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Determinants of Adoption of ICT-Based Pest Information Services by Tomato Farmers in the Central Highlands of Kenya

By:

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Abstract
ICT-based pest information services (IBPIS) are a novel pathway that can help farmers access pest information. However, there is scanty literature on their adoption and results are often mixed. This study assessed the determinants of adoption of IBPIS by tomato farmers using 2021 data from central highlands of Kenya. Adoption of IBPIS was found to be influenced by gender, membership in social groups, off-farm employment, farmer level of trust in IBPIS, transport costs to markets, area under tomato, farmer education, land size and tomato production system. Broadcasting timing, lack of ICT tools, and high cost of using IBPIS hindered adoption.

Keywords: ICT, pest information services, adoption, tomato, Kenya

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1. Introduction

1.1 Background

Tomato (*Solanum lycopersicum*) is one of the widely cultivated vegetables, ranking second after potato in terms of value and production (Mitra & Yunus, 2018). It plays a major role in household food and nutrition security, rural employment and rural incomes (Ganesan *et al*., 2012 Geoffrey *et al*., 2014). In Kenya, the sub-sector contributes 14% of the aggregate vegetable output and 6.72% to total horticultural output (Najjuma *et al*., 2016). Kenya is ranked 43rd globally in tomato production, with 410,033 tons of tomato per year (Gatahi, 2020). The country's tomato sub-sector is dominated by smallholder farmers, who produce over 70% of total tomato output (Ndirangu *et al*., 2018). However, tomato yields in Kenya have been low due to abiotic and biotic factors, key among them being pests and diseases (Ochilo *et al*., 2019). Recently, the Kenyan government has come up with approaches such as development of integrated pest management strategies, including breeding of disease-resistant varieties and development of effective agro-chemicals, quality fertilizers and technologies aimed at increasing smallholder farmers productivity (Government of Kenya, 2018; Wambua *et al*., 2019). However, this has not translated to increased productivity. Data from FAOSTAT shows that tomato productivity actually decreased from 29.2 tons/ha in 2010 to 21.7 tons/ha in 2019, representing a 25.5% decrease. This is in sharp contrast with the potential yields of 45-300 tons/ha (Ndegwa *et al*., 2019), and far behind the yields of countries such as Egypt (35 tons/ha) and France (120 tons/ha) (Najjuma *et al*., 2016).

Farmers mostly use agrochemicals to manage these pests but due to challenge in monitoring the pests, it is not effective because applications of insecticides are normally done on a calendar program (Sadat & Chakraborty, 2017). Periodic unpredictability of the populations of pests, leads 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. However, 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).

Statement of the Problem

Despite tomatoes' numerous benefits, its 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. The control of these pests is often difficult to small-scale tomato farmers as they do not have knowledge on how to differentiate pests as different pests warrant different management practices. It is also worsened by lack of accurate, timely and adequate information on pest management. 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 pests and diseases. Although efforts have been made to apply ICTs in agricultural pest

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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

Objectives

The objectives of the study were; to assess the determinants of adoption of ICT-based pest information services by tomato farmers and to assess the factors that limit the adoption of ICT-based pest information services by tomato farmers in the Central Highlands of Kenya.

1.2 The Potential of ICT in Provision of Pest Information

Use of information and communication technology (ICT), the new science of collecting, storing, processing and transmitting information (Milovanović, 2014), could alleviate pest information asymmetry through collecting and disseminating data on tomato pests and diseases, that could be costly to do manually. ICT 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 phone, powered by wireless networks and an internet-enabled sphere. The list of ICT components is inexhaustive, 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. Through the use of digital 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.

Use of ICT in providing farmer advisory services is on the rise. For instance, in Asia, 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 providers on how to provide agricultural information to farmers using ICT tools (Baig & Aldosari, 2013). India's *National e-Governance Plan in Agriculture (NeGP-A)*, which has components such as Agri-clinics and touch screen kiosks, that integrates ICT in provision of agricultural information, is a case in point (Naika *et al*., 2021). 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.

Digital pest information in Africa is accessible 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 makes it ineffective in pest control (Kroschel *et al*., 2016). Moreover, information source 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). In Kenya, there is scarcity of extension services, with the current ratio of extension workers to farmers being 1:1000, which is far below the Food and Agriculture Organization of the United Nations (FAO) recommendation of 1:400 (Gichamba *et al*., 2017). Farmers get some pest information from extension officers, but agro-dealers, seed companies, agro-chemical companies, other farmers and NGOs also play an important role.

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Farmers do not have adequate information on pests, for instance on other methods of pest management besides chemical methods (Vétek *et al*., 2017).

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 determinants of and constraints to adoption of ICT-based pest information services. This study sought to investigate the factors that influence the adoption of ICT-based pest information services among tomato farmers in the Central highlands of Kenya.

1.3 Use of ICT in Provision of Pest Information in Kenya

Kenya is one of the sub-Saharan African countries with high and increasing penetration of ICT use which is being leveraged for provision of agricultural information. For example, the Kenya Agriculture and Livestock Research Organization (KALRO), has launched over thirty agricultural applications to help farmers in their daily activities. Among these are the Fall Army Worm application, Potato Cyst Nematode Control, Control MLN Disease, Kenya Agri Observatory Platform and the KALRO-GIZ application, amongst many, and are available in the Google Play of smart phones (Kalro, 2022)). These applications give farmers step-by-step guidelines on production of different crops, including identification and management of different crop pests and diseases. 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 engaged in tomato production, because the applications require technical know-how to source information from them. Further, the applications require internet connectivity which might be an issue in the rural areas (Republic of Kenya, 2019).

Another ICT tool being used to disseminate agricultural information in Kenya is the television. Munene & Mberia (2016), in their study on the television program *Shamba Shape-up Show*, explain how TV programs have played a huge role in dissemination of agricultural information and knowledge to small scale farmers. Television has been found to increase farmer's knowledge through educational interventions and useful messages (Nazari & Hassan, 2011). Other television programs that facilitate agricultural productivity and access to pest information in Kenya include; various programs broadcasted by *KTN Farmers TV*, *Seeds of Gold* (by NTV) and *Mugambo wa Murimi* (Voice of Farmers) aired on vernacular TV station (*Inooro TV*). Other digital technologies include social media platforms such as Facebook that have groups where farmers can get information from and interact with specialists in farming; local FM radio stations; short message services (SMS) by the Ministry of Agriculture (*MoA-INFO*); and mobile and internet-based applications such as *Ujuzi Kilimo* (agricultural knowledge).

Notwithstanding the numerous ICT-based information services above, Kenyan farmers are still battling the effects of many pests in tomato production, which shows that they are not effectively benefitting from the ICT-based pest information services. Yet, there is literature gap on the factors that influence adoption of ICT-based pest information services. This study will help in understanding the factors that influence the adoption of ICT-based information services.

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2. Methodology

2.1 Theoretical framework

This study is based on the random utility model (RUM) which is attributed to Thurstone's 1927 work (McFadden, 1976). According to this model, when faced with several options, an individual will choose the option that maximizes his or her utility. This choice is influenced by observable characteristics of the individual and the options themselves, as well as unobserved characteristics or random factors. In this context, farmer's decision to use or not to use ICT-based information services was assumed to be influenced by their characteristics such as gender, age, education level, household characteristics, and unknown random factors. Using this theory, it can be assumed that a farmer belongs to a particular population and there are available options of ICT-based information services (IBPIS) illustrated as $A = A_1, A2, \dots, A_n$, where the subscripts 1 up to *n* represent the different kinds of IBPIS available to tomato farmers, which are affected by internal (*I*) and external (*E*) factors, such that $\boldsymbol{X} = (X^I X^E)$. A farmer's decision to adopt an IBPIS can be thought of as a binary variable that takes the value of one if the farmer adopts the service and zero otherwise, in which case a binary response model such as logit or probit would be appropriate for analyzing the adoption behavior.

For this study, a logistic regression model (logit) was deemed appropriate to assess factors influencing adoption of ICT-based tomato pest information services in line with the RUM (Wooldridge, 2013). The logit model is specified as follows:

$$Pr(Y_i = 1|X_i) = \mathrm{F}(\beta_0 + \boldsymbol{X'}_i\boldsymbol{\beta}) \quad (1)$$

where; $Pr(Y_i = 1|X_i)$ is the probability that a farmer (*i*) adopts an IBPIS, given his/her characteristics (X); Y_i is a binary dependent variable with a value of 1 if a farmer adopts IBPIS and 0 otherwise. $\boldsymbol{X'}_i$ is a vector of explanatory variables that include social-economic factors, demographics, education levels, membership to groups and distance to nearest market as described in Table 1. Represented by β_0 is the model intercept, while $\boldsymbol{\beta}$ is a vector of parameters to be estimated, measuring the effect of independent variables on

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awareness; and F is the logistic distribution function that ensures estimated probabilities range between 0 and 1. The Logit model assumes all independent variables are exogenous and follows a logistic distribution.

2.2 Empirical Framework

Following the logistic model above, the following two empirical models were derived;

$$Y_{ji} = \beta_{j0} + \beta_{1j}X_{1i} + \beta_{2j}X_{2i} + \cdots + \beta_{nj}X_{ni} + \varepsilon_j \quad (2)$$

where, for each IBPIS *j* and farmer *i*, *Y* is the log odds of adoption of radio-based television-based, or mobile and internet-based pest information services; $X_1 - X_n$ are farmer personal, household and farm characteristics, which included education level, gender, age, off-farm employment, language literacy, distance to the nearest market, household size, membership to social group, perception towards the IBPIS, tomato production system, the size of land owned, tomato production area, and a County dummy. The symbols 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*** and follow logistic distribution (Wooldridge, 2013).

The second model was specified as:

$$Y_i = \beta_0 + \beta_1X_{1i} + \beta_2X_{2i} + \cdots + \beta_nX_{ni} + \varepsilon \quad (3)$$

where, for each farmer *i*, *Y* is the log odds of adoption of at least one IBPIS and all other notations and symbols are as defined in equation (2).

Equations (2) and (3) were estimated by maximum likelihood using STATA software. Robust standard errors were used to correct for potential heteroscedasticity.

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2.3 Study Area and Sample

The study was conducted in Meru and Nyeri Counties 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. Tomato is among the main horticultural crops produced in the counties and many farmers are making a living from its production. 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 trained enumerators.

This study targeted small-scale tomato farmers and the target sample size was 196 farmers. The farmers were selected using a multi-stage sampling method, whereby 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. One Sub-County per sampled county was also purposively selected based on their infrastructural accessibility, good agricultural weather conditions and fertile soils for agriculture and farming activities. Three Wards per sub-County were purposively selected per sub-County based on the number of tomato producers. The sampled Wards in Nyeri were Kamakwa, Rware and Gatitu; while in Meru, the Wards selected were Kariene, Gatimbi and Katheri. The list of the tomato farmers was obtained from the Horticultural Crops Directorate offices and this acted as the sampling frame for the tomato growers. In the last stage, farmers were randomly selected from the sampling frame and proportionate distribution of the farmers in all the Locations within the Wards was done to make a total of 31 respondents from every Ward.

2.4 Data and Measurement

Data was collected using a structured questionnaire with both closed and open-ended questions. 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 adoption and the farmers' sources of pest and pest management information.

During the actual data collection, each household in the sample was visited to administer the questionnaire. 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. The enumerators underwent training on how to use the data collection toolkit and on the collection of the data.

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3 Results

3.1 Characteristics of the sample

Table 1: Descriptive statistics of the sample (N=170) (Characteristics of the sample)

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
ICTs	Number of ICT tools owned	3.66	1.02
		Frequency	*% of sample*
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			
Primary	Up to primary level	48	28.2
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
Greenhouse	Production system is greenhouse	25	14.7
Offfarm	Farmer had some off-farm employment	64	37.7
Ownership of ICT tools			
Radio	Farmer owns a radio	160	94.1
Television	Farmer owns a TV	153	90.0
Smart phone	Farmer owns a smart phone	108	63.5
Feature phone	Farmer owns a feature phone	97	57.1

Source: Field Survey 2021

Table 1 above show the sample characteristics of the farmers who participated in the study. Out of the targeted a sample size of 196 tomato farmers, 170 farmers filled the questionnaire fully, which represent 87% response rate. Of total sample, 97 farmers (57%) were from Meru County, while 73 (43%) were from Nyeri County. About 54% of the farmers were male, while the average age of the farmers was 37 years, implying that tomato farmers were

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relatively youthful. The farmers were fairly literate, with 15.3% having completed a university education, 27% having completed tertiary/vocational education and 29.4% having completed secondary education. Only 28% of the farmers had less than secondary education. About 18.2% of farmers were members of a tomato-producing farmer organization. The farmers in the study owned an average of 2.25 acres, with 1.33 acres dedicated to tomato production. Apart from farming, 37.7% of the sampled farmers were also engaged in off-farm employment activities. More than 94% of the respondents reported owning television and radio, while around 64% and 57% owned smart phones and feature phones, respectively. On average, a household owned about four ICT tools.

3.2 Awareness and adoption of ICT-based pest information services

Table 2: Awareness of various ICT-based pest information services

ICT-based pest information service	Statistics	
	Frequency	%
Radio Programs	170	100
TV Programs	157	93.3
Mobile & internet-based services	142	83.5
WhatsApp	84	49.4
Facebook	83	48.8
MoA-INFO	53	31.2
You Tube	38	22.4
Twitter	30	17.6
iShamba SMS Service	18	10.6
Mobile Application	13	7.6
Online storage	4	2.4
Ujuzi Kilimo	4	2.4

Source: Field Survey 2021

The study assessed farmers' awareness of ICT-based pest information services. Table 2 above show that, all of the farmers were aware of at least one radio program that broadcasts agricultural pest information. About 93% of farmers were aware of TV programs, and 83.5% were aware of mobile and internet-based information services (MIBPIS) that provide pest information services. Awareness of MIBPIS was highest for WhatsApp (49%) and Facebook (49%), flowed by MoA-INFO (31%) and YouTube (22%), while the Ujuzi Kilimo messaging service (2.4%) and online storage services (2.4%) were the least known.

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Table 3: Adoption of information from ICT-based pest information services

Pest Information Service	Statistics	
	Frequency	%
Radio programs	58	34.1
Television programs	52	30.6
Mobile and Internet-Based information services	48	28.2
At least one IBPIS	82	48.2

Source: Field Survey 2021

Farmers were asked if they had used information from ICT-based pest information services to manage pests in tomato production in the season before the survey, and the findings are shown in Table 3 above. According to the data, 48.2% of farmers used information from at least one IBPIS to manage tomato pests. Radio programs were the most commonly utilized information service (34.1%), followed by TV programs (30.6%) and MIBPIS (28%). This shows that the use of the information from the mentioned IBPIS in tomato farming is substantially lower compared to awareness levels. However, there is still potential to increase farmer adoption of IBPIS in Kenya.

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3.3 Determinants of adoption of ICT-based pest information services

Table 4: Logit regression results for determinants of adoption of IBPIS in tomato farming

Variable	Adoption models for ICT-based pest information services			
	Radio	TV	MIBPIS	At least one
	(1)	(2)	(3)	(4)
Farmer is male	1.197***	0.941**	1.661***	0.638
	(0.413)	(0.443)	(0.622)	(0.413)
Farmer age (years)	-0.006	-0.015	0.002	0.002
	(0.021)	(0.018)	(0.028)	(0.022)
Household size	0.058	-0.049	-0.046	0.087
	(0.121)	(0.090)	(0.073)	(0.137)
Formal education level				
Secondary	-1.769**	0.365	0.325	-0.896
	(0.899)	(0.781)	(0.913)	(0.643)
Vocational/college	-2.580**	0.541	0.532	-1.085
	(1.040)	(0.934)	(0.982)	(0.807)
University	-1.920	0.480	0.555	-1.482
	(1.363)	(1.235)	(1.182)	(1.203)
Farmer understanding of English				
Average	-0.429	-0.078	-0.324	0.002
	(0.717)	(0.705)	(0.772)	(0.580)
Very well	0.693	0.388	0.299	0.313
	(0.851)	(0.873)	(0.997)	(0.771)
Membership to a social group	1.435*	0.774	1.969*	0.995
	(0.773)	(0.621)	(1.152)	(0.694)
Transport cost to main market (KSh)	0.013	0.009	0.044**	0.017*
	(0.012)	(0.012)	(0.019)	(0.010)
Size of land owned	-0.307*	-0.056	-0.640***	-0.103
	(0.181)	(0.183)	(0.245)	(0.176)
Tomato production area	0.096	0.177	0.363**	0.200
	(0.174)	(0.158)	(0.183)	(0.181)
Greenhouse production system	-1.124	-1.639**	-1.990**	-1.253*
	(0.830)	(0.703)	(0.809)	(0.658)
Off-farm employment	1.906**	0.390	1.334**	1.190**
	(0.744)	(0.561)	(0.617)	(0.568)
Trust on information from ICT sources				
Neutral	-0.354	0.256	-1.270	-0.170
	(0.687)	(1.076)	(1.195)	(0.953)
Trust/strongly trust	.	2.021*	1.274	1.707
	.	(1.217)	(1.364)	(1.173)
Number of ICT tools owned				0.468**
				(0.223)
Nyeri County	0.594	-0.099	-0.161	0.189
	(0.431)	(0.485)	(0.589)	(0.423)
Constant	-2.506	-2.991*	-5.663***	-4.580**
	(1.732)	(1.567)	(1.894)	(1.783)
N	161	170	170	170
Prob > chi2	0.016	0.006	0.001	0.001
Pseudo R^2	0.227	0.216	0.408	0.240

Note: Figures logit coefficients, with robust standard errors in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Base dummy for education is primary education and below.
Source: Field Survey 2021

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The findings on table 4 show that the gender of the farmer had a significant positive influence on the use of pest-information services acquired through radio programs, TV programs, and MIBPIS, with male farmers being more likely to use pest information acquired from ICT sources than their female counterparts. The results also show that the level of education had a significant negative effect on the use of radio-based sources of pest information services. The result suggests that as the farmers' education increases, they become less likely to use the radio-based pest information services. This can be explained by the fact that as an individual's education progresses, he or she develops a better understanding of many sources of pest information, including those that are non-ICT-based.

The findings further show that membership in any social group had a significant positive influence on the use of pest information acquired through MIBPIS and radio programs, and that its influence is significant at 10% level. This means that, if a farmer is a member of any social group, they are more likely to adopt MIBPIS and radio-based information services, compared to farmers who do not belong to such groups. This can be explained by the fact that the farmer is influenced by other members of the group to use information from MIBPIS and radio programs. Other results show that the size of land owned by the farmer had a significant negative influence on the adoption of IBPIS by tomato farmers. However, this variable doesn't influence the adoption of television-based pest information services by the farmer. By contrast, tomato production area had a positive and significant influence on the adoption of MIBPIS. This is perhaps because as farmer's increase their area under tomatoes, pest problems increase, necessitating the search of information through modern ICT sources.

The results further show that the production system that a farmer uses had a negative effect on the adoption of IBPIS. Farmers producing tomatoes under greenhouses were less likely to adopt pest information from any ICT-based service, as compared with farmers producing under open field systems. Greenhouse structure acts as a physical barrier to pest infestation; hence farmers using this production technology may not require much pest information. Other results show that having off-farm employment was positively correlated with adoption of IBPIS, and this is attributable to the fact that with the extra income earned, farmers are better able to purchase and maintain ICT tools, airtime and data for accessing information.

Transport to the market also influences the adoption of at least one IBPIS, particularly MIBPIS, with an increase in the transport cost to the market influencing the adoption positively. This implies that farmers living further away from market centres were more likely to use ICT services to acquire pest information, perhaps to reduce the cost and time of acquiring the information through extension officers and agro-dealers. Lastly, the number of ICT tools owned by the farmer had a positive influence on the adoption of at least one IBPIS. This implies that as the number of ICT tools owned by farmer increases, the likelihood of the farmer adopting at least one ICT-based pest information service increases.

3.4 Factors limiting the adoption of ICT-based pest information service

We sought to know the reasons why tomato farmers did not adopt IBPIS information and the results are shown in Figure 1. The common factor that hindered adoption of IBPIS among the majority of the farmers was that farmers did not require the pest information from ICT-based sources, reported by 34-54% of the non-adopters, depending on the information service. Poor timing of information services and programs was another obstacle to use of IBPIS as reported by 35% and 45% of the non-adopters of radio and TV-based pest information services,

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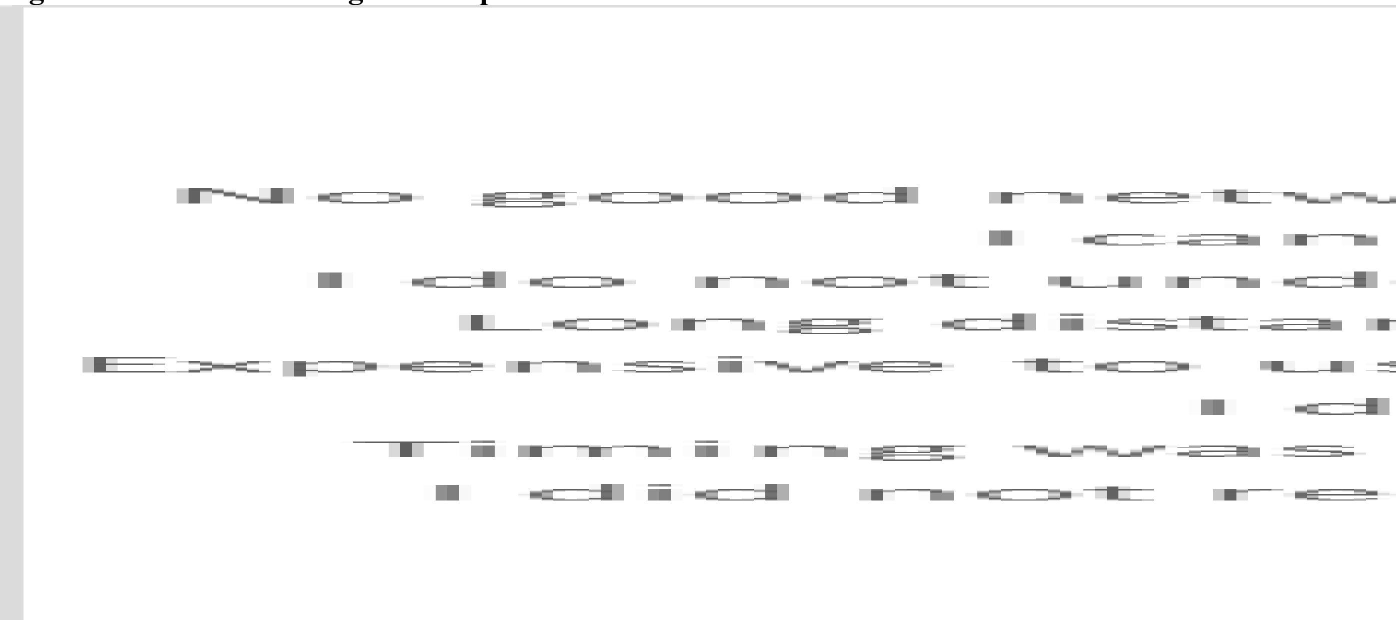
respectively. Lack of ownership of ICT devices was reported as other limitations as reported by 40% of the non-adopters of MIBPIS. The high cost of using the devices was another constrain, reported by about 18% of the non-adopters of MIBPIS.

Figure 1: Factors Limiting the Adoption of ICT-Based Pest Information Services



Source: Field Survey 2021

4 Discussion

This study contributes to the growing body of evidence demonstrating the novelty of the use of ICT-based information platforms in the dissemination of pest information services, particularly in an environment where public extension services are dwindling. This study assesses the determinants of adoption of ICT-based information services (IBPIS) by tomato farmers in the central highlands of Kenya. The results show that use of IBPIS is substantially lower compared to levels of awareness. Radio programs were the most frequently used information service (34.1%), followed by TV programs (30.6%) and then MIBPIS (28%). Our findings show adoption levels that are lower than those reported in a number of recent studies in developing countries. For instance, the study by Mtega (2018), found that in Tanzania, 61% of the farmers used agricultural information from radio while 48% used mobile-based information. Similarly, a recent study in India found that 48% of farmers use radio, 54% use television, and 69% use mobile-based internet sources (Mishra *et al*., 2020). Evidence shows that radio-based extension programs increased knowledge of fall armyworm and adoption of preventive and management practices in Zambia (Rwar*e et* al., 2021). Radio programs are preferred by farmers because they use local dialects, are cost-effective and help farmers acquire timely agricultural and pest information since extension officers are inadequate. Use of mobile-based technology is increasing among farmers to acquire agricultural information and pest information services. Awou*r et* al., (2019) show that the e-pest surveillance solution framework, a digital platform that uses mobile devices, could support farmers to detect and control crop pest invasions as well as link them with accessible agro-vet stores and extension service providers.

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The study finds male farmers were more likely to use pest-information services acquired through radio programs, TV programs, and MIBPIS. Rware *et al*. (2021) similarly found that male farmers were more likely to participate in radio programs on sensitization and control of fall armyworm in Zambia. Further, Wawire *et al*. (2017) found that male farmers were more likely to use ICT tools to acquire agricultural marketing information in Kenya. This can be explained by the fact 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) reported 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 study further shows that; membership in social groups was associated with the use of pest information acquired through MIBPIS, radio programs, and any ICT-based pest information services. Evidence shows that social influence has a positive effect on behavioral intentions, which in turn affects the adoption of ICT in developing countries (Nassa*r et* al., 2019). These findings are consistent with recent research in Kenya which has found that social groups and farmer groups increase awareness and information dissemination that influences the likelihood of ICT use in agricultural value chains (Wawire *et al*. 2017; Katunyo, 2019). This result agrees with a recent study in Vietnam which found that membership in social groups influenced adoption of ICT adoption among intensive shrimp farmers (Ulhaq *et al*., 2022).

Furthermore, this study showed that the size of land owned by the farmer had a significant negative influence on the adoption of IBPIS by tomato farmers. By contrast, the tomato production area had a positive and significant influence on the adoption of MIBPIS. These findings are consistent with Ali (2012), who found that farmers with small farms were more likely to use ICT-based information to make farming decisions, and Chandio and Yuansheng (2018), who reported that production area had a positive influence on the adoption of ICT by rice farmers in Pakistan. In particular, the production of tomatoes under greenhouses had a negative effect on the use of IBPIS. This could be attributed to less pest pressure since greenhouse technology physically restricts pests' entry into the production area, hence less demand for pest information. Similar studies in developed nations show that greenhouse production systems reduce the likelihood of adoption of ICT in farming, as shown in Italy (Bucci *et al*., 2019).

The study has also shown that off-farm employment has a positive influence on the adoption of IBPIS. This can be explained by the fact that tomato farmers with off-farm employment earn more income with which they can purchase and maintain the ICT tools (for instance, airtime and data bundles) that facilitate access to information services, increasing the likelihood of adoption. Positive perception also influenced the use of IBPIS. This is because as trust in information increased, the farmer became more likely to use information from that source. A study by Abdullahi *et al*. (2021) found that adoption of ICT in agribusiness in Somalia was mainly inspired by the insights the farmers had towards ICT. Similarly, the study by Nwokoye *et al*. (2019) found that the perception of the farmer towards the ease of use of ICT was a major determinant of adoption of ICT among rice farmers in Nigeria. Transport to the market also influences the adoption of any IBPIS, with an increase in the transport cost to the market influencing the adoption of MIBPIS positively. Katunyo (2019) found that the higher the transport costs to the market, the more likely a young person will use ICT. This study finds that the number of ICT tools owned by the farmer influences adoption of at least one IBPIS. Aminou *et al*. (2018) similarly found that as the number of ICT tools owned by a farmer increase, so does the likelihood of adoption of the agricultural information services provided by these tools. Lastly, the study examined hindrances to the adoption of IBPIS. The main constraints were: no need for pest information, inconvenient broadcasting timing, lack of ownership of ICT tools, and the high cost associated with use of IBPIS. These findings are consistent with previous studies. Mtega (2018) found that farmers mainly rely on farmer-to-farmer extension services, hence the low demand for ICT-based agricultural information services in Tanzania. In another study, Awojide and Akintelu (2018) found that farmers in Nigeria lacked technological infrastructure, which hindered their adoption of ICT-based information services. According to Patil *et al*. (2008), high costs of ICT use in India are the biggest barrier to ICT adoption in agriculture.

5 Conclusion and policy implications

This study assesses the determinants of adoption of CT-based pest information services (IBPIS) by tomato farmers in the central highlands of Kenya. We argued that use of ICT is a novel pathway that can help farmers access pest information services, particularly in an environment with declining public extension services. The study found high levels of awareness of various IBPIS, such as radio programs, TV programs, and mobile and internet-based pest information services (MIBPIS), but use of pest information was low. About 34% of farmers used pest information from radio programs, 31% from TV programs, and 28% from MIBPIS.

From the logistic regression, adoption of IBPIS was positively influenced by gender (male), membership in social groups, off-farm employment, levels of trust in ICT-based information sources, transport costs to nearby market centres, and area under tomato production. The factors that had a negative influence on adoption were the level of education, the size of the land owned, and the practice of greenhouse production systems. The study also found out that the factors limiting the tomato farmers' use of IBPIS include the majority of farmers not requiring pest information from the ICT-based sources, inconvenient broadcasting timing, lack of ownership of ICT tools, and the high cost particularly associated with use of MIBPIS.

The study recommends that radio and television stations that air agricultural information should ensure that the programs are aired at times when the majority of the farmers can have time to listen to and understand the information being relayed. In addition, there is the need for information dissemination agencies to design gender-sensitive ICT technologies, digital platforms, and dissemination pathways. Further, there is the need to encourage farmers to form cooperatives to address constraints they face in accessing essential agricultural information and other services. Information disseminators should also leverage on existing farmer groups as focal points for information dissemination. Furthermore, the government should come up with policies and interventions that will enable farmers to access agricultural information through many more services and arenas free of charge. Finally, there is a need to 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.

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References

Abdullahi, H. O., Hassan, A. A., Mahmud, M., & Ali, A. F. (2021). Determinants of ICT adoption among small scale agribusiness enterprises in Somalia. *International Journal of Engineering Trends and Technology, 69*(2), 68-76.

Aker, J. C., Ghosh, I., & Burrell, J. (2016). The promise (and pitfalls) of ICT for agriculture initiatives. *Agricultural Economics*, *47*(S1), 35-48.

Ali, J. (2012). Factors affecting the adoption of information and communication technologies (ICTs) for farming decisions. *Journal of Agricultural & Food Information*, *13*(1), 78-96.

Aminou, F. A. A., Houensou, D. A., & Hekponhoue, S. (2018). Effect of mobile phone ownership on agricultural productivity in Benin: The case of maize farmers. *Journal of Economics*, *6*(4), 77-88.

Awojide, S., & Akintelu, S. O. (2018). Empirical investigation of factors affecting information and communication technologies (icts) in Agric-Business among small scale farmers in Esan Community, Edo State, Nigeria. *Journal of Research in Marketing*, *9*(1), 713-722.Awour, F., Otanga, S., Kimeli, V., Rambim, D., & ABUYA, T. (2019). e-Pest surveillance: large scale crop pest surveillance and control. *2019 IST-Africa Week Conference (IST-Africa)*, 1–8. https://doi.org/10.23919/ISTAFRICA.2019.8764824.

Baig, M. B., & Aldosari, F. (2013). Agricultural extension in Asia: Constraints and options for improvement. *J. Ani Plant Sci*, *23*, 619-632.

Bucci, G., Bentivoglio, D., & Finco, A. (2019). Factors affecting ICT adoption in agriculture: A case study in Italy. *Calitatea*, *20*(S2), 122-129.

Chandio, A. A., & Yuansheng, J. I. A. N. G. (2018). Determinants of adoption of improved rice varieties in northern Sindh, Pakistan. *Rice Science*, *25*(2), 103-110.

Chen, A. N., Castillo, J., & Ligon, K. (2015). Information and communication technologies (ICT): Components, dimensions, and its correlates. *Journal of International Technology and Information Management*, *24*(4), 2.

Dufty, N & Jackson, T. (2018). Information and communication technology use in Australian agriculture. ABARES research report 18.15, Canberra. ISBN 978-1-74323-406-8 ISSN 1447-8358. Available at: agriculture.gov.au/publication. Accessed on 25th August 2021.

França, R. P., Iano, Y., Monteiro, A. C. B., & Arthur, R. (2020). Improvement of the transmission of information for ICT techniques through CBEDE methodology. In *Utilizing educational data mining techniques for improved learning: emerging research and opportunities* (pp. 13-34). IGI Global.

Ganesan, M., Rajesh, M., Solairaj, P., & Senthilkumar, T. (2012). Tomato as a pioneer in health management. *Int. J. Pharm. Chem. Biol. Sci*, *2*(3), 210-217.

Gatahi, D. M. (2020). Challenges and Opportunities in Tomato Production Chain and Sustainable Standards. *International Journal of Horticultural Science and Technology*, *7*(3), 235-262.

Geoffrey S. K., Hillary N. K., Kibe M.A., Mariam M., & Mary, M. C. (2014). Challenges and strategies to improve tomato competitiveness along the tomato value chain in Kenya. *International Journal of Business and Management 9*(9), *205.*

Gichamba, A., Wagacha, P. W., & Ochieng, D. O. (2017). An assessment of e-extension platforms in Kenya. *International Journal of Innovative Studies in Sciences and Engineering Technology, 3*(7), 36-40.

Citation: Mwenda, E; Muange, E. N & Ngigi, M. W. (2022). Determinants of Adoption of ICT-Based Pest Information Services by Tomato Farmers in the Central Highlands of Kenya. *Journal of African Interdisciplinary Studies,* 6(4), 18 – 36.

Government of Kenya. (2018). *County Government of Kirinyaga: County Integrated Development Plan 2018-2022*. Kutus, Kenya: Office of the Governor, Kirinyaga County.

Guedes, R. N. C., Roditakis, E., Campos, M. R., Haddi, K., Bielza, P., Siqueira, H. A. A., ... & Nauen, R. (2019). Insecticide resistance in the tomato pinworm Tuta absoluta: patterns, spread, mechanisms, management and outlook. *Journal of Pest Science*, 1-14.

Kalro (2022). https://www.kalro.org/mobile-applications/

Kante, M., Oboko, R., & Chepken, C. (2017). Influence of Perception and Quality of ICT-Based Agricultural Input Information on Use of ICTs by Farmers in Developing Countries: Case of Sikasso in Mali. *The Electronic Journal of Information Systems in Developing Countries*, *83*(1), 1-21.

Katunyo, P. N. (2019). Determinants of Information Communication Technologies Usage In Agricultural Value Chains By Rural Youth In Busia County, Kenya (Doctoral dissertation, UoN).

Krell, N. T., Giroux, S. A., Guido, Z., Hannah, C., Lopus, S. E., Caylor, K. K., & Evans, T. P. (2021). Smallholder farmers' use of mobile phone services in central Kenya. *Climate and Development*, *13*(3), 215-227.

Kroschel, J., Mujica, N., Carhuapoma, P., & Sporleder, M. (2016). Pest distribution and risk atlas for Africa. Potential global and regional distribution and abundance of agricultural and horticultural pests and associated biocontrol agents under current and future climates. *International Potato Center (CIP), Lima, Peru*.

Kuroda, R., Lopez, M., Sasaki, J., & Settecase, M. (2019). The digital gender gap. *Policy Brief prepared for W20 Japan, EY-GSMA*.

McFadden, D. (1976). Quantal choice analysis: A survey. *Annals of Economic and Social Measurement, 5(4)*, 363 – 390.

Miller, J. R. (2020). Sharpening the precision of pest management decisions: Assessing variability inherent in catch number and absolute density estimates derived from pheromone-baited traps monitoring insects moving randomly. *Journal of Economic Entomology*, *113*(5), 2052-2060.

Milovanović, S. (2014). The role and potential of information technology in agricultural improvement. *Економика пољопривреде*, *61*(2).

Mishra, A., Yadav, O. P., Dubey, S. K., Kumar, N., & Mishra, S. (2020). Extent of use of ICT Tools for Accessing the Agricultural Information in Lucknow District of Uttar Pradesh. *Journal of Community Mobilization and Sustainable Development Vol*, *15*(3), 759-763.

Mitra, S., & Yunus, M. (2018). Determinants of tomato farmers' efficiency in Mymensingh district of Bangladesh: Data Envelopment Analysis approach. *J Bangladesh Agril Univ*, *16*(1), 93-97.

Mtega, W. P. (2018). The usage of radio and television as agricultural knowledge sources: The case of farmers in Morogoro region of Tanzania. *International Journal of Education and Development using Information and Communication Technology, 14*(3), 252-266.

Munene, M. W., & Mberia, H. (2016). Effects of Television Agricultural Shows on Small-Scale Farmers' Information Need in Kenya: A Case Study of Kikuyu Sub-County. *International Journal of Academic Research in Business and Social Sciences*, *6*(4), 102-110.

Citation: Mwenda, E; Muange, E. N & Ngigi, M. W. (2022). Determinants of Adoption of ICT-Based Pest Information Services by Tomato Farmers in the Central Highlands of Kenya. *Journal of African Interdisciplinary Studies,* 6(4), 18 – 36.

Naika, M. B., Kudari, M., Devi, M. S., Sadhu, D. S., & Sunagar, S. (2021). Digital extension service: quick way to deliver agricultural information to the farmers. In *Food Technology Disruptions* (pp. 285-323). Academic Press.

Najjuma, E., Mbeche, R., & Kavoi, M. M. (2016). Assessment of technical efficiency of open field tomato production in Kiambu County, Kenya (stochastic frontier approach). *Journal of Agriculture, Science and Technology 17*(2), *21-39.*Nassar, A. A. M., Othman, K., & Nizah, M. A. B. M. (2019). The Impact of the Social Influence on ICT Adoption: Behavioral Intention as Mediator and Age as Moderator. *International Journal of Academic Research in Business and Social Sciences*, *9*(11), 963–978.

Nazari, M. R., & Hassan, M. S. B. H. (2011). The role of television in the enhancement of farmers' agricultural knowledge. *African Journal of Agricultural Research*, *6*(4), 931-936.

Ndegwa, A., Gathambiri, C., Magoti, R., Pole, F., Wesonga, J., & Maina, M. (2019). *Inventory of climate smart agriculture tomato technologies, innovations and management practices.* Kenya Agricultural and Livestock Research Organization (KALRO). Available at https://www.kcsap.go.ke/wp-content/uploads/2019/10/TOMATOES-1.pdf. Accessed on 5th January, 2022.

Ndirangu, S. N., Mbogoh, S. G., & Mbatia, O. L. E. (2018). Evaluation of the Elasticity of Farm Output among Smallholder Farmers in Selected Agro-Ecological Zones of Embu County, Kenya. *Asian Journal of Agricultural Extension, Economics & Sociology*, *26*(3), 1-10.

Ngigi, M. W., Mueller, U., & Birner, R. (2017). Gender differences in climate change adaptation strategies and participation in group-based approaches: An intra-household analysis from rural Kenya. *Ecological Economics*, *138*, 99-108.

Nwokoye, E. S., Oyim, A., Dimnwobi, S. K., & Ekesiobi, C. S. (2019). Socioeconomic determinants of information and communication technology adoption among rice farmers in Ebonyi State, Nigeria. *Nigerian Journal of Economic and Social Studies*, *61*(3).

Ochilo, W. N., Nyamasyo, G. N., Kilalo, D., Otieno, W., Otipa, M., Chege, F., ... & Lingeera, E. K. (2019). Characteristics and production constraints of smallholder tomato production in Kenya. *Scientific African*, *2*, e00014.

Patil, V. C., Gelb, E., Maru, A., Yadaraju, N. T., Moni, M., Misra, H., & Ninomiya, S. (2008, August). Adoption of information and communication technology (ICT) for agriculture: An Indian case study. In *IAALD AFITA WCCA 2008. World Conference on Agricultural Information and IT*.

Republic of Kenya. (2019). National Broadband Strategy 2018-2023. Available at *https://www.ict.go.ke/wp-content/uploads/2019/05/National-Broadband-Strategy-2023-FINAL.pdf***.** Accessed on 20th August, 2021.Rware, H., Kansiime, M. K., Mugambi, I., Onyango, D., Tambo, J. A., Banda, C. M., Phiri, N. A., Chipabika, G., Matimelo, M., Chaaba, D. K., Davis, T., & Godwin, J. (2021). Is radio an effective method for delivering actionable information for responding to emerging pest threats? A case study of fall armyworm campaign in Zambia. *CABI Agriculture and Bioscience*, *2*(1), 32. https://doi.org/10.1186/s43170-021-00053-8.

Sadat, A., & Chakraborty, K. (2017). Farmers' knowledge, perceptions and practices in jute insect pest management and cultural strategy in the upper Gangetic plains of West Bengal, India. *Indian Journal of Agricultural Research*, *51*(04), 320-326.

Citation: Mwenda, E; Muange, E. N & Ngigi, M. W. (2022). Determinants of Adoption of ICT-Based Pest Information Services by Tomato Farmers in the Central Highlands of Kenya. *Journal of African Interdisciplinary Studies,* 6(4), 18 – 36.

Smith, J. (2015). Crops, crop pests and climate change–why Africa needs to be better prepared. https://www.google.com/search?client=firefox-b-d&q=Smith%2C+J.+%282015%29.+Crops%2C+crop+pests+and+climate+change%E2%80%93why+Africa+needs+to+be+better+prepared.+

Ulhaq, I., Pham, N. T. A., Le, V., Pham, H. C., & Le, T. C. (2022). Factors influencing intention to adopt ICT among intensive shrimp farmers. *Aquaculture*, *547*, 737407.

Vétek, G., Asea, T., A., Chubinishvili, M., Avagyan, G., Torchan, V., Hajdú, Veres, A & Nersisyan, A. (2017). *Integrated pest management of major pests and diseases in Eastern Europe and the Caucasus*. Budapest: Food and Agriculture Organization (FAO).

Waage, J. K., Woodhall, J. W., Bishop, S. J., Smith, J. J., Jones, D. R., & Spence, N. J. (2008). Patterns of plant pest introductions in Europe and Africa. *Agricultural Systems*, *99*(1), 1-5.

Wambua, D. M., Ndirangu, S. N., Njeru, L. K., & Gichimu, B. M. (2019). Effects of recommended improved crop technologies and socio-economic factors on coffee profitability among smallholder farmers in Embu County, Kenya. *African Journal of Agricultural Research*, *14*(34), 1957-1966.

Wawire, A. W., Wangia, S. M., & Okello, J. J. (2017). Determinants of use of information and communication technologies in agriculture: the case of Kenya agricultural commodity exchange in Bungoma county, Kenya. *J. Agric. Sci*, *9*(3), 128-137.

Wooldridge, J. M. (2013). *Introductory Econometrics: A Modern Approach*. (5th ed.) Cengage Learning.

Wright, D., Hammond, N., Thomas, G., MacLeod, B., & Abbott, L. K. (2018). The provision of pest and disease information using Information Communication Tools (ICT); an Australian example. *Crop protection*, *103*, 20-29.