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The Impact of Information and Communication Technologies in Improving Crop Productivity among Youths in Misungwi and Kilosa Districts, Tanzania

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Abstract

There has been significant growth in the development of Information and Communication Technologies (ICTs) in Africa over the past decade. This study looked at the evidence on the role of emerging ICTs namely, mobile phones and computers in crop productivity sector in Tanzania with lessons from Misungwi and Kilosa districts. The study investigated the manner in which young farmers' access to ICTs would help improve crop productivity. A cross-sectional research design with multistage sampling was employed. About 400 respondents and 11 key informants participated in the household survey and in-depth interview, respectively. Propensity Score Matching (PSM) and Inverse Probability Weighted Adjusted Regression (IPWRA) techniques were used to analyze data on the impact of ICTs on crop productivity. The results show that adopters of ICTs had higher productivity compared to non-adopters at 1% level of significance. The findings consolidate the need of promoting ICTs penetration and/or adopting for having inclusive development in enhancing crop productivity. The Government of Tanzania (GoT) through Tanzania Communication and Regulatory Authority (TCRA) is urged to formulate and implement policies that enable universal access mechanisms of ICTs via low pricing and sharing schemes, and increase the development of its infrastructure needed for penetration to the community and especially in the rural areas.

Keywords

Knowledge, Information and Communication Technologies, Crop Production, Young Farmers, Propensity Score Marching

1. Introduction

Information and knowledge use in crop productivity has increasingly become important for effective decision making by farming communities (Opara, 2008; Taragola & Van Lierde, 2010). Rapid technological progression and the change of agricultural systems have considerably highlighted the need for well-organized transfer of a developed information and knowledge to farmers through various media (Magesa et al., 2014). Information and knowledge on improved crop productivity technologies and practices in Tanzania is delivered by publicly funded agricultural extension services which has failed to respond to the changing needs for farming societies (Wambura et al., 2015).

Information and Communication Technologies are believed to bring about social and economic development by creating an enabling environment in various facets including agriculture sector (Opata et al., 2011; Deichmann et al., 2016; Chiazoka et al., 2021). Almost every activity in the modern world is becoming more dependent on the ICTs endeavours. Through ICTs, farmers can learn various farming technologies that include rainfall forecasts, crop prices, pesticides and insecticides application and use such information to improve crop productivity. The importance of ICTs in development process is long recognized by World Bank through Sustainable Development Goal (SDG) No. 8, which emphasizes the benefits of new technologies especially ICTs in the fight against poverty (World Bank, 2009). According to Brynjolfsson and Hitt (2003) and Mittal and Tripathi (2009), the use of ICTs in agriculture supports crop productivity indirectly. The level of this support depends on complementary investment to resources such as labour skills, human capital, and organizational processes.

Information and Communication Technologies play an important role in agricultural development through information and knowledge dissemination (Zahedi & Zahedi, 2012; Mugwisi et al., 2015; Allen et al., 2017). Thus, the use of ICTs improves information flow and connects young farmers in the environment where there are limited extension services. Although ICTs improve information flow among young farmers, there is inadequate evidence showing whether ICTs can improve crop productivity among young farmers who are already accustomed to the use of ICTs in their day-to-day activities (Fawole, 2008; Halewood & Surya, 2012; Barakabitze et al., 2017). Previous studies such as Mtega and Msungu (2013) and Temba et al. (2016) show the existence of positive impact of the use of ICTs on agricultural productivity to smallholder farmers. Information on the impact of ICTs use on crop productivity of the youths' agro-enterprises still creates a room for discussion. Therefore, this study sought to establish the impact of ICTs usage on crop productivity from agro-enterprises specifically undertaken by young farmers.

In Tanzania, the youths can contribute to increased economic development through their participation in crop productivity, which is the main activity in rural areas (United Republic of Tanzania (URT), 2016a; Lindsjö et al., 2020). About 67% of labour force encompasses youths aged between 15 and 35 years, and mostly unemployed (URT, 2015). The youths have the potential to make major inputs to crop productivity development at different levels and can provide a great opportunity for developing an agricultural based rural economy if accurately strapped up. Furthermore, the budding economy can produce many employment opportunities, only if the available youth's labour force is fully utilized, leading to the increase in income per capital with a significant contribution to poverty reduction. Crop productivity sub-sector provides opportunities for the youths to fully realize their prospective and to access those opportunities available to them along the agricultural value chain. In this regard, the Tanzanian Development Vision 2025 and the Tanzanian Five Year Development Plan 2016/17-2020/21 are envisaged to promote employment growth amongst the youths. Similarly, the Tanzanian National Employment Policy (2008) and the Tanzanian National Employment Creation Programme (2006-2010) recognized agriculture as one of the lead employing sectors. However, the sector is considered less attractive for the youths to participate fully (URT, 2016b).

This study focused on establishing the differences in crop productivity between ICTs adopter and non-adopters. In this study, ICTs adopters are young farmers who use mobile phone (feature phones and smart phones) and computers in accessing agricultural related information while young farmers who do not use these devices in accessing agricultural related information are regarded as ICTs non-adopters. This paper attempts to answer two research questions: 1) What factors influence the decision of young farmers in using ICTs for agricultural purposes? 2) What is the impact of ICTs usage in crop productivity among young farmers? This study, therefore, tries to address the ongoing challenge of seeking solutions of low productivity in agricultural production through young farmers as change agents and ICTs as conduit for technology and knowledge transfer.

2. Theoretical Review

This study was guided by the Unified Theory of Acceptance and Use of Technology (UTAUT) model developed by Venkatesh et al. (2003) to analyze the impact of ICTs adoption in crop productivity among young farmers. The study presents findings on the understanding, availability and use of ICTs to support crop productivity in the study areas and factors that determine the adoption and use of ICTs in crop productivity. Several models exist to explain user acceptance of technology and innovations. The UTAUT is a result of an analysis and integration of eight common technology acceptance and usage models, such as Rogers (1995) with Diffusion of Innovation Theory (DOI), and Davis (1989) with Technology Acceptance Model (TAM). The UTAUT model proposes four main factors influencing adoption and use of ICTs, which include performance expectancy, effort expectancy, social influence and facilitating conditions. This model was chosen because of its representation of a wider range of factors as shown in the next section determining adoption and use of ICTs, not fully represented in the individual models.

3. Factors Influencing ICT Adoption in Crop Productivity

The adoption of ICTs for news consumption can be seen as the diffusion of innovation driven by various factors. Based on ICT users in crop productivity, a number of theoretical models have been applied as a reliable framework for exploring technology diffusion and adoption (Venkatesh et al., 2003). Among all, the innovation diffusion theory (IDT) by Rogers (1983) has been regarded as reliable and justifiable for explaining technology diffusion and adoption. IDT suggests five variables—relative advantage, compatibility, complexity, trialability, and observability as factors influencing technology adoption (Chan-Olmsted et al., 2013).

Relative advantage is the degree to which an innovation is perceived as being superior to its predecessor in terms of economic profitability, low initial cost, reduced discomfort, savings of time and effort, and the immediacy of the reward. As observed by Wanyoike et al. (2012), relative advantage is expressed by perceived benefits. According to Adegbidi et al. (2012), perceived benefits of ICT adoption in crop productivity often include focus on improving crop productivity, farming efficiency, operational effectiveness, and the need of reaching out for new markets and opportunities. Compatibility is the degree to which an innovation is perceived as being in agreement with the existing beliefs, experiences, and the needs of potential adopters. The faster rate of adoption occurs when the adopter perceives an innovation as meeting the needs of clients. Aubert et al. (2012) holds that an innovation is more likely to be adopted if it is compatible with individual, job responsibility and value system. Compatibility of ICT adoption may include meeting the requirements of accessing knowledge and information pertaining to crop productivity.

Complexity is the degree to which an innovation is perceived as being relatively difficult to understand and use (Chan-Olmsted et al., 2013). The perceived complexity of an innovation is negatively related to its rate of adoption. The ICT adoption by young farmers requires organizational personnel to possess sufficient technical competencies. Triability is the degree to which an innovation can be used on a trial basis before the confirmation of adoption. As Rogers (1995) underscores, “the trialability of an innovation, as perceived by members of a social system, is positively related to its rate of adoption.” Moreover, Alam et al. (2007) maintain that trialability has become an important feature of innovation because it provides a means for prospective adopters to reduce their uncertainties regarding unfamiliar technologies or products. Observability is the degree to which the potential adopter perceives that the results of an innovation are visible to others (Adegbidi et al., 2012). Displaying an innovation’s superiority in a tangible form will increase its adoption rate.

4. Empirical Review

In the context of determinants of ICTs usage, variables to ICT usage are based on theoretical foundations and from previous empirical results. Farmers with large land size (in acres) adopted ICTs more than did those with small land size

(Akudugu et al., 2012). Farmers who mechanized their farming activities registered to adopt ICTs than did those who depended on human capital in their crop productivity (Abdulai & Huffman, 2014).

Other arguments made by scholars are that farmers learning by doing has a positive relationship with ICTs usage (Mariano et al., 2012), and large households are a factor that has a negative relationship with ICTs adoption. This is because the larger the size of the household, the less the adoption of ICTs as members of the family in the larger households can be the main source of information and knowledge on crop productivity and share among themselves (Azad & Rahman, 2017). Also, Aubert et al. (2012), from their study in Canada, hold that the "perceived ease of use" and the "usefulness" in terms of affordability, reliability, and friendliness to user of technology were significant indicators of ICT usage. A study by Hassan et al. (2012) in Malaysia highlights three factors namely, age, electronic media usage, and ICT usage to have a significant relationship with the perception towards ICT usage with age having the highest contribution. On the other hand, Nyamba and Mlozi (2012) in Tanzania found that phone ownership, the type of agricultural information to be communicated, farming system practiced, and network coverage were significant positive factors for ICTs adoption.

As for the influence of ICTs on crop productivity, a number of impact studies have been conducted. Ibrahim et al. (2018) used UTAUT model to analyze factors influencing acceptance and use of ICT innovations by agribusinesses in Nigeria and found that performance expectancy significantly influences technology innovations use. Along the same line, Kahenya et al. (2014) investigated factors that influence use of ICTs by government agricultural extension officers within Kiambu County of Kenya by utilizing the UTAUT model and found that there were statistically significant and strong positive relationships between improved productivity, facilitating conditions and management support and that of usage of ICTs. Byomire et al. (2016) assessed the role of ICTs in improving urban agriculture productivity in Uganda. The authors observe that, although ICTs forms such as mobile phones act as a catalyst of improving crop productivity and incomes, the quality of information, timeliness of information and trustworthiness of the information are the three important aspects that have to be delivered to the farmers to meet their needs and expectations. Ogutu et al. (2014) claimed that the use of mobile phones among farmers in Kenya played a positive impact in their income and productivity because of the availability of market information obtained through text messages and calls. Halewood and Surya (2012) also maintain on the benefits of using ICTs in promoting access to price information in Africa that may lead to an increase of up to 36% of farmers' income, and up to 36% of traders' income in countries such as Kenya, Ghana, Uganda, and Morocco.

From this background, it is evident that various studies used a general assumption on the farmer. They did not consider closely and adequately the age of the farmer as a variable worthy of attention in relation to the adoption and use of ICTs in crop productivity. Considering the rate at which more ICTs fluent young people are joining the agricultural sector at various nodes along the value chains, it is important to understand the dynamics of this technology, particularly how its use influences crop productivity. This is in recognition of the fact that agricultural practices of youth ICT adopters could be different from non-adopters.

5. Conceptual Framework

The discussed theories are integrated in the conceptual framework here under for the purpose of setting study direction (Figure 1).

Practically, the ICTs adoption is influenced by behavioral intention to use ICTs among young farmers (Zaremohzzabieh et al., 2016; Ali et al., 2020; Ulhaq et al., 2022). The behavioral intention depends on institutional factors, farmers' specific characteristics and UTAUT variables viz Performance Expectancy which is the degree to which an individual believes that using ICTs will help to improve crop productivity and Effort Expectancy which refers to the perceived amount of effort that the user needs to put to learn and operate ICTs. Other UTAUT variables are Social Influence, the degree to which an individual perceives ICTs as important to enhance crop productivity after getting experiences from others such as colleagues and peers and facilitating conditions which are the provision of support for users in terms of ICTS gadgets such as mobile phones, computers and software necessary to work on ICTs compatibility with other systems.

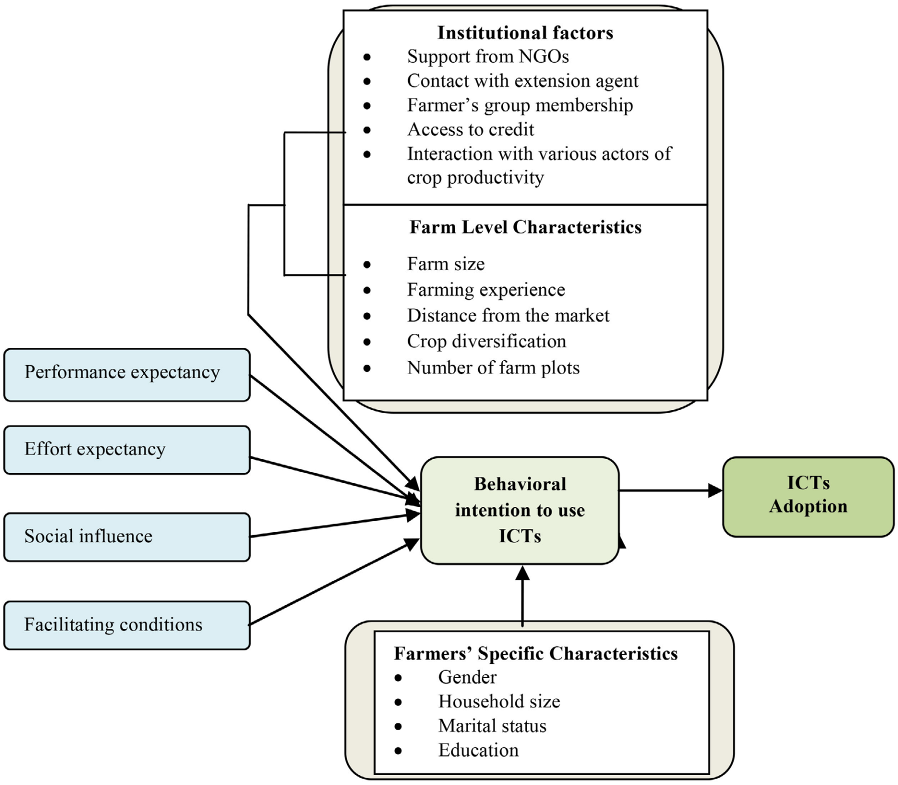

Figure 1. Conceptual framework.

6. Methodology

6.1. Source of Data

The data for this study were obtained from Misungwi and Kilosa districts, which were designed to assess the factors influencing adoption of ICTs and impact of ICTs in crop productivity. The data were collected through a household survey from 400 young farmers randomly selected tomato, paddy and cotton growing households in Misungwi and Kilosa districts which represent diverse agro-ecological zones, socio-economic environments, cultural diversity and multitude of production systems. For instance, Kilosa District is considered as a high potential area for the export-oriented crops such as tomato and rice. Misungwi District, on the other hand, is a prominent cotton, paddy and tomato growing area (Kajembe et al., 2013). Thus, the choice of the two districts presents different levels of commercialization and crop productivity. Kilosa District is mainly inhabited by the Luguru and Kaguru ethnic groups while Misungwi is mainly inhabited by Sukuma ethnic group. The two districts have ICTs infrastructures in the form of call centers which provide opportunities for young farmers to interact or communicate with other service providers. Besides, both districts are served by agricultural training and research institutions.

The survey contained detailed information on a range of socio-economic attributes, adoption of ICTs, membership of formal and informal farmer groups, access to credit, NGOs and extension, crop diversification, distance from market among others.

6.2. Empirical Strategy

Identification of the causal effects of ICTs adoption on potential outcome indicators is not trivial due to endogeneity bias. Accurate measurement of impacts requires controlling for both observable and unobservable characteristics through random assignment of individuals into treatments. In the absence of random assignments, selection bias may persist since observed and unobserved characteristics of individuals may affect the likelihood of receiving treatments as well as outcome indicators. In this paper, we employ propensity score matching (PSM), and Inverse Probability Weighted Adjusted Regression (IPWRA) approaches to control for endogeneity bias. The basic idea behind PSM is to match each treated household with a similar untreated household and then measure the average difference in the outcome variable between the treated and untreated households. In other words, we are interested in the question, "How would the welfare level of households have changed had the treated households chosen not to be in the treatment group?" Following the average treatment effect on the treated (ATT) is defined as:

$$\text{ATT} = E\left[F(1) - F(0) \mid T = 1\right] \tag{1}$$

where $F(1)$ and $F(0)$ are outcome indicators (in our case, adoption of ICTs level of treated and untreated households respectively). T is a treatment indicator. However, we can only observe $E\left[F(1)|T=1\right]$ in our data set and $E\left[F(0)|T=1\right]$ is missing. In essence, we cannot observe the impact of ICTs adoption level that the treated households had before treatment, once they are treated. Simple comparison of adoption of ICTs and impact of crop productivity of young farmers with and without treatment status introduces bias in estimated impacts due to self-selection bias. The magnitude of self-selection bias is formally presented as:

$$E\left[F(1)-Y(0)|T=1\right]=\text{ATT}+E\left[F(0)|T=1-F(0)|T=0\right] \tag{2}$$

By creating comparable counterfactual households for treated households, PSM reduces the bias due to observables. Once households are matched with observables, PSM assumes that there are no systematic differences in unobservable characteristics between treated and untreated households. Given this assumption of conditional independence and the overlap conditions, ATT is computed as follows:

$$\text{ATT}=E\left[F(1)|T=1,p(x)\right]-E\left[F(0)|T=0,p(x)\right] \tag{3}$$

The study used three matching methods which are: Nearest Neighbor Matching (NN), Caliper or Radius Matching and Kernel matching. In NN treatment, a unit was matched to the comparison unit with closest propensity score. Caliper or radius matching imposed a threshold or maximum propensity score distance and matching was done within a range of radius and Kernel matching used several controls, to act as the matches for a treated group. The idea of Kernel matching is to calculate the average propensity score from a neighborhood of propensity of several comparison members (non ICTs adopter households), match this average propensity score to the propensity score of a treated (ICTs adopter households) and then proceed to obtain the average treatment. We use kernel to test the robustness of the results (Shahidur et al., 2010).

However, ATT from PSM can still produce biased results in the presence of mis-specification in the propensity score model (Robins et al., 2007; Wooldridge, 2007, 2010). A potential remedy for such misspecification bias is to use IPWRA. According to Wooldridge (2010), IPWRA estimates will be consistent in the presence of mis-specification in the treatment/outcome model, but not both. As a result, the IPWRA estimator has the double-robust property that ensures consistent results as it allows the outcome and the treatment model to account for mis-specification. Following Imbens and Wooldridge (2009), ATT in the IPWRA model is estimated in two steps. Suppose that the outcome model is represented by a linear regression function of the form $Y_i=\alpha_i+\beta_i x_i+\varepsilon_i$ for $i=\left[0\,1\right]$ and the propensity scores are given by $P(x;y)$. In the first step, we estimated the propensity scores as $P(x;\check{y})$. In the second step, we then employed linear regression to estimate $(\alpha_0\beta_0)$ and $(\alpha_1\beta_1)$ using inverse probability weighted least squares as:

$$\frac{\text{mean}}{\alpha_0\beta_0}\sum_i^N\left(Y_i-\alpha_0-\alpha_0\beta_1/p(x,\check{y})\right) \text{ if } T_i=0 \tag{4}$$

$$\frac{\text{mean}}{\alpha_1\beta_1}\sum_i^N\left(Y_i-\alpha_1-\alpha_1\beta_1/p\left(x,\breve{y}\right)\right)\quad\text{if}\quad T_i=1 \tag{5}$$

The ATT is then computed as the difference between Equation (4) and Equation (5).

$$\text{ATT}=\frac{1}{N_W}\sum_i^{N_W}\left[\left(\breve{\alpha}_1-\breve{\alpha}_0\right)-\left(B_1-B_0\right)x_i\right] \tag{6}$$

where $\left(B_1,B_0\right))$ are estimated inverse probability weighted parameters for treated households while $\left(\breve{\alpha}_1,\breve{\alpha}_0\right)$ are estimated in-verse probability weighted parameters for untreated households. Finally, N_W stands for the total number of treated households.

7. Results and Discussion

7.1. Determinants of ICTs Adoption in Crop Productivity

Table 1 presents the main determinants of ICTs adoption. The results show that sex, education, crop diversification, access to credit, contact with extension agents, receiving advice from NGOs, and farm location were statistically significant in influencing young farmers into adopting ICTs in their crop productivity. The difference was observed among ICT types and the model was significant at 1% level.

Table 1 shows that sex of the respondent was an important determinant ($\rho \leq 0.01$) that influenced the adoption of ICTs in the study area. Being male increases the probability of adopting more than one ICT devices by 22.5% among young farmers. The results further indicate that all devices (feature phones, smart phones and computers) were highly significant at 1%. Owning a feature phone increases the probability of adopting ICTs by 1.82%, owning smart phone increases the probability of adopting ICTs by 1.37% and owning computer increases the probability of adopting ICTs for crop productivity by 1.33%. These findings are consistent with the findings in a study by Hollenstein (2004); Kiiza and Pederson (2012); Adegbidi et al. (2012); Tata and McNamara (2016); and Fuchs et al. (2010) who observe that farmers' sex has a positive influence on the adoption of technology. In general, women hesitate to adopt ICTs in crop productivity than is the case with men. Women adopt new technology such as ICTs if it is evaluated to be useful to them and to their family (Ragasa, 2012).

Primary education of the respondents was an important factor in determining ICTs' adoption at 5% significant level. Furthermore, secondary and post secondary education was very significant at 1% level. These results are consistent with earlier studies (Zorn et al., 2011; Ali, 2012; Masuki et al., 2010) that literacy level positively increases awareness and hence facilitates the adoption of a number of ICT devices.

Results in **Table 1** show that crop diversification has a negative effect of ICTs adoption. The value was statistically significant at 1%. These findings are in contrast to the findings in a study by Ali (2012), Mittal and Mehar (2016) who found that, a crop-diversified farmer, inclined to introduce new crops, is likely to adopt ICTs based crop productivity. One of the reasons could be that young farmers who do not diversify as opposed to those who diversify crops seek for more information via ICTs on a particular crop.

Table 1. Marginal effects on factors influencing ICTs adoption.

Variables	Coefficient	Feature phone adopters	Smart phone adopters	Computer adopters
Age	0.0228	0.00182	0.00128	0.00124
	(0.0211)	(0.00169)	(0.00119)	(0.00116)
sex	0.740***	0.0591***	0.0416***	0.0401***
	(0.225)	(0.0182)	(0.0137)	(0.0133)
Household size	−0.0597	−0.00477	−0.00336	−0.00324
	(0.0410)	(0.00331)	(0.00233)	(0.00226)
Primary education	0.894**	0.125*	0.0416**	0.0233**
	(0.428)	(0.0662)	(0.0164)	(0.00913)
Secondary education and above	2.512***	0.154**	0.167***	0.144***
	(0.494)	(0.0673)	(0.0338)	(0.0320)
Member in farmers' group	0.435	0.0347	0.0245	0.0236
	(0.306)	(0.0246)	(0.0174)	(0.0168)
Crop diversification	−0.799***	−0.0638***	−0.0449***	−0.0433***
	(0.223)	(0.0185)	(0.0137)	(0.0133)
Access to credit	0.494**	0.0394*	0.0278*	0.0267*
	(0.252)	(0.0204)	(0.0145)	(0.0140)
Contact with extension agents	0.523**	0.0418**	0.0294**	0.0283**
	(0.220)	(0.0179)	(0.0129)	(0.0125)
Advice from NGOs	1.048***	0.0837***	0.0589***	0.0567***
	(0.358)	(0.0303)	(0.0211)	(0.0204)
Farm location	0.991***	0.0791***	0.0557***	0.0537***
	(0.233)	(0.0191)	(0.0149)	(0.0144)
Constant cut1	2.124**			
	(0.865)			
Constant cut2	4.717***			
	(0.895)			
Constant cut3	5.970***			
	(0.913)			
Observations	400	400	400	400

***$p < 0.001$, **$p < 0.05$, *$p < 0.1$.

It is also evident from **Table 1** that, access to credit had positive and significant influence on the extent of intensity of ICTs adoption by cotton producers at 5%. Farm households with access to credit planted more area compared to farming households who had no access to credit. Some of the reasons are that input technologies such as improved seeds are costly. Money could be needed to purchase seeds as well as complementary inputs where necessary. This explains why access to credit is often observed as an important determinant of the adoption of all ICTs devices for crop productivity (Jayne et al., 2004; Mineiro et al., 2019). It is also evident from this study that more than 75% of young farmers do not have access to credit.

Young farmers' contact with extension agents is significant at 5%. This finding is in agreement with the general belief that the use of ICTs increases extension agent contact and increases farmers' productivity capacity. Accordingly, young farmers who use the ICTs frequently, receive more information and probability of adopting new technology increases (Bolarinwa & Oyeyinka, 2011). Extension officers provided young farmers with updated information on technologies related to crop productivity. According to Magesa et al. (2014), the extension agent becomes a critical source of information during the adoption itself.

Access to NGOs was positive and highly significant at 1%. Young farmers' contact with NGOs determines the information that farmers obtain on the crop productivity activities and the application of innovation through counselling and demonstrations by NGOs staff. The effect of exposure of young farmers to NGOs programmes is enormous. For instance, Anoop et al. (2015) found that farmers who have access to NGOs and extension agents' contacts adopted an alley of farming technologies 72% higher than farmers who had no access to NGOs and extension agents' contacts. The reason could be that, increased farmers' interaction with NGOs personnel in the form of multiple visits by staff such as extension agents and technical support to farmers greatly increases farmers' knowledge of the available technologies (ICTs) and their potential benefits, hence acts as a triggering mechanism for ICTs adoption.

During focus group discussions held at MATI Ukiriguru in Misungwi District, participants had a consensus that education, sex and contact with extension influenced adoption of ICTs for crop productivity. Accordingly, education catalyses information flow and exposes the farmer to more pathways of getting information. Sex also significantly affected ICTs adoption where males have more merits of adopting ICTs than is the case with females because of social constructions. Extension agents play a great role in influencing young farmers to adopt ICTs. Extension agents work as technology transfer and innovation from researchers to young farmers for diffusion.

However, as stated earlier, the results in **Table 1** cannot be used to make inferences regarding the impact of ICTs adoption on crop productivity without controlling for other confounding factors. Results in **Table 2** show the effect of ICTs adoption in crop productivity.

7.2. Multivariate Analysis Using the PSM Model Results

The impact of ICTs on crop productivity was first analyzed using PSM. The predicted scores range from 0.0361 to 0.9999 for the matching between adopters and non-adopters; from 0.1916 to 0.9999 for adopters and from 0.03466 to 0.9860 for non-adopters. The common support area where the predicted values for adopters and non-adopter were found was also clear from the density distribution (**Figure 2**). The test balancing condition was performed to make sure that it is satisfied since it is a vital issue in PSM as it decreases the influence of confounding variables (Rosenbaum & Rubin, 1983).

The covariance balancing test was conducted to ensure that the balancing condition was satisfied. **Table 2** results show that after matching the standardized mean bias was reduced from 32.5% pre-matching to 12.9% for Radius matching, from 32.5% to 18.8% for Nearest neighbor and from 32.5% to 14.4% for Kernel matching. There were no systematic differences in the distribution of covariates between adopters and non-adopters of ICT tools because the standardized mean bias was fairly low. Furthermore, there were no statistical significant differences in the distribution of covariates between the two groups. Therefore, the propensity score estimation concerning balancing the distribution of covariates between adopters and non-adopters was correctly specified (**Table 2**). After ensuring that the balancing condition is satisfied and verifying the matching quality, the impacts were estimated as presented in **Table 3**.

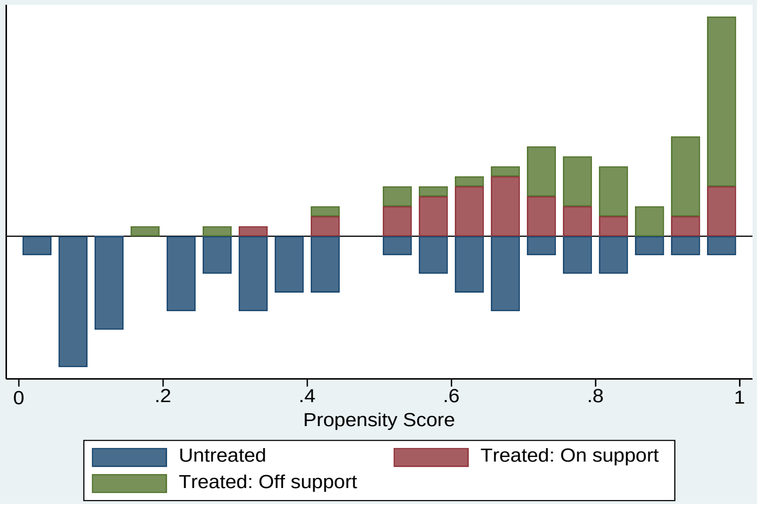

Figure 2. Common support region of propensity scores for the adoption of ICT tools.

Table 2. The PSM matching quality test.

N	Radius matching		Nearest neighbor		Kernel matching	
	Before matching	After matching	Before matching	After matching	Before matching	After matching
Pseudo R^2	0.304	0.103	0.304	0.138	0.304	0.059
$LR\chi^2$	53.08	10.52	53.08	12.99	53.08	12.86
$p > \text{Chi}^2$	0.000	0.786	0.000	0.603	0.000	0.613
Mean standardized bias	32.5	12.9	32.5	18.8	32.5	14.4

Table 3. Differences in ATT for treated and control groups.

Matching algorithm	Treated	Control	Differences	SE	Tstat
Radius matching	260.23	135.09	125.14	49.18	2.54
Nearest neighbor	275.83	119.31	156.52	54.08	2.89
Kernel matching	258.40	170.06	88.33	54.49	1.62

Table 4. The PSM and the IPWRA estimates.

Variables	PSM	IPWRA
ICTs adoption	0.8159** (0.3331)	0.11649** (0.3452)
N	400	400

**$p < 0.05$.

7.3. The Propensity Score Estimation Results

Three matching algorithms were used to estimate the impact of the adoption of ICT tools on crop productivity. The analysis relied on the execution of common support to ensure that adopters and non-adopters were distributed on the same domain. The adoption of ICTs has positive and significant effects on productivity at a 5% level (**Table 4**). The increase in yield ranges between 88.33 kg/acre and 156.52 kg/acre.

Table 4 reports the treatment effect estimates for ICTs adoption using alternative estimation techniques. Columns 1 and 2 present treatment effects of ICTs adoption based on PSM and IPWRA specifications. The IPWRA was used to check robustness of the PSM estimates because of its property of double robustness check. In general, the reported effects of ICTs adoption are robust across all estimation strategies. This shows that the impacts of ICTs on productivity are positive and significant at 5% level. In particular, we found that ICTs adoption increases the probability of increasing crop productivity by 33.31% using PSM and 34.52% using the IPWRA specifications.

These results underscore the reality that, public investments that aim at improving ICT adoption can have a significant effect on crop productivity. These results are consistent with those of Zeng et al. (2015) who researched on sex impacts of improved maize varieties on poverty in rural Ethiopia and by using PSM they found that improved maize varieties have led to a 0.8% - 1.3% drop of poverty headcount ratio and relative reductions of poverty depth and severity. Abadi et al. (2018) researched on the impact of remittances on household food security and found that households with access to remittance have significantly lower coping strategy index (CSI), reduced coping strategy index (rCSI) and household food insecurity access scale (HFIAS) on average as compared to households without remittance income.

8. Conclusion and Recommendations

8.1. Conclusion

Considering the level of ICT adoption among young farmers the following attributes are considered to influence ICTs adoption among young farmers: Gender is found to be one of the determinants influencing ICTs adoption. Due to cultural context of the study areas, women lag behind in adopting ICTs in crop productivity. Young farmers with an increase in education are more likely to adopt ICTs than those with low education. Farmers who diversify crops are likely to adopt ICTs negatively as a result of not concentrating on one crop which requires accessing more information as way to mitigate risks of failure. Access to credit was found to be significant, as a farmer whose focus is on maximizing crop productivity will secure some credit facilities for that. Farmers who interact with extension agents and NGOs are likely to adopt ICTs to seek more information on input supplies and output supplies.

ICTs adoption as well as other key household characteristics has heterogeneous effects on the propensity score of improving crop productivity among young farmers. In particular, there was a positive relationship between ATT of ICTs adoption and propensity scores for crop productivity. This result implies that the effect of scores for crop productivity is stronger for households with the highest propensity to adopt ICTs.

8.2. Recommendations

Based on key household characteristics, a key policy recommendation is that the Ministry of Agriculture is recommended to consider ICTs adoption among young farmers to have heterogeneous effects and understanding the potential role of such heterogeneity is important to improve crop productivity. The paper highlighted the importance of designing "best fit" interventions instead of "one size fits all" options by development stakeholders such as donors and governments in order to capture essential heterogeneity among young farmers.

Promoting the acquisition of ICTs tools such as smart phones or wider public access to computers by Tanzania Communication and Regulatory Authority (TCRA) is a necessary first step towards enhancing ICT use by young farmers in Tanzania. Equipping districts with ICT facilities by District Councils such as call centres could help young farmers to access information and knowledge related to crop productivity and improve their livelihoods. As part of innovation, these centres may be used by young farmers when they are in need of extension services.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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