POTENTIAL OF USING MOBILE PHONES FOR CROP DISEASES MANAGEMENT AMONG HETEROGENEOUS FARMERS IN RWANDA

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Summary

Smartphones and new communication tools are likely to transform the way information exchange and social interactions take place. However, how ICT developments will influence communication, social interaction, and decision-making among farmers are intriguing questions yet to be studied. Thus, the aim of this study is to evaluate the use of and experience with mobile phones among banana growers in Rwanda within the context of establishing an effective method for the prevention and control of Banana Xanthomas Wilt (BXW), an infectious plant disease. Specifically, we want to assess whether farm clusters associate with the different behaviors and perceptions of the use of mobile phones. A structured questionnaire was used to collect household information from banana growers (n=690) in eight representative districts across eight (out of ten) major agro-ecological zones within Rwanda. We combined principal component analysis and cluster analysis to develop typologies of banana growers. Our analysis identified three types of banana growers: Beer banana farmers, Livestock farmers, and Cooking banana farmers. Farmer typologies were distinct and differentiated by use of and experience with mobile devices, the main form of mobile phones. We then conducted a statistical analysis to regress the use of mobile phones on the farmer typology and other socioeconomic control variables. Our results showed that cooking banana farmers are more likely to own a smart phone and perceive mobile phones as very useful in effectively controlling BXW. Beer banana farmers, by contrast, are less likely to own a smart phone, lack the knowledge of how to make use of such services, and tend to perceive mobile phones as irrelevant to controlling BXW. One of the main causes of this is their low level of literacy. This lack of knowledge and lack of hardware pose an obstacle to using mobile phone services, even though the beer banana farmers in our study exhibited an openness toward exploring their potential usefulness.

Keywords

Mobile phone-based extension, Farm diversity, Banana production systems.

1 Introduction

Agricultural development is both crucial, and global issue with increasing demand for the world to feed its population. The fact that the increase in yield does not grow at pace with the increase in food demand the food gap is expanded day by day signposting the potential of food shortage in the future (LONG et al., 2015). Plant disease is one of the major threats seriously compromising food production thus negatively affecting food security (STRANGE and SCOTT, 2005). For example, the Banana Xanthomonas Wilt (BXW), caused by *Xanthomonas campestris* currently known as *Xanthomonas vasicola pv. Musacearum* (BIRUMA et al., 2007), has become the number one threat to banana intensification programs aiming at availing food for the increasing population in East and Central Africa (NAKATO et al., 2014). Banana is a key crop, especially in the eastern and central part of Africa, in the livelihoods of smallholder farmers occupying almost a quarter of arable land, contributing more than 50% to the diets (NKUBA et al., 2015; GAIDASHOVA, 2006) and grown by 90% of households (NSABIMANA et al., 2008). The crop is grown for 3 main purposes namely for cooking (41% of the total banana cultivated area), for dessert (14% of the total banana cultivated area), and beer (45% of the total banana cultivated area) in Rwanda (NSABIMANA et al., 2008; BAGAMBA et al., 1998).

ICT tools and especially mobile phone-based ICT technologies have recently come up as a potential way of reorganizing extension systems (Schut et al., 2016). The idea is that mobile phone-based ICT technologies, including smartphones and new communication tools, offer an opportunity to innovatively improve disease control efforts through timely surveillance of incidence. ICT technologies can improve communication among farmers themselves in the context of informal knowledge sharing networks which are developed because of limited operation in space of extension agents (VOUTERS, 2017). A review by MCCAMPBELL et al. (2018) distinguished four intervention pathways for the application of citizen science and ICT within the context of effective control of this banana disease in Central and East Africa. These four pathways are 1) providing data for prevention, 2) providing technical information for control, 3) providing knowledge to influence decision making, and 4) improving collective action. From this perspective, it is argued that the use of mobile-based communication platforms will enhance self-organized networks to timely diagnose BXW emerging outbreaks and to exchange knowledge which will lead to timely actions for prevention rather than control (MCCAMPBELL et al., 2018).

Although ICT tools, including mobile phones, potentially offer many benefits, the question of how these ICT developments will influence the communication and social interactions among farmers, and their subsequent decision-making are yet to be studied. As a first step towards answering this question, we aim to assess the different attitudes related to the use and perceptions of ICT-related agricultural services (especially mobile phones) by different types of farmers. This is necessary because farms are diverse and heterogeneous in terms of socio-economic conditions which affect their behaviors on resource use and priorities hence the better understanding of this might explains differences in behaviors regarding production and consumption in the agricultural production system (BARNES et al., 2011; TITTONELL et al., 2005). Most projects in agriculture are designed assuming that farmers are homogeneous hence interventions are similar to all. To some extent, the low uptake of agricultural innovations has been associated with the failure of proper consideration of smallholder farm diversity (HAMMOND et al., 2017; COE et al., 2016). A similar problem can be found concerning the potential use of mobile phones. Although there have been studies to understand factors affecting farmers in adopting phone-based services in agriculture (TADESSE and BAHIIGWA, 2015; ADEGBIDI et al., 2012; ISLAM and GRÖNLUND, 2011) these studies have also assumed that farmers are homogenous.

In this paper, we use farm clustering to classify farm households based on socio-economic characteristics to understand how they would react differently to the adoption of new technologies based on their diverging priorities (HAMMOND et al., 2017). In this study, we thus consider farm diversity by discussing the use and perception of mobile-based information delivery against banana farm clusters. The findings of this study will provide significant background information to projects targeting the use ICT based intervention for improved agricultural management.

2 Methodology

2.1 Study area

This study was performed in Rwanda, the country located in East-Central Africa between latitudes 1°04’ and 2°51’ South and longitudes 28°45’ and 31°15’ East. In terms of area covered by banana in Districts, Muhanga, Gatsibo, Karongi, and Rulindo have higher land allocated to banana production, equivalent to 22.5%, 11.1%, 10.1%, and 7.1% respectively of the total agricultural area.

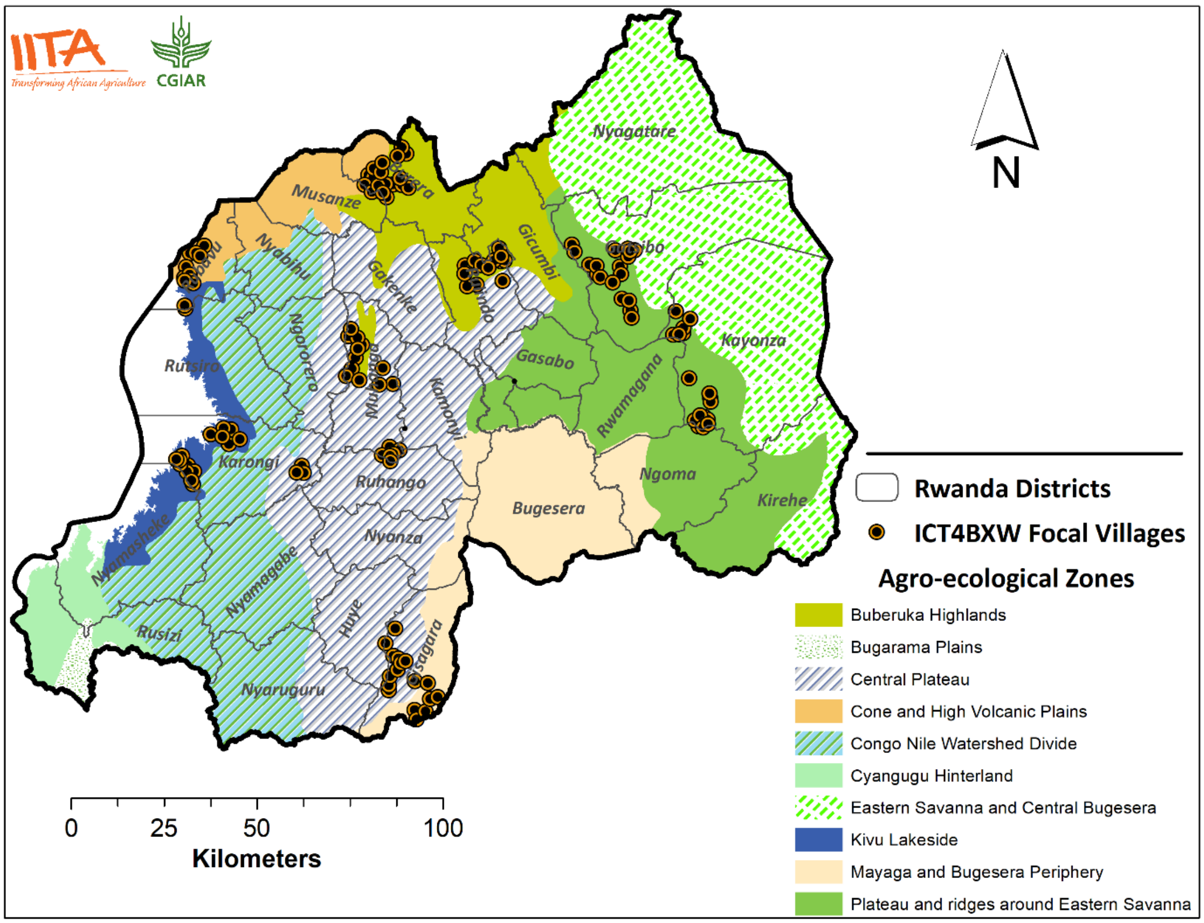

Figure 1: Study area

2.2 Sampling and data collection

The household survey was conducted from July through August 2018 by trained RAB technicians from Banana program to establish the baseline of "Citizen Science and ICT for advancing the prevention and control of Banana Xanthomonas Wilt (BXW) in East and Central Africa" project. Within 8 selected districts Sectors and Cells were selected based on expert input from the district and sector agronomists. Stratified sampling was used to select villages, strata being the distance from the District extension office and the incidence of BXW. Two criteria were considered when selecting villages: (1) distance between the village and the district headquarters whereby three-point scale was used (close, medium, and far) and (2) Level of BXW incidence whereby three-point scale was used (low, medium, high). Incidence levels were determined based on reports from the sector and cell agronomists and field observations from RAB banana experts and technicians when passing through the village. The sampling team aimed for the selection of villages with a minimum distance of 5km or a non-intervention and non-control village in between two selected villages. The selection of farmers considered the gender of the household head, where, amongst 5 farmers selected in each village 2 were female-headed households and female enumerators were assigned to interview this category of farmers. The total expected number of farmers interviewed was 720 however only 690 farmers were interviewed reason being the lack of villages that fall within the long distance to the district headquarters' category in Rubavu District thus reducing the number of the village from 144 to 138. The questionnaire used open, half-open, and closed questions, retrieving information at the household level to establish baseline information for the "Citizen Science and ICT for advancing the prevention and control of Banana Xanthomonas Wilt (BXW) in East and Central Africa" project shortened as ICT4BXW. For this study, we only analyze those questions of the survey that included ownership and use of mobile phones as ICT tools, the relevance of mobile phones in BXW management and challenges farmers are facing concerning the use of mobile phones in agriculture. General questions such as gender, age, education level characterizing respondents were included for analysis.

2.3 Data analysis

Principal component analysis (PCA), a data reduction method unmasking, through orthogonal transformation, hidden structures in a dataset was used to identify variables more explaining farm differences and identify components to be used in grouping farmers into clusters (BARNES et al., 2011; KOURTI, 2009). Clustering was performed using the hierarchical method where hierarchy brings close a tree-like structure called dendrogram and clusters are formed by connecting k+1 cluster solution into two clusters using group resemblances. Both descriptive and inferential statistics were performed. Column means were run to identify significant differences between farm clusters at 95% probability level. Dichotomous outcome variables of interest were subjected to a binary logistic regression analysis with independent explanatory dichotomous, categorical, and continuous variables. We used FactoMineR, an R package dedicated to multivariate data analysis (LÊ et al., 2008), for principal component analysis whereas we used gplots R package to visualize and plot means (BONEBAKKER et al., 2012) in version 1.1.456 – © 2009-2018 RStudio.

3 Results

3.1 PCA and clustering results

Figure 2 shows the scree plot highlighting 10 components, from a total of 12 variables that were included in PCA, whereby five components with eigenvalues greater than 1 retained for cluster analysis explain 63.3% of the total variation. The figure also presents variables contribution to the construction of two main components (explaining 32.5% of the variation) where the land allocated to beer banana or cooking banana are the main variables contributing whereas the number of extension visits received contribution is not so significant.

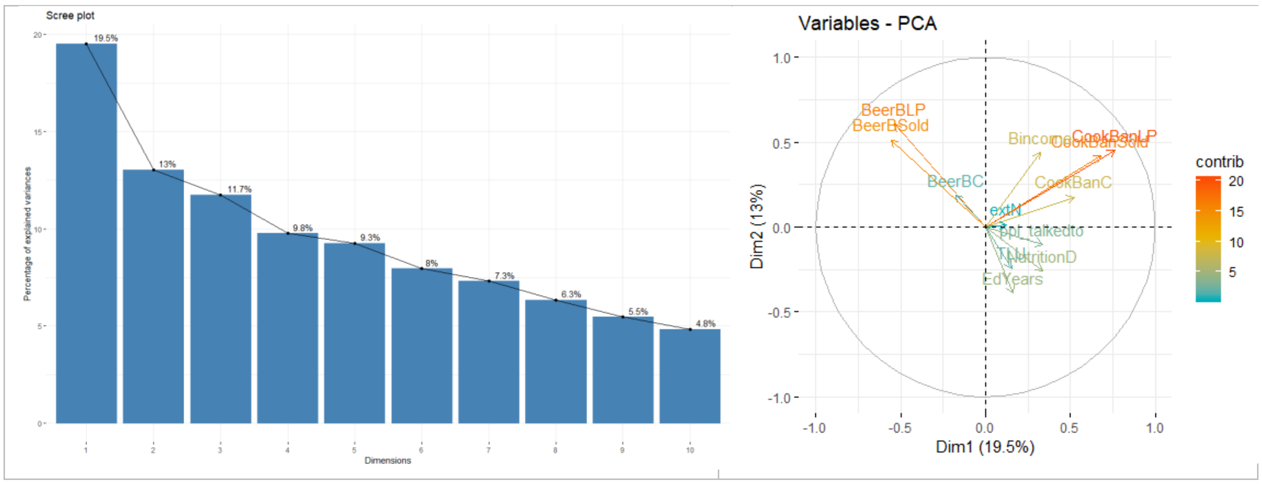

Figure 2: Principal component analysis Scree plot and contribution of variables to components

Table 1 presents identified variables responsible for farm heterogeneities which can be summarized in 3 groups namely farm/respondent characteristics (Nutrition Diversity and Education Years), type of banana grown, distribution in the field, and use (Cooking or beer banana with their respective proportion of land allocated to them, banana income and promotion sold and consumed) and access to extension services (Number of extension visits and People talked to). By observing the v.test values, which indicate if the mean of the cluster is lower or greater than the overall mean, we could name clusters considering that higher values of v.test show variables that are more associated with the cluster. Cluster one is more associated with the proportion of beer banana sold, the proportion of land allocated to beer banana, and the proportion of beer banana consumed as highlighted in the table thus they are named Beer Banana Farmers (BBF). The second cluster which is more associated with tropical livestock unit (Livestock numbers converted to a common unit), education years and nutrition diversity is named Livestock Based Farmers (LBF) whereas the third cluster named Cooking Banana Farmers (CBF) is more associated with the proportion of land allocated to cooking banana and proportion of cooking banana sold and consumed.

Table 1: Variables responsible for farm heterogeneity and resulting clusters

Variable	V.test Mean C1	V.test Mean C2	V.test Mean C3
Nutrition Diversity	-5.12	**2.55**	2.89
Number of extension visits	-2.02	**-**	-
Education Years	-3.10	**2.91**	-
Tropical Livestock Unit	-2.56	**3.38**	-
Cooking Banana Land P.	-11.20	-8.38	**20.62**
Cooking Banana P. Consumed	-9.13	-7.81	**17.81**
Cooking Banana P. Sold	-9.60	-8.26	**18.78**
Beer Banana Land P.	**16.77**	-12.41	-5.30
Beer Banana P. Consumed	**6.39**	-5.60	-
Beer Banana P. Sold	**19.45**	-14.27	-6.27
Banana income	-	-4.94	5.77
People talked to	-4.15	-	3.95
Named according to V.test	***Beer Banana farmers(BB)***	***Livestock based farmers(LB)***	***Cooking Banana farmers(CB)***

Characteristics of respondents by clusters

Table 2 presents characteristics of households and respondents by banana farm clusters in terms of gender and farm experience in BXW infection. The majority of respondents (57.8%-64.4%) were males but the difference was very high in livestock-based farmers. There was no significant difference between typologies in terms of having experienced or experiencing BXW (Table 5) suggesting that they are all equally vulnerable.

Table 2: Descriptive statistics characterizing household and respondents by banana farm clusters

Variable	Category	Beer BF(270)	Livestock BF(219)	Cooking BF(201)	$\chi 2$tests of independence
Gender of respondents	Female(276)	(114)42.2%	(78)35.6%	(84)41.8%	$\chi 2(2)=$ 2.58 NS
	Male(414)	(156)57.8%	(141)64.4%	(117)58.2%	
Experienced BXW	No(225)	(98)36.3%	(64)29.2%	(63)31.3%	$\chi 2(2)=$ 2.96 NS
	Yes(465)	(172)63.7%	(155)70.8%	(138)68.7%	

Figure 3 summarizes the means of quantitative variables characterizing respondents by clusters. The average age of beer banana farmers (49.9±14.8 years) was slightly higher than the rest of banana farmers. The livestock-based farmers were significantly highly educated (6.6±3.3 years of education) than other groups. The average family size and tropical livestock unit were higher for livestock-based farmers while cooking banana farmers had higher banana income (15.4±41.0*10000 Rwandan Francs) and the proportion of cooking banana sold. Concerning the average number of people talked to, an indication of information exchange regarding BXW management, cooking banana farmers had a high average number (18±46 people).

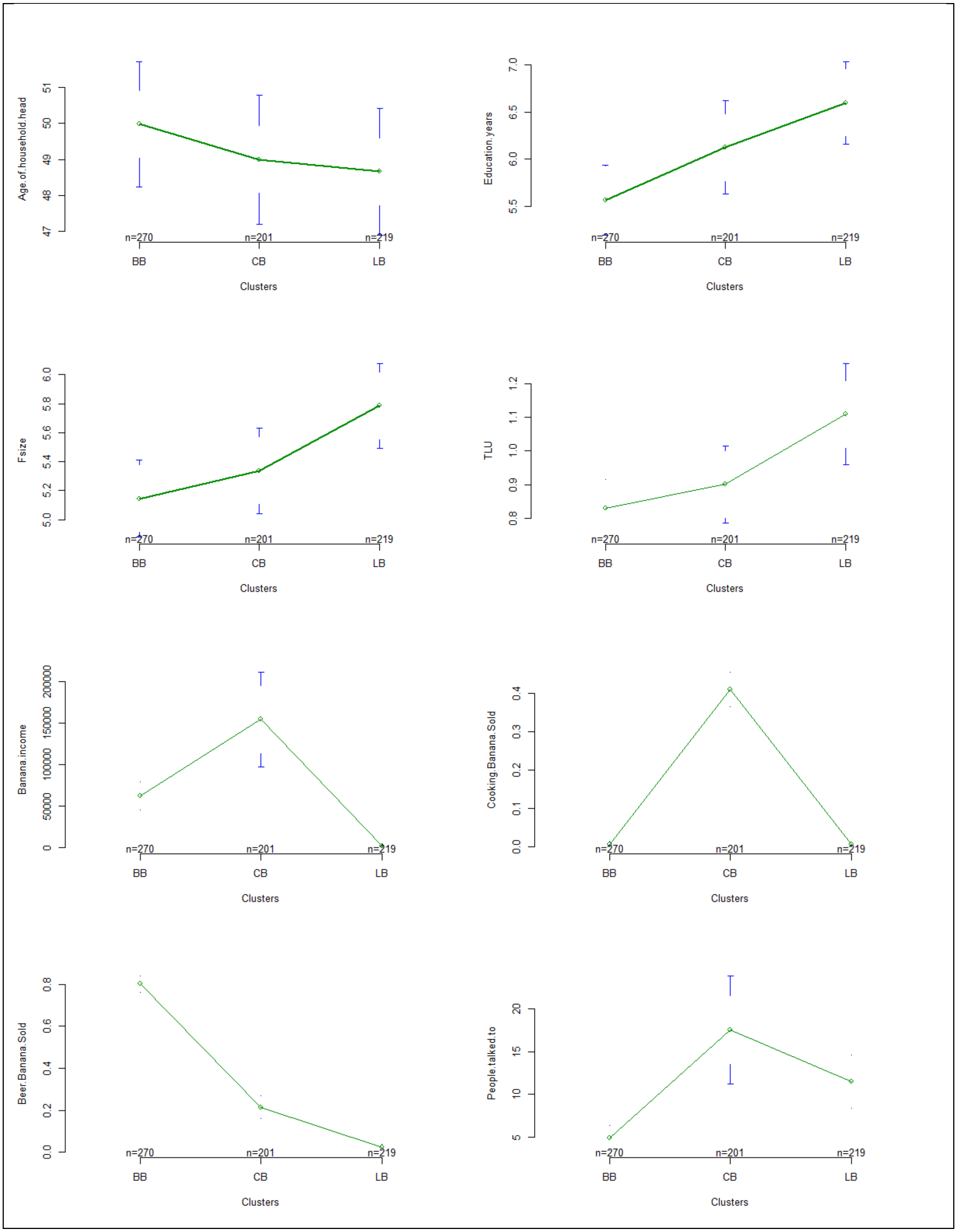

Figure 3: Characteristics of household and respondent by banana farm clusters

Implications of farmer typology for mobile phones use

In results presented in Tables 3 and 4 cooking banana farmers are used as a reference in the logistic regression analysis. Results presented in table 3 show that cooking banana farmers are more likely to own both smart and basic phones. Beer banana farmers had a significantly decreasing likelihood of owning and use a mobile phone both smart and basic compared to cooking banana farmers. Furthermore, beer banana farmers had also more than two times higher likelihood of not having mobile phones. Although livestock banana farmers had a decreasing likelihood of owning and using both smart and basic mobile phones this was not significant compared to cooking banana farmers.

Table 3: Results of logistic regression about clusters ownership and use of mobile phones

Response variable	Predictor variable	Coefficient	S.E.	p-value	Odds ratio
Own smartphone	**Banana grower cluster**			0.059	
	Beer BF	-1.0	0.5	0.044*	0.4
	Livestock BF	-1.0	0.5	0.065	0.4
	Constant	-2.8	0.3	0.000***	0.1
Own basic phone	**Banana grower cluster**			0.001***	
	Beer BF	-0.7	0.2	0.001***	0.5
	Livestock BF	-0.2	0.2	0.314	0.8
	Constant	1.3	0.2	0.000***	3.7
Does not own a phone	**Banana grower cluster**			0.001***	
	Beer BF	0.8	0.2	0.000***	2.3
	Livestock BF	0.4	0.2	0.132	1.4
	Constant	-1.4	0.2	0.000***	0.2
Used smartphone	**Banana grower cluster**			0.009**	
	Beer BF	-1.6	0.6	0.005**	0.2
	Livestock BF	-1.0	0.5	0.050	0.4
	Constant	-2.6	0.3	0.000***	0.1
Used basic phone	**Banana grower cluster**			0.001***	
	Beer BF	-0.8	0.2	0.001***	0.4
	Livestock BF	-0.3	0.3	0.279	0.7
	Constant	1.8	0.2	0.000***	6.2

Key: *BF= Banana farmers, S.E=Sandard error*

Mobile phones use barriers

Results presented in table 4 show that cooking banana farmers had no particular barriers in the provided list however they are more likely to face other challenges which include the fact that ICT-based tools are expensive, language barriers, etc. Beer banana farmers are more likely to lack awareness of the existence of mobile-based extension services than others and are also two times more likely to lack the technical know-how to use phone-based extension services. Livestock banana farmers, though having a positive likelihood of facing barriers such as awareness, availability, and lack of technical Know-how.

Table 4: Results of logistic regression about clusters mobile phones use barriers

Barriers to the use of mobile phones	Predictor variable	Coefficient	S.E.	p-value	Odds ratio
Awareness	**Banana grower cluster**			0.074	
	Beer BF	0.4	0.2	0.029*	1.5
	Livestock BF	0.1	0.2	0.544	1.1
	Constant	-0.1	0.1	0.438	0.9
Availability	**Banana grower cluster**			0.544	
	Beer BF	0.4	0.4	0.435	1.4
	Livestock BF	0.5	0.5	0.272	1.6
	Constant	-3.2	0.4	0.000***	0.0
Know-how	**Banana grower cluster**			0.079	
	Beer BF	0.4	0.2	0.027*	1.5
	Livestock BF	0.2	0.2	0.361	1.2
	Constant	-0.8	0.2	0.000***	0.5
Time	**Banana grower cluster**			0.321	
	Beer BF	0.2	0.5	0.741	1.2
	Livestock BF	0.6	0.5	0.178	1.9
	Constant	-3.3	0.4	0.000***	0.0
Language	**Banana grower cluster**			0.743	
	Beer BF	-0.3	0.5	0.523	0.7
	Livestock BF	-0.4	0.5	0.495	0.7
	Constant	-3.1	0.3	0.000***	0.0
Literacy	**Banana grower cluster**			0.533	
	Beer BF	0.5	0.4	0.271	1.6
	Livestock BF	0.2	0.5	0.608	1.3
	Constant	-3.2	0.4	0.000***	0.0
Others	**Banana grower cluster**			0.026*	
	Beer BF	-0.7	0.2	0.007**	0.5
	Livestock BF	-0.4	0.2	0.125	0.7
	Constant	-1.2	0.2	0.000***	0.3

Key: *BF= Banana farmers, S.E=Sandard error*

Table 5, containing a summary of descriptive statistics about farmer's perception about the use of mobile phones for BXW management practices information delivery, shows that the majority of respondents, in all banana farm clusters, perceived the use of ICT-based agricultural services as somewhat useful but beer banana farmers had a big number of farmers perceiving the ICT-based agricultural services as irrelevant.

Table 5: Relevance of mobile phones for BXW management by clusters

ICT relevance Category	Beer BF(270)	Livestock BF(219)	Cooking BF(201)	$\chi 2$tests of independence
Neutral(79)	(40)14.8%	(30)13.7%	(9)4.5%	$\chi 2(2)= 25.57$**
Not useful(24)	(13)4.8%	(2)0.9%	(9)4.5%	
Somewhat un-useful (123)	(46)17%	(32)14.6%	(45)22.4%	
Somewhat useful(368)	(134)49.6%	(129)58.9%	(105)52.2%	
Very useful(96)	(37)13.7%	(26)11.9%	(33)16.4%	

4 Discussion

The use of ICT in agriculture is considered a key pillar of Rwandan economic transformation towards a middle-income country (LICHTENSTEIN, 2016). According to SALAMPASIS and THEODORIDIS (2013), an ICT tool is defined as an application or a device used to collect and exchange data through interaction or transmission. In this study, we evaluated the potential of using phone-based extension services for effective BXW management. For this reason, we analyzed baseline study survey data to understand how ready farmers are in this regard. In addition to this, to facilitate effective intervention tailoring, we considered farm heterogeneities by grouping them into clusters of similar socio-economic characteristics. It has been discussed that the limited adoption of innovation is probably associated with using a one-size-fits-all model (HAMMOND et al., 2017; COE et al., 2016).

The PCA identified 12 variables responsible for banana farmers' heterogeneity which were used in farm clustering. The identified farm clusters, zooming in the main focus of the farm banana production system, seemed to be appropriate and meaningful in the Rwandan banana farming system. The main focus of the first cluster (BBF) is the beer banana which is allocated to a large portion of banana land, the second cluster (LBF) main focus is livestock whereas the third cluster (CBF) main focus is cooking banana also allocated to a large portion of banana land. As discussed by BIDOGEZA et al. (2009) results from clustering must be clear and realistic to represent the empirical situation. Several studies emphasized that clustering individuals in more similar characteristics groups is a potential entry point to the diffusion of innovation and uptake since this probably results in almost similar behaviors (HAMMOND et al., 2017; BARNES et al., 2011; BIDOGEZA et al., 2009; BLAZY et al., 2009). With the results of this study, we believe that the main focus of a farm cluster is also the priority of that farm thus any intervention plan should take this into account. For example, in the context of BXW prevention and control, animals have significant implications (TINZAARA et al., 2011; NANKINGA and OKASAAI, 2006). In this regard, BXW interventions design for livestock-based farmers should consider that the group might consider that animals are more important than banana. In line with the arguments of JANSSEN et al. (2017) that for the community to benefit from ICT based model they should be involved in co-development to cover the priority needs of beneficiaries, we argue that developing a phone-based application to manage BXW in banana production system, for example, should consider to include in some ways livestock management options for the sake of livestock-based farmers. This supports the theory of diffusion of innovations by ROGERS (2003) mostly the point that innovation is quickly adopted when it fits in the existing social values and practices.

Concerning banana farm clusters owning and using a mobile phone, the different groups have a varying likelihood to own and use mobile devices. The cooking banana farmers seemed to be better-off given banana income possibly the reason why they are more likely to own and use mobile phones. This is in agreement with the study by TADESSE and BAHIIGWA (2015) who studied the impact of using mobile phones in agricultural marketing in Ethiopia. The majority of farmers had the basic type of mobile phones which has implications on the potential of using the agricultural mobile application as most applications are designed to be used in smartphones. The study by TADESSE and BAHIIGWA (2015) identified age and education level as significant determinants of owning and using a mobile phone where younger are more likely to own and use the phone and higher education increases the probability. This is in slight agreement with our findings since the average age of beer banana farmers who are less likely to own and use phones is high and the cooking banana farmers who are more likely to own and use phones had higher education level compared to other groups of farmers. McCampbell et al. (2018) review suggests four pathways of using ICT (Mobile phone) based extension services to prevent BXW occurrence we assume that smartphone owners, in the case of this study cooking banana farmers, have a lot more ways to provide information back, but for normal phone users (Beer banana farmers) this use is limited. However, there are also many ways that basic phones can be used to provide farmers with information and learning tools such as SMS and voice based. From this respect cooking banana farmers and livestock banana farmers are more likely to be open for providing data for prevention and sharing/receiving technical information for control whereas beer banana farmers can also be connected for connective actions.

The main challenge of the use of ICT (Mobile phone) based extension services was a lack of awareness of the existence of such services and the limited technical know-how. This implies that the release of mobile-based applications will require sensitization for raising awareness especially to beer banana farmers who are more likely to face these challenges than the rest of banana farmers groups. Awareness, technical know-how, and availability of services are important variables that influence the adoption, perception, and use of ICT-based solutions.

5 Conclusion and recommendations

Results show that cooking banana farmers are more likely to have and use mobile phones both smarts and basics than other banana growers' clusters. Beer banana farmers have a higher likelihood of not having a phone and have a big number of farmers perceiving the mobile phones for BXW management as irrelevant. The use of mobile phones is limited by lack of awareness and lack of technical know-how in beer banana farmers whereas cooking banana farmers are limited by other challenges such as being expensive. The studied farmers provide the potential for using mobile phones extension services however beer banana farmers, less likely to own smartphones, are limited to few options. We conclude that the use and perception of phone-based extension delivery are differentiated with banana production system described as farm clusters in this study and major barriers to "use and perception of phone-based extension services" are associated with limited access and linkage to extension delivery system. We thus recommend the consideration of heterogeneity of banana growers when designing and deploying ICT-based technologies to prevent and control BXW.

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