in the season preceding the survey and the results are presented in Table 4.11. The results show that overall; 48.2% of the farmers had used information from at least one ICT-based pest information service for tomato pest management. The most used information service was radio programs (34.1%), followed by TV programs (30.6%) and mobile and internet-based information services (MIBIS) (28%). A higher proportion of farmers in

Meru reported having used information acquired through TV (37%) and MIBIS (35%) in pest management, against 21% and 19% of farmers in Nyeri, respectively. Agricultural and pest information through radio programs was mostly useful in tomato production for farmers in Nyeri (40%) compared to 30% in Nyeri County.

Table 4.11 Adoption of Information from IBPIS

Pest Information Service	Overall		Nyeri		Meru	
	Frequency	**%**	**Frequency**	**%**	**Frequency**	**%**
Radio Programs	58	34.1	29	40.0	29	29.9
Television Programs	52	30.6	16	21.9	36	37.1
Mobile and Internet-Based	48	28.2	14	19.2	34	35.1
At least one	82	48.2	35	48.0	47	48.5

The use of the information from the named ICT-based pest information services in tomato farming is low in Kenya compared to other countries. For instance, a study by Mtega (2018) that aimed at analyzing the usage of radio and television in Tanzania shows that 61% of the farmers used information from radio while 48% used mobile-based information compared to the 34% and 28% of radio and mobile-based reported in this study. Another study by Kiptum (2016), that aimed to determine parameters suitable for the establishment of an ICT-based framework for adoption in the dissemination of agricultural information among farmers in Kenya, found that the proportion of farmers who were using information from mobile phones was 48%, while information from radio was used by 13.7% of farmers and information from television was used by 7.8% of the farmers. Comparing these percentages with the findings of this study, it shows that the use of information from ICT-based sources especially radio and TV has increased over the years due to increased reliance on other farmers as the source of information. A recent study in India that was aimed at evaluating the extent of use of ICT tools in obtaining agricultural information found that 48% farmers use radio, 54% use television and 69% use mobile-based internet sources (Mishra *et al*., 2020). These findings contradict the findings of this study, which found that radio is the most commonly used ICT device while MIBIS is the last.

4.7 Determinants of Farmer Adoption of ICT-based Pest Information Services

Table 4.12 shows the result of the Logit regression on determinants of use of ICT-based tomato pest information services. The results show that the level of education had a significant ($p<0.05$) negative influence on the use of radio-based sources of pest information services. The coefficients show that as the level of education of the farmer goes up, the less likely the farmer will adopt the radio-based pest information services. This can be explained by the fact that; with more education, the individual gains knowledge and understanding of various sources of information, such as internet-based sources. A study by Nwokoye *et al*. (2019), similarly found that among rice farmers in Nigeria the education attainment of the farmer had a negative influence on the adoption of ICT technologies.

Our findings show that gender of the farmer had a significant ($p<0.01$) positive influence on the use of pest-information services acquired through radio programs, TV programs and MIBIS. This implies that male farmers were more likely to use pest information acquired from ICT than their female counterparts. Wawire *et al*. (2017), similarly found that male farmers were more likely to use ICT tools to acquire agricultural marketing information in Kenya. Evidence shows that women are less likely to own, access or use ICT and digital platforms (Kuroda *et al*. 2019) because of low access to resources, low levels of education, and time limitations due to gender-related responsibilities at household and community levels (Ngigi *et al*. 2017). Krell *et al*. (2021) found that mobile use and other mobile-based services are lower among women due to limited technical knowledge, perceptions of internet use, and cost of ownership and use.

The findings further show that membership to any social group had a significant ($p<0.1$) positive influence on the use of pest information acquired through MIBIS and radio and its influence is significant at a 10% significant level. This means that, if a farmer is a member of any social group, the farmer is more likely to adopt MIBIS and radio-based information services. This can be explained by the fact that the farmer is influenced by other members of the group to use information from MIBIS and radio. These findings are consistent with recent research in Kenya (Wawire *et al*. 2017; Katunyo, 2019) who found that social groups and farmer groups increase awareness and information dissemination that influence likelihood of ICT use in agricultural value chains. A recent study in Vietnam discovered that membership in social groups and trust in ICT-based information sources positively influenced ICT adoption among intensive shrimp farmers (Ulhaq *et al*., 2022).

Current study shows that the size of land owned by the farmer had a significant negative influence on the adoption of ICT-based pest information services by tomato farmers. The larger the size of land, the lower the probability of the farmer to adopt any ICT-based pest information service. The bigger the size of land, the lower the likelihood of the farmer of adopting radio and MIBI at 5% and 1% significant levels. However, this variable doesn't influence the adoption of television pest information services by the farmer. Ali (2012), similarly found that farmers with small farms were more likely to use ICT-based information to make farming decisions. However, tomato production area had positive and significant influence on adoption of MIBIS. Similarly, Chandio and Yuansheng (2018), found that production area had a positive influence on adoption of ICT by rice farmers in Pakistan.

We have found out that production system that a farmer adopts has a negative influence towards the adoption of ICT-based pest information services. Farmers producing tomato under greenhouse were less likely to adopt overall ICT, radio programs and MIBIS, as compared with farmers under open field production systems. This could be attributed to less pest pressure since greenhouse technology physically restricts entry of pests into the production area hence most farmers may not require pest information. A study that was aimed at identifying factors that affect the adoption ICT adoption in agriculture in Italy, found out that the greenhouse production system negatively influences adoption of any ICT technology ($p>0.01$) (Bucci *et al*., 2019).

The results from this study indicate that main occupation of the farmer positively influences the adoption of MIBIS and radio-based pest information services. This implies that tomato farmers with off farm employment can earn more income with which to purchase and maintain the ICT tools for instance airtime, data bundles, hence access information services that increase likelihood of adoption.

Perception of the farmer also influenced the adoption of ICT-based pest information services. The results show that, as the trust of the farmer increases towards the information, the more likelihood of the farmer to adopt television-based pest information service. Abdullahi *et al*. (2021), found that adoption of ITC-based information services was mainly inspired by the insights the farmer has towards ICT. Another study by Nwokoye *et al*. (2019) that was aimed at analyzing the socioeconomic factors that determine the adoption of ICT among rice farmers in Nigeria found out that the perception of the farmer towards the ease of use of ICT was a major determinant of adoption.

Transport to the market also influence adoption of any ICT-based pest information services. Increase in the transport cost to the market significantly ($p<0.05$) influences the adoption of MIBIS at 5% significance level. A recent study by Katunyo (2019), found that the higher the transport cost to the market, the more likely a youth will use ICT. The study further found that the farmers who are located far from the market are more likely to use ICT-based information services.

The number of ICT tools owned had a positive influence on adoption of at least one ICT-based pest information services at a significance level of 0.05. This implies that as the number of ICT tools owned by a farmer increase, the likelihood of the farmer to adopt at least one ICT-based pest information service increases. A recent study by Aminou *et al*. (2018), similarly found that as the number of ICT tools owned by a farmer increases, so does the likelihood of adoption of the agricultural information services provided by these tools.

Table 4.12 Logit Regression Results on Determinants of Use of IBPIS

Variable	Used pest information from any ICT (4)	Used pest information from radio (1)	Used pest information from TV (2)	Used pest information from MIBIS (3)
Farmer is male	0.638	1.197***	0.941**	1.661***
	(0.413)	(0.413)	(0.443)	(0.622)
Farmer age (years)	0.002	-0.006	-0.015	0.002
	(0.012)	(0.021)	(0.018)	(0.028)
Household size	0.087	0.058	-0.049	-0.046
	(0.137)	(0.121)	(0.090)	(0.073)
Formal education level				
Secondary	-0.896	-1.769**	0.365	0.325
	(0.643)	(0.899)	(0.781)	(0.913)
Vocational/college	-1.085	-2.580**	0.541	0.532
	(0.807)	(1.040)	(0.934)	(0.982)
University	-1.482	-1.920	0.480	0.555
	(1.203)	(1.363)	(1.235)	(1.182)
Farmer understanding of English				
Average	0.020	-0.429	-0.078	-0.324
	(0.345)	(0.717)	(0.705)	(0.772)
Very well	0.176	0.693	0.388	0.299
	(0.454)	(0.851)	(0.873)	(0.997)
Membership to a social group	0.995	1.435*	0.774	1.969*
	(0.694)	(0.773)	(0.621)	(1.152)
Transport cost to main market (KSh)	0.011*	0.013	0.009	0.044**
	(0.006)	(0.012)	(0.012)	(0.019)
Size of land owned	-0.103	-0.307*	-0.056	-0.640***
	(0.176)	(0.181)	(0.183)	(0.245)
Tomato production area	0.200	0.096	0.177	0.363**
	(0.181)	(0.174)	(0.158)	(0.183)
Greenhouse production system	-1.253*	-1.124	-1.639**	-1.990**
	(0.658)	(0.830)	(0.703)	(0.809)
Off-farm employment	1.190**	1.906**	0.390	1.334**
	(0.568)	(0.744)	(0.561)	(0.617)
Trust on information from ICT sources				
Neutral	-0.170	-0.354	0.256	-1.270
	(0.953)	(0.687)	(1.076)	(1.195)
Trust/strongly trust	1.707	.	2.021*	1.274
	(1.173)	.	(1.217)	(1.364)
Number of ICT tools owned	0.468**			
	(0.223)			

Nyeri County	0.189	0.594	-0.099	-0.161
	(0.223)	(0.431)	(0.485)	(0.589)
N	170	161	170	170
Prob > chi2	0.001	0.016	0.006	0.001
Pseudo R^2	0.240	0.227	0.216	0.408

Note: Marginal effects; Robust standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. The base dummy for education of the farmer is primary education and below.

4.8 Factors Limiting the Adoption of IBPIS

The factors that were inherent in majority of the farmers as limiting their adoption of ICT-based pest information services were:

1. Farmers not requiring the pest information – this was cited by more than half of the non-adopters of radio and of non-adopters of TV pest information services and 34% of non-adopters of MIBIS. This may have been occasioned by farmers having accessed pest information in the past or not having encountered any pest challenge that they could not handle. In addition, some of the farmers could also have accessed information from non-ICT-based service providers such as other farmers, extension officers and agro dealers. Mtega (2018) found out that 97% of the farmers get information from other farmers which explain why farmers might not be needing information from ICT-based pest information services.

2. Poor timing of information services/programs - lack of convenience in timing of delivery of the information for the farmers was reported by 35% and 45% of the no-adopters of radio and TV-based pest information services, respectively. Write a statement or so on the issue of timing when it comes to delivery of information through broadcast media. In a study that sought to investigate the usage of radio and television as sources of agricultural knowledge among farmers in Tanzania by

Mtega (2018) found out that to improve the adoption of ICT-based pest information services, the service providers should enhance timely dissemination of needed knowledge. The study also found out that more than half of the farmers prefer evening broadcasting of the relevant agricultural information.

3. Lack of ownership of ICT devices- as reported by 40% of the non-adopters, lack of ownership of mobile phones was reported to limit the adoption of MIBIS. This finding concurs with the findings of a research that aimed at investigating factors affecting ICT in agri-business among small-scale farmers in Nigeria by Awojide and Akintelu (2018) found out that lack of technological infrastructure limited adoption of these ICT-based information services.

4. High cost of using the devices- around 18% of the non-adopters reported that the cost of using MIBIS was high and as a result, it limited their ability to adopt. A study by Patil et al. (2008) that was aimed at understanding the main constraints that limit farmer adoption of ICT in agriculture in India found that cost was among the main limiting factors as reported by 23% of the farmers.

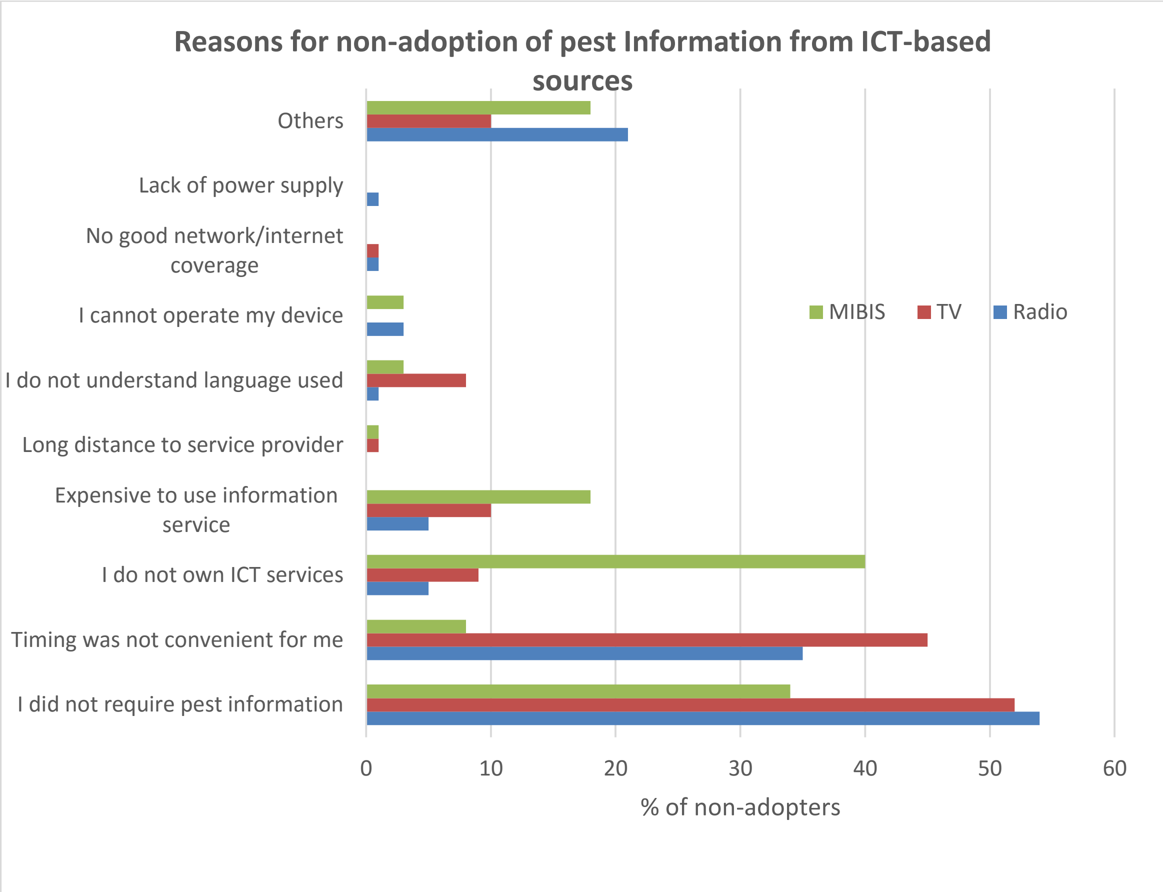

Figure 4.1: Factors Limiting the Adoption of IBPIS

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter presents a summary of the study, the conclusions made from the findings of the study, the contribution of the study findings to knowledge, the recommendations that can be made from this study and areas for further research.

5.2 Summary

Tomato is one of the most widely consumed vegetable globally. It is an essential source of nutrients, income for farmers and employment along its value chain. Tomato farming has been associated with many challenges, including unreliable weather conditions, stringent market standards, pests and diseases and inadequate extension services. Pests have been one of the biggest challenges in tomato farming. Besides, farmers have been experiencing the challenge of accessing and using pest information in a timely and quick manner to enable effective decisions on pest control. Use of ICT is a novel pathway to help farmers’ access pest information services, particularly in an environment with declining public extension services. The potential of the use of ICT-based innovations in providing customized pest information and services to improve smallholder farmers' performance in sub-Saharan Africa (SSA) remains largely untapped. Past studies have looked at application of ICT in different aspects of agriculture such as marketing, with little focus on the use of ICT to access and use pest information services in tomato farming.

The study contributes to the emerging literature on the application of ICT in pest information and management by evaluating the role of ICT-based pest information services in tomato pests' information sourcing and management in the Central Highlands of Kenya. The study employs a random sample of 170 tomato farmers to address the specific objectives: (i) To examine and characterize the current information services for tomato pests and their management in the Central Highlands of Kenya (ii) To assess farmer awareness and adoption of ICT-based pest information services in tomato production in the Central Highlands of Kenya (iii) To assess the determinants of and factors limiting of adoption of ICT-based pest information services by farmers in the Central Highlands of Kenya.

The data was collected from a random sample of 170 tomato farmers, 97 farmers from Meru and 73 farmers from Nyeri County. The survey questionnaire was designed to collect quantitative and qualitative data from farmers, while key informant interviews on tomato pest management were done with extension officers to assist in designing the data collection instrument. Data was collected using a structured questionnaire with both closed and open-ended questions. The KoBo Toolkit, a mobile-based application was used to collect data, which was later exported to Statistical Package for the Social Sciences (SPSS) and Stata software, for analysis. Data was cleaned and analyzed using descriptive and inferential statistics and logistic regression. Descriptive and inferential statistics were used to describe and summarize the data and statistical testing of regional differences. Logit models were used to evaluate the factors that determine the adoption of ICT-based pest information services by tomato farmers in the central highlands of Kenya. Descriptive statistics was also applied to examine factors that limit the adoption of ICT-based pest information services.

The results indicate that the current pest information services available to the farmers are non-ICT-based and ICT-based. For the non-ICT-based pest information services, the available sources of pest information are; other farmers, agro dealers, ago chemical sales representatives, HCD officers, private agricultural extension officers, public agricultural extension officers, plant clinics and Non-governmental Organization's extension agents. For the ICT-based pest information services, the following were available; radio and television programs and mobile- and internet-based information services (MIBIS).

The study findings revealed that majority of the farmers were aware of both the non-ICT and ICT sources of agricultural information. For the non-ICT based pest information services, Farmers were most aware of other farmers as reported by 82% of the farmers, followed by agro dealers (81%), public extension officers (47%), agro chemicals sales representatives with (30%), HCD officers (17%), private extension officers and plant clinics (5% each) and Non-Governmental Organizations' Extension officers (2%). Results show that 94% of the farmers owned radio, 90% owned television, 63% and 57% of the farmers owned smartphones and feature phones respectively and every farmer owned at least a smart phone or a feature phone, 22% owned either a laptop or a desktop or both, 30% owned DVD/CD player while 2% and 3% of the farmers owned satellite dishes and internet cables respectively. For the ICT-based pest information services, the study found out that the available services were; radio used by 44% of the farmers, television and smartphones both used by 35%, feature phones 21%, laptops 5%, internet devices and satellite dishes with 1% and 0.6% respectively.

The adoption of the ICT-based pest information services was found to be at 34% for radio-based information services, 30% for television-based programs, 28% for MIBIS and 48% for the adoption of at least one ICT-based pest information services. Logistic regression analysis, indicate that the adoption of ICT-based pest information services by farmers was negatively influenced by education level of the farmer. For instance, the negative influence on adoption of radio-based pest information services can be explained by the fact that increase in level of education enhances knowledge of the farmer on other sources of information such as internet sources and platforms. The adoption of all the three ICT-based pest information services was influenced by gender, with male having the dominance in adoption. Membership of the farmer into any social group influences the adoption of MIBIS and radio-based services. The adoption of the ICT-based pest information service was influenced by the size of land owned by the farmer with increase in land size influencing the adoption of MIBIS and radio-based pest information services negatively. Green house production system was also found to negatively influence the adoption of MIBIS and television-based information service at 5% and 10% significance levels respectively. Other factors that were found to influence adoption of ICT-based information services either negatively or positively were; main occupation of the farmer; if a farmer had an off-farm employment, he/she is likely to adopt than those without, because of extra income with which they can buy and maintain digital tools and access the information services; the cost of transport to the nearby market; farmers who live far away from the market centers are likely to adopt ICT-based perhaps because the cost of travelling to acquire information from other sources such as agro dealers or extension officers is high; the size of land under tomato production and the perception of the farmers towards the ICT-based pest information services positively influences adoption in the sense that as the level of trust increases so does the likelihood of that farmer adopting the ICT-based pest information services.

The results from the study indicate that the factors limiting the tomato farmers from adopting the ICT-based pest information services are; majority of the farmers did not require the pest information from the ICT-based sources, mainly because they had other sources of information and other farmers did not own the ICT tools such as mobile phones. For adoption of radio and television-based pest information services, the timing of the information broadcast was not convenient for them.

5.3 Conclusions

The study concludes that farmers continue to depend on tradition methods to acquire agricultural information and pest information services. Overall, 77% of farmers acquire agricultural information from non-ICT-based sources such as other farmers, agro-dealers and extension officers, as compared to 48% of farmers who acquire pest information from ICT-based sources.

This results show that farmers are aware of ICTs, that provide pest information services but the use of ICT-based pest information is low. The factors influencing adoption of ICT-based pest information include gender, levels of education, membership to social groups; production technology used, off farm employment, level of trust of the information and number of ICT tools owned. Factors limiting access to and use of ICT-based pest information services are inconvenient timing of information dissemination, high costs of accessing the information and lack of ownership of ICT devices.

There is awareness and use of ICT-based pest information services as compared to the findings of other earlier studies due to the high rate of ICT development. However, there is a need to come up with mechanisms that will boost the adoption of ICT-based pest information by the farmers so that its benefits in the agricultural sector can fully be reaped.

The challenge lies in the hands of the various agricultural institutions and stakeholders in ensuring an enabling environment for the farmers to see the benefits of adopting the ICT-based pest information services and actually fully adopting them.

5.4 Contribution of the Study Findings to Knowledge

This study aimed to evaluating the role of ICT-based pest information services in tomato pests' information sourcing and management in the Central Highlands of Kenya.

This study focused on relatively unexploited research in the application of ICT-based pest information services in tomato pest management. The fact that agriculture is the backbone of the majority of SSA economies and is projected to feed more than 9 billion people globally by the year 2050, it makes this study significant. The study presents new insights concerning the application of ICT-based pest information services in tomato farming, the horticultural sub-sector and the agricultural sector at large, in Kenya. It further contributes to the empirical literature on factors influencing the adoption of ICT-based pest information services and factors limiting the adoption.

5.5 Policy Recommendations

One of the main factors highlighted by the farmers that limit their ability to adopt the ICT-based pest information services was the lack of convenience of the information delivery. To curb this problem, the radio and television stations that air agricultural information should ensure that the programs are set at times when majority of the farmers can have time to listen and understand the information being relayed.

The finding that male farmers were more likely to access and use ICT-based pest information services than female farmers suggests the need by information dissemination agencies to design gender-sensitive ICT technologies, digital platforms, and dissemination pathways. The findings that membership to a social group influenced adoption of ICT-based pest information services suggest the need to encourage farmers to form cooperatives to address constraints they face in accessing essential agricultural information and other services. It further suggests that information disseminators should leverage on existing farmer groups as focal points for information dissemination.

The two levels of government should also come up with policies and interventions that will enable farmers to access agricultural information through many more services and arenas that are free of charge to the farmers. Besides, there is a need to evaluate and create awareness about the use of already developed and available ICT-based agricultural and pest information services such as MOA-info, iShamba SMS Service and social media by tomato farmers.

The National government with the partnership of County governments should strive to meet and surpass the Malabo Declaration of budgetary allocation to the agricultural sector. This would in return provide resources that will be geared towards research on application ICT in different activities of the agricultural sector, may it be production or even marketing of the agricultural produce. Through these resources, the different agricultural institutions can come up with special programs such offering farmers special loans that will increase the ownership of ICT-tools such as mobile phones.

5.6 Areas for Further Studies

Future research could be built on the findings of this study in order to increase the existing knowledge of application of ICT-based information services in agriculture. Such studies could for instance increase the sample size, change the research design and change the study areas to cover different agro-ecological zones, to validate this study and its findings. The study could also be extended to other crops and other crop production management practices.

Further studies could also be done to bring out an understanding of what can be done to improve the awareness and adoption of ICT based pest information services. More research should be conducted to evaluate the impact of ICT on knowledge of pest management, productivity and profitability.

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APPENDICES

Appendix 1: Survey Questionnaire

My name is Mwenda Evans, a student in Machakos University. I am conducting a survey on

"The role of ICT-based pest information services in tomato production in the Central highlands of Kenya: the case of Nyeri and Meru Counties". The study will identify the challenges faced by tomato farmers in accessing information for identification and management of tomato pests and recommend ways of improving access to this information. I kindly request you to participate in this important survey. Your responses will be used for academic purposes only and will be treated with utmost confidentiality. If you have any questions regarding the study you may ask.

Would you wish to participate in the study? Please tick 1=Yes____ 0=No ____

QUESTIONNAIRE NO (_____)

Section A: Identification and General Information

	Item	**Response (Fill-in/Tick)**
A1	Name of the enumerator	
A2	Survey date (DD/MM/YYYY)	
A3	County	1= Meru; 2= Nyeri
A4	1. Sub county	Code 1= Imenti Central; 2= Nyeri Township
	2. Ward	Code 1=Kariene; 2= Gatimbi; 3= Katheri 4=Kamakwa; 5=Gatitu; 6=Rware
	3. Village	
A5	GPS coordinates	
	Distance to nearest market centre- with a market day (Km)	

	Transport cost to this market centre (KSh)	
	Distance to nearest motorable all weather road (Km)	
	Transport cost to this road (KSh)	
	Distance to nearest agricultural extension office (Km)	
	Transport cost to this office (KSh)	
	Is your house connected to electricity?	0=No 1=Yes
	Do you have a solar power system?	0=No 1=Yes
	Do you have a power generator?	0=No 1=Yes
	Do you have a rechargeable battery?	0=No 1=Yes

Section B: Household Socio-economic Characteristics

B.1Name of household head	
B.2 Household head age in years	
B.3 Gender of household head	1=male 0=female
B.4 Household head highest level of education reached	0= None; 1= Adult education 2=Primary; 3=secondary; 5=tertiary/vocation 6=University
If respondent is not Household head:	
B.5 Name of respondent	
B.6 Gender of the respondent	1=male 0=female
B.7 Age of the respondent in years	
B.8 Respondent highest level of education reached	0= None; 1= Adult education 2=Primary; 3=secondary; 5=tertiary/vocation 6=University
Ability to communicate in local language (Kimeru/Kikuyu)	
1. How well does the respondent understand the local language	0=does not understand 1=a little (few words, but not a sentence) 2=average (can understand short sentences) 3=very well (can understand a long sentence)
2. How well can respondent speak in local language	0=cannot speak 1=a little (few words, cannot construct a sentence) 2=fluent (can construct a sentence) 3=very fluent (can construct a full sentence)
3. How well can you write/read in local language	0=cannot write 1=a little (few words, cannot construct a sentence) 2=fluent (can construct a sentence) 3=very fluent (can construct a full sentence)
Ability to communicate in Swahili language	
1. How well does the respondent understand Swahili language	0=does not understand 1=a little (few words, but not a sentence) 2=average (can understand short sentences) 3=very well (can understand a long sentence)
2. How well can respondent speak **Swahili**	0=cannot speak 1=a little (few words, cannot construct a sentence) 2=fluent (can construct a sentence) 3=very fluent (can construct a full sentence)
3. How well can respondent read or write in **Swahili**	0=cannot write/read 1=a little (few words, cannot construct a sentence) 2=fluent (can construct a sentence) 3=very fluent (can construct a full sentence)
Ability to communicate in **English** language	

1. How well does the respondent understand **English** language	0=does not understand 1=a little (few words, but not a sentence) 2=average (can understand short sentences) 3=very well (can understand a long sentence)
2. How well can respondent speak **English**	0=cannot speak 1=a little (few words, cannot construct a sentence) 2=somwhat fluent (can construct a short sentence) 3=very fluent (can construct a full sentence)
3. How well can respondent read or write in **English**	0=cannot write/read 1=a little (few words, cannot construct a sentence) 2=fluent (can construct a sentence) 3=very fluent (can construct a full sentence)
B.9 Household size	
B.10 Experience in tomato production (years)	
B.11 Main occupation of the respondent	0=not working 1=farming 2=formal employment (farm) 3=formal employment (non-farm) 4=self-employment 5=casual employment on-farm 6=casual employment non-farm
B.12 Secondary occupation of the respondent	0=not working 1=farming 2=formal employment (farm) 3=formal employment (non-farm) 4=self-employment 5=casual employment on-farm 6=casual employment non-farm
B.13 Size of land during last season (acres)	
1. Owned	
2. Rented	
B.14 Membership in any social group	0=No 1=Yes
B.15 Activities of the group (tick all that apply)	Codes Group1 Group2 Group3 1=Farming _____ ____ _____ 2=Savings and credit _____ ____ _____ 3=Welfare _____ ____ _____ 4=Religious _____ ____ _____ 5= Marketing _____ ____ _____
Are you a member to a social media group (WhatsApp, Facebook, etc) dealing with	0=No 1=Yes

production of **any crop**?	
Are you a member to a social media group (WhatsApp, Facebook, etc) dealing with **tomato** production?	10=No 1=Yes

Section C: Ownership and use of ICT tools

ICT tool	Do you /other member of this household own this tool (0=No; 1=Yes)	If Yes, Number owned in this household	Do you use the tool to access agricultural information (0=No; 1=Yes)	If yes, what type of information? (Use **CODES** below, list all that apply)
Radio				
TV				
Satellite dish				
CD/DVD Player				
Desktop Computer				
Laptop computer				
Mobile phone (smart phone)				
Mobile phone (other)				
Internet device (cable/modem)				

Codes for information obtained from the ICT told named;

1= Land preparation information;

2= Information on planting materials;

3=Information on fertilizers

4= Information on pest and pest management;

5= Information on diseases and disease management

6=Information on pesticides;

7=Information on input markets;

8= Information on produce marketing

9= Climate information services e.g weather forecast

Section D: Pest information Service Awareness and Adoption

Pest information service/ provider	Do you know of any (0=No, 1=Yes)	Ever accessed pest information (for any crop) through the service /provider (0=No; 1=Yes)	Did you use pest information service/provider for tomato pest info last season (0=No; 1=Yes)	If no, Give reasons (**codes A** below)	If yes, how much in total did the service cost you (KSh)
Non ICT-Based Pest Information Services					
Public agricultural extension officers					
Private agricultural extension officers					
HCD Officers					
NGO extension officer					
Agrodealer					
Agrochemical sales represtatatives					
Other farmers					
Plant clinics					
ICT-Based Pest Information Services					
Radio programs					

Pest information service/ provider	Do you know of any (0=No, 1=Yes)	Ever accessed pest information (for any crop) through the service /provider (0=No; 1=Yes)	Did you use pest information service/provider for tomato pest info last season (0=No; 1=Yes)	If no, Give reasons (**codes A** below)	If yes, how much in total did the service cost you (KSh)
Rware FM (Murimi Njorua)					
Thiiri FM					
Inooro FM					
Muga FM					
Kameme FM					
Others					
Radio adverts					
TV programs					
1. KTN Farmers TV					
2.Shamba shape-up					
3.Mugambo wa Murini (voice farmers)					
4. Seeds of gold					
5. TV Adverts					

Pest information service/ provider	Do you know of any (0=No, 1=Yes)	Ever accessed pest information (for any crop) through the service /provider (0=No; 1=Yes)	Did you use pest information service/provider for tomato pest info last season (0=No; 1=Yes)	If no, Give reasons (**codes A** below)	If yes, how much in total did the service cost you (KSh)
Mobile phone/ internet- based (Codes)					
1.Facebook					
2.WhatsApp					
3.Youtube					
4.Twitter					
5.Mobile applications e.g Kenya Agri-Observatory platform					
6. Digital storage devices (CDs / DVDs/Flash Disks)					
7. Online storage					
8. UjuziKilimo					
9. iShamba (SMS service-fee charged)					
10. MoA-INFO (SMS service-free)					

Pest information service/ provider	Do you know of any (0=No, 1=Yes)	Ever accessed pest information (for any crop) through the service /provider (0=No; 1=Yes)	Did you use pest information service/provider for tomato pest info last season (0=No; 1=Yes)	If no, Give reasons (**codes A** below)	If yes, how much in total did the service cost you (KSh)
11. Email					

CodesA: 1=I did not require pest information; 2=Long distance to reach service provider; 3=Expensive to reach service provider; 4= I do not own ICT device; 5=I do not understand language used; 6=I cannot operate my device; 7=No good network/internet coverage; 8=Timing was not convenient for me; 9=Lack of power supply; 10=Other, specify …………………………………………

To what extent do you trust information from Non-ICT-Based Pest Information Services? **1=**Strongly distrust 2=Distrust 3=Neither distrust nor trust 4=Trust 5=Strongly trust

To what extent do you trust information from ICT-Based Pest Information Services? **1=**Strongly distrust 2=Distrust 3=Neither distrust nor trust 4=Trust 5=Strongly trust

What are the factors that limit you in the adoption of ICT-based pest information in tomato production? (Rank list)

Appendix 2: Research Permit

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: **635214**

Date of Issue: **01/October/2021**

RESEARCH LICENSE

This is to Certify that Mr.. EVANS MWENDA of Machakos University, has been licensed to conduct research in Meru, Nyeri on the topic: THE ROLE OF ICT-BASED PEST INFORMATION SERVICES IN TOMATO PRODUCTION IN THE CENTRAL HIGHLANDS OF KENYA: THE CASE OF NYERI AND MERU COUNTIES for the period ending : 01/October/2022.

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