ICTs for conservation agriculture: influence of actor positioning in knowledge networks in Laikipia and Machakos counties, Kenya

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Abstract. Knowledge networks play a significant role in the transfer of innovations such as conservation agriculture. In this paper, we examine the position of actors in the network and socio-economic factors influencing use of ICTs. ICTs potentially enable information to reach large numbers of farmers. We collected data through 298 household surveys, 29 key informant interviews and five focus group discussions. We used social network analysis for centrality measures. To statistically test the relationship between socio-economic factors and use of ICTs, we used multinomial logistic regression analysis. Results suggest that gender and land under conservation agriculture *(p=<0.05)* significantly influence use of radio, TV and mobile phones. Education (*p=.024)* was more likely to influence use of print media. Age *(p>0.05)* was not a statistically significant factor. Positions of influence were occupied by extension officers (20%) and farmers (41%). The study recommends the use of ICTs with conventional approaches in CA knowledge networks.

Keywords: innovations, knowledge networks, social networks, ICTs, conservation agriculture, Kenya.

Introduction

Conservation Agriculture (CA) is a production system underpinned by three interlinked principles: minimum or no mechanical soil disturbance, soil organic cover and crop diversification (Kassam et al. 2014). Ngwira, Thierfelder & Lambert (2013) observed that for small-scale farmers in sub-Saharan Africa, this cropping system is still new and areas under CA are still small. Individual CA principles have been practiced by farmers for a long time. However, the uptake is still low and CA is generally not among the major agricultural issues championed by ministries of agriculture (Balarabé 2011). Nevertheless, with the increasing climate variability, CA is gaining prominence as a sustainable land management practice (FAO 2017).

CA was introduced in Kenya in 2002 under the pilot Conservation Agriculture for Sustainable Agriculture and Rural Development (CA-SARD) project, implemented by the Food and Agriculture Organization (FAO) and financed by the German Trust Foundation (K'Owino 2010). Being a relatively new production system, CA is still not well understood by a wider section of the farming community. In Kenya, CA adoption has been growing among large-scale operators, with minimal growth among smallholders (Milder, Majanen & Scherr. 2011). Despite the potential of CA to improve crop productivity, the adoption of the practice is still very low. In various farming communities where CA has been adopted, for example, in Tanzania, the production of maize increased from an average of 0.5 t/ha to 1.5 t/ha; in other cases, yield increases of up to 4 t/ha were reported when maize was intercropped with lablab (Mkonda & He 2017). Despite this improvement in crop yield, farmers are still unwilling to commit to the practice. Extension services are equally not well equipped with the technical skills of the practice. Access to the knowledge and experience generated is also very limited (Cicek et al. 2017).

Some of the challenges for the slow application of CA by smallholder farmers are attributed to the current knowledge dissemination approaches, like 'on-farm demonstrations' which are costly when implemented on a large scale. Zambrano & Seward (2012) argue that lack of knowledge and skills on CA among field officers and farmers are a major constraint to adoption of the farming practice.

Use of networks of agents has the potential to enhance adoption and dissemination of complex technologies like CA. The impact of these networks depends on the assets they command, their learning routines and the socio-economic environment in which they operate (Ekboir 2003). Mloza-banda et al. (2012) observed that CA entails a qualitative change in agriculture as it engages multiple actors and a farming environment in a long process of social construction and re-construction of both existing and new cropping techniques, together with institutional actors. Such changes necessitate specific processes of knowledge sharing and learning from experience.

ICTs are one of the promising areas in agricultural extension that can enable services to reach a large number of farmers. An ICT is any device, tool or application that permits the exchange or collection of data, information and knowledge through interaction or transmission. ICT is an umbrella term that includes anything ranging from radio to satellite imagery to mobile phones or electronic money transfers (Salampasis & Theodoridis, 2013, p.2). Rao (2006) suggests that ICTs can become key enablers of the agri-food sector by making dynamic and real-time global level exchange of data, information and knowledge quick, interactive and easy throughout the agricultural value chain. Blitzer et al. (2016) further suggest that ICT-based advisory services are promoted for their potential to enable targeted service delivery and offer diverse real time agricultural information through a range of different channels. The types of ICT innovations include advisory services, early warning systems, financial services, traceability of agricultural products and agricultural statistical data gathering and sharing (Siraj 2012).

For wider acceptance and adoption of practices like CA, it is important to understand the actors involved and the roles they play, the communication channels used and the socio-economic factors influencing use of these channels. In this paper, actors denoted as 'nodes' refer to the different institutions and individuals promoting CA. The social network refers to the series of direct ties from one actor to a collection of other actors, whereas ties are the relationships between the actors. Each relationship refers to a particular type of resource exchange. Haythornthwaite (1996) suggests that patterns of relationships will show who exchanges information with whom. Borgatti & Foster (2003) further suggest that individuals need to have certain kinds of relationships in order to utilize each other's knowledge. These relationships influence how new knowledge and innovations spread. The aim of this paper was to:

1. Elucidate the positioning of actors in the CA knowledge network and how this influences use of ICTs.
2. Analyse the institutional relationships influencing use of knowledge channels.
3. Examine the socio-economic factors determining the use of ICTs.

The study is based on the following hypotheses: (i) institutions with more linkages and networks positively influence diffusion of knowledge, (ii) actors in central positions exhibit a positive association with a variety of knowledge channels, and (iii) socio-economic factors are positively associated with age, gender, education, land size and choice of knowledge channels.

Analytical framework

We examine the institutional and socio-economic factors influencing use of ICTs from two theoretical viewpoints: the social network theory (Borgatti & Hargin, 2011) and the diffusion of innovation theory (Rogers 2003). These theories provide a framework for understanding how actors operate within a network environment, the relationships and factors influencing these relationships. Mitchell (cited in Park 2011, p. 1279) defines social networks as 'a set of linkages among a defined set of persons, with the additional property that the characteristic of these linkages as a whole may be used to interpret the social behaviour of the persons involved'. Cross and Prusak (cited in Chan & Liebowitz, 2005. p. 4) identify four common role players: (i) central connectors who are the actors that link most people in an informal network with one another; (ii) boundary spanners who connect an informal network with other parts of the organization or similar networks in other organizations; (iii) information brokers who keep the different sub-groups in the network together; and (iv) the peripheral specialists who provide expertise to anyone in an informal network. Each of these four roles is significant for the network and is critical to the productivity of the network or organization.

Previous studies using social network theory examined knowledge sharing relationships between science and farmers. Wood et al. (2014) investigated farmer networking as an interpersonal practice. Their findings suggest that farmers exchange knowledge in densely tied and strongly organized interpersonal networks. These networks decisively shape the communication of agricultural science in ways that limit professional closure and effectively disable the linear transfer of technology. Hoffman, Lubell & Hills (2015) further argue that knowledge networks are the social infrastructure that support social learning. An individual's ability to engage in social learning activities such as the generation, access and spreading of ideas is either constrained or enabled depending on the structure of the network and the individual's position in that network. The social network theory has been used by several scholars to analyse and study social behaviours, organizational behaviour and how actors relate within these networks, but little research has been undertaken using the network theory to understand the knowledge sharing relationships in CA networks and among small-holder farmers.

The second theoretical framework, the diffusion of innovations theory, refers to diffusion as a kind of social change. The theory defines diffusion as 'a process by which alteration occurs in the

structure and function of a social system' (Rogers 2003, p. 5). This theory seeks to explain how, why and at what rate new ideas and technologies spread through a social system. The theory has four main elements that influence the spread of a new idea: (i) the innovation, (ii) communication channels, (iii) time and (iv) the social system. These four elements work in conjunction with one another to enable replication of practices and spread of innovations. Innovation is a cumulative and interactive process where new actors keep coming in at each stage of production. Successful innovations are surrounded by a social process of improvement where producers of innovative products learn by doing as they build and improve the products (King et al. 1994). The diffusion of innovations theory has guided many studies that examine agricultural knowledge systems (Torres et al. 2012; Wood et al. 2014; Hoffman, Lubell & Hillis 2015; Meijer et al. 2015). In this paper, diffusion is viewed as a process by which the innovation, in this case CA, is communicated through the public and private extension systems to small holder farmers. The study used three of the elements of the diffusion theory: the innovation, communication channels and the social systems to examine the CA network.

Data and methods

Study area

Laikipia and Machakos counties are both situated in semi-arid areas of Kenya, with adverse weather conditions. Data was collected from the five sub-counties of Machakos central, Mwala, Yatta, Laikipia East and Laikipia North in Kenya. A multi-stage sampling approach was used, whereby the two counties of Machakos and Laikipia were first identified, then the five sub-counties where there is a high concentration of CA farmers were identified, and finally the nine wards which had large numbers of households practicing CA were purposively selected. The household survey using questionnaires covered 298 households. Households were selected from groups registered with the county departments of agriculture. Key informant interviews were held with 29 respondents comprising county officials and ICT service providers and five focus group discussions were held with farmer groups.

Data collection

A team of five researchers were involved in data collection between March to May 2015 in Laikipia County and between August and October 2016 in Machakos County. The team was selected based on their knowledge of CA, experience working with farmers and knowledge of the geographical area. A one-week training session was undertaken that involved going through the household questionnaires and key information interview guides. These were then pre-tested with 20 respondents from farming communities in Laikipia County who were not part of the survey population. The semi-structured questionnaires and interview guides had five main sections: socio-demographic characteristics, farmers' agricultural practices, sources and approaches used to get CA information, ICTs and extent of their use in the CA knowledge pathways. All respondents were contacted through face-to-face interviews and agreed to participate in the study through informed and voluntary consent.

Analysis

We analysed the data with SPSS version 21, for the socio- demographic characteristics and the knowledge sources focusing on descriptive statistics (frequencies and percentages). To determine the socio-economic factors influencing the use of knowledge channels, a multinomial logistic regression analysis was used. To interpret the results, two types of statistics were used, the first was the logistic coefficient (B), which is the expected amount of change in the logit for each unit change in the predictor. The closer a logistic coefficient was to zero, the less influence the predictor had in predicting the logit. The second statistic was the p-value (Sig.). The alpha level was set at 0.05 showing that a relationship was significant at or below 0.05, above 0.05 the relationship was insignificant. The other statistic used (Table 4) was the standard error (SE). This is the standard error of the individual regression coefficient for the model being estimated. The smaller the deviance, the better the fit of the logistic model. Bayaga (2010) suggests that an overall test of relationship and the classification accuracy should be run to determine the presence of a relationship between the dependent and independent variables in a multinomial logistic regression analysis. The presence of a relationship is based on the statistical significance of the model chi- square in the model-fitting information. In this paper, the probability of the model chi-square (28.387) was 0.000, less than the level of significance of 0.05 (i.e. $p<0.05$), suggesting that there was a relationship between the dependent and independent variables. Another measure used to assess the usefulness of the model was the classification accuracy which compared the predicted group membership based on the logistic model to the actual known group membership which is the value for the dependant variable. The overall percentage for all predictors and the constants were accurate as follows: radio 67%, mobile phones 58%, TV 68%, newspapers 83%,

farmer field schools 82%, fellow farmer 73%, government extension 77%, field days 63% and NGOs at 79%.

To analyse and visualize the network, social network analysis was used to examine the information relationships and identify which actors were the most influential. The degree centrality measures were used to examine the prominence of actors in the network and reflected how influential an actor was in the network, by the amount of information flow controlled. To map the social network, four key variables were identified, and these included the actors in the network, their roles, the types of information exchanged and the means of communication used to exchange information. The type of data used to map the network were: (in) the person, organization or institution, (ii) the type of information exchanged, and (iii) means of exchanging this information.

Variables

Table 1 presents a summary of the dependent and independent variables used in the study. The dependent variable of knowledge channels: ICTs (radio, mobile phones, TVs, newspapers and information kiosk) was coded as dichotomous for logistic regression analysis (with 1 as important and otherwise 0). The independent variables were categorical and continuous.

Table 1. Summary of variables used in the study

Variable	Type	Description
Knowledge channels: ICTs	Dependent	Mobile phones Radio TVs Newspapers Information kiosk
Socio-demographic	Independent	Age Gender Education
Economic	Independent	Land- agricultural production Land- conservation agriculture

Source: Household survey data Laikipia & Machakos, 2016.

Results and discussion

Socio-demographic characteristics

The age of the respondents was measured in years, with the mean age of the survey population being 53 years, while 62% of the respondents were female and 38% male. Kenya follows the 8-4-4 system of education with eight years in primary school, four years in secondary school and four years for either vocational or university education. The mean education in years in the study area was nine and the majority of the farmers had completed primary education. Education is considered to be one of the factors that can influence a farmer to bear the risks associated with new technologies and modern information sources. Farmers with better education are early adopters of modern technologies and apply modern inputs more efficiently throughout the adoption process (Mittar & Mehar 2015). The main occupation of the respondents was farming at 88%. CA farmers were 47% and conventional farmers were 40%. Land size is a proxy for a farmer's economic status and was measured in acres. The total land size owned by the respondents was at an average of 5.2 acres, with land under agricultural production at an average of 3 acres and land under CA at an average of 1.3 acres (Table 2).

The CA knowledge network

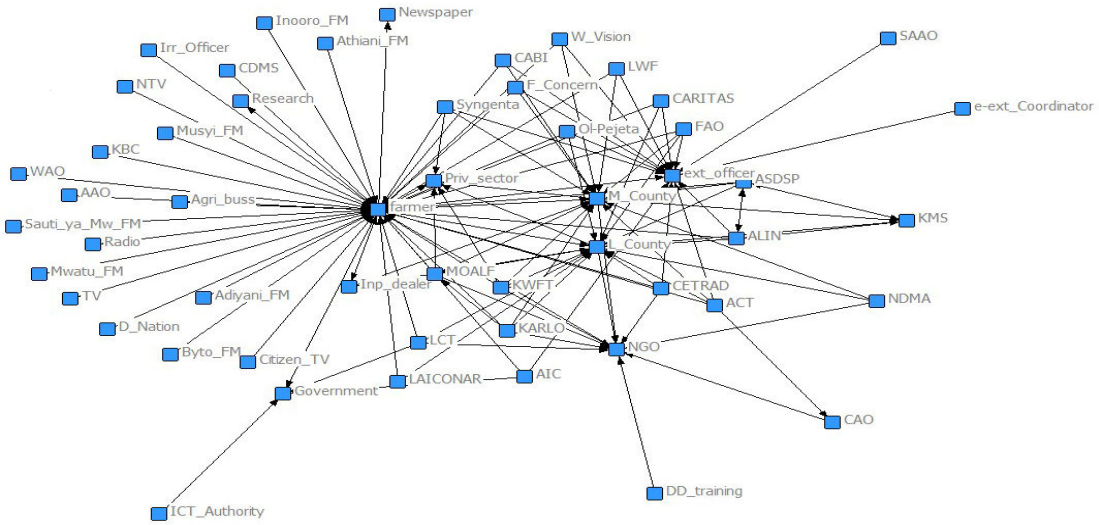
The CA knowledge network provides a framework for understanding how information flows between the actors, the relationships or associations that result from sharing information and how this can influence the adoption of an innovation. The network size consisted of forty-seven nodes with 165 observed relationships and a network density of 0.076. However, 2162 (47*47-1) relationships were possible. In this network, the maximum number of possible connections or ties any individual actor had was 46. The network was linked by the information sharing relationships.

Table 2. Socio- demographic characteristics of respondent

Household characteristics	Total (*n*=298)
Gender of respondents	
Female (%)	62.1
Male (%)	37.9
Age (mean)	53.1
Education in years (mean)	9.3
Main occupation respondent (%)	
Farming	88.3
Agro-pastoralist	8.1
CA service provider	0.7
Government employee	1.3
Self-employed	1.7
Agriculture practice (%)	
Conservation agriculture	46.6
Conventional	39.6
Organic	10.1
Livestock	3.4
Dairy farming	0.2
Land in acres (mean)	
Total land size	5.2
Land hired	3.5
Land bought	5.0
Land donated	1.6
Land inherited	4.2
Land re-settlement scheme	4.1
Land under agriculture production	3.0
Land under CA	1.3

Source: Household survey data Laikipia & Machakos, 2016.

Figure 1. Network of CA knowledge actors showing the information relationships



Source: Key informant interviews Laikipia and Machakos counties, 2016.

In the CA actor network, the nodes represent the actors and the ties represent the knowledge sharing relationships. The central nodes in the network were the farmers, Laikipia County, Machakos County, the private sector and the extension officers. The network also illustrates how the positioning of the actors reflects their influence in the network. Nodes that have a higher centrality measure are located at the centre of the network and nodes with lower centrality measures are located at the periphery of the network. It should also be noted that all the ICT actors (radios, TV and the e-extension coordinator) were periphery actors indicating the low importance and use of ICTs in the network. This analysis suggests that farmers are a strong link in the CA network. Together with the county governments of Laikipia and Machakos and the private sector, these actors influence the information exchange process and the type of communication channels to use.

Degree centrality

The degree centrality is a measure of how connected an actor is to the rest of the network. Actors with a high centrality have a great potential to be aware of other actor's expertise and can spread information rapidly because they are well connected. In this study, the out-degree centrality position was occupied by extension officers at 20%, followed by the Ministry of Agriculture, Livestock and Fisheries (MALF) at 15%; Laikipia county and Machakos county at 10% each. MALF is the line ministry for any agricultural related activities in the country, and therefore any organization that implements agricultural activities in the country has to be aligned to it, making it a central actor. At the county level, the county governments were the central actors as they are the policy organs at that level. The in-degree centrality position was occupied by the farmers at 41%, Laikipia County at 28% and Machakos County at 26%. Extension officers and farmers were the most influential actors by their central positioning in the network. Central actors are the ones who link most people in an informal network and they are usually not the formal leaders but know who can provide the expertise needed. However, as observed in this CA network, there were few central actors (Figure 1), thereby indicating that the network was not functioning efficiently and to its optimal capacity.

Cliques and sub-groupings

The CA network had 47 cliques, non-random connections between the actors, as illustrated in Table 3. In each of the cliques there was a pattern of sub-groupings with each having a private sector actor, a public sector or government actor and a farmer in the most of the sub-groupings. The farmer was the predominant overlapping actor, present in 31 cliques. This gives the farmers a degree of power in this network and they could be referred to as the central connectors. Clark (2006) suggests that networks are built from small sub-groupings or cliques and this enables understanding of the structure of networks. In a network, actors with access to a range of sources of information usually belong to various cliques and this gives them a certain degree of power as they act as intermediaries for those who have fewer contacts and therefore less access to information.

Knowledge sources and use of ICTs

The knowledge sources most preferred by farmers in order of importance were the conventional channels (Table 4). The extension officers were ranked as the most important source at 68%, followed by Non-Government Organizations (NGOs) at 33% and Farmer Field Schools (FFS) at 29%. Among the ICTs, radio was ranked as the most important source at 70%, followed by mobile phone at 34% and television at 10%. In the responses, extension services were preferred when used jointly with radio programs and field days were preferred when used jointly with mobile phones. This ranking for most important knowledge source correlates to the findings in the social network analysis (Table 3), where the extension officers occupy the out-degree position of prominence (20%). These results support the hypothesis that actors in central positions show a positive association to a variety of knowledge channels and that periphery actors are negatively associated with use of multiple knowledge channels. Although radio, TV and newspapers were periphery actors in this network, they too play prominent roles in the network as media outlets.

Table 3. Out-degree and In-degree measures by frequency and percentage

SN	Actor	Out-degree	%	In-degree	%
1	Assistant Agric. Officer-AAO	1	1	1	1
2	African Conservation Tillage-ACT	10	5	4	2
3	Agriculture information centre-AIC	9	4	1	1
4	Arid Land Information network-ALIN	11	5	4	2
5	Agricultural Sector Development support program- ASDSP	20	9	6	3
6	Adiyani_FM	1	1	2	1
7	Agri-business	5	2	1	1
8	Athiani_FM	1	1	2	1
9	Byto_FM	1	1	2	1
10	Centre for Agriculture & Bioscience International - CABI	3	1	3	1
11	Chief Agric. Officer-CAO	7	3	2	1
12	CARITAS	4	2	3	1
13	County Director Met. Services-CDMS	3	1	1	1
14	Centre for Training Research Dissemination -CETRAD	3	1	0	0
15	Citizen_TV	1	1	2	1
16	Deputy Director training- DD_training	10	5	1	1
17	Daily Nation	1	1	1	1
18	Food and Agriculture Organisation-FAO	15	7	4	2
19	Farm Concern-F_concern	3	1	1	1
20	ICT_Authority	10	5	1	1
21	Inooro_FM	1	1	1	1
22	Input_ dealer	3	1	1	1
23	Kenya Agric. Research & Livestock Organisation - KARLO	20	9	1	1
24	Kenya Broadcasting Corp-KBC	1	1	1	1
25	Kenya Meteorological services-KMS	12	6	7	3
26	Kenya Women Finance Trust -KWFT	3	1	1	1
27	Laikipia County Natural Resource Network- LAICONAR	6	3	2	1
28	Laikipia County Times-LCT	4	2	1	1
29	Laikipia County –L_County	22	10	59	28
30	Machakos County- M_County	22	10	56	26
31	Lutheran World Federation-LWF	6	3	4	2
32	Ministry of Agric. Livestock & Fisheries	32	15	18	9
33	Musyi_FM	1	1	2	1
34	Mwatu_FM	1	1	2	1
35	National Drought Management Authority- NDMA	9	4	2	1
36	Nation Television-NTV	1	1	1	1
37	Ol_Pejeta conservatory	6	3	2	1
38	Private sector	1	1	31	15
39	Sauti _ya_ Mwananchi_FM	1	1	1	1
40	Syngenta	4	2	1	1
41	World Vision	1	1	3	1
42	e- Ext- Coordinator	4	2	1	1
43	Extension officer -Ext- Officer	43	20	15	7
44	Farmer	11	5	88	41
45	Senior Agricultural Officer-SAO	7	3	1	1
46	Ward Agricultural Officer-WAO	1	1	1	1
47	Irrigation officer-Irr Officer	1	1	1	1

Source: Key informant interviews Laikipia and Machakos counties, 2016.

Table 4. Preferred knowledge sources by frequency of importance

SN	Source	Most (%)	Second (%)	Third (%)
1.	Extension officers	70	21	11
2.	NGOs	33	55	12
3.	Farmer Field Schools	29	18	54
4.	Research centres	25	50	25
5.	Fellow farmers	20	33	47
6.	ICTs	18	82	-
7.	Field days	11	25	64
8.	Trainings & workshops	8	48	44
9.	Exhibitions	-	33	67
	ICT sources			
1.	Radio	70	27	3
2.	Mobile phone	34	54	13
3.	Television	10	22	67
4.	Newspapers	2	20	78
5.	Information Kiosk	0	50	50

n=298

Source: Household survey data Laikipia & Machakos counties, 2016

Socio–economic factors influencing use of ICTs

Among the socio-economic factors, the results suggest that gender, education, land under agriculture production, and land under CA significantly influence the ICT a farmer may use (Table 5). The farmer's age had no effect on the choice of ICT. The coefficient for age was negative for all the ICTs, suggesting that older farmers have extensive experience and would rely more on their own knowledge than use ICTs as sources of information. Use of mobile phones, radios and TVs were significant at (p<0.05) and land under CA (p<0.05). Use of newspapers was significantly influenced by gender (p=0.021) and education (p=0.024) and use of information kiosks was significantly influenced by education (p=0.014). This suggests that gender and education will most likely influence the type of ICT a farmer may use. The more educated a farmer is, the more likely they will use newspapers and the information kiosk to access agricultural information. The results also suggest that farmers with more acreage under agricultural production and under CA will use more than one knowledge source. Overall the results support the hypothesis that a significant positive relationship exists between socio-economic factors, gender, education level, land under agricultural production and land under CA. Mittal & Mehar (2015) have demonstrated in their studies that age, education, farm size are important parameters that determine a farmers' decision to select from different information sources.

Conclusion

This aim of this paper was to understand the positioning of actors in the CA knowledge network and socio-economic factors influencing use of ICTS. Using the three elements of the diffusion of innovation theory, the innovation, communication channels and the social systems, results indicate that innovations like CA are spread through social systems of individuals and institutions through their information sharing relationships using a variety of communication channels. Weak collaborative linkages were observed among the actors in the CA knowledge network indicating a weak knowledge sharing relationship. The subgroupings were also clustered around a few organizations, leaving out the majority of the actors. This suggests that there is a need to strengthen the knowledge sharing relationships with other actors participating in CA activities but are not aligned to the influential CA cliques. In this network, extension officers, radio and mobile phones were ranked as the most important sources. The positioning of farmers as actors of influence and prominence and their preference for use of radio and mobile phones give an indication to what type of ICTs should be promoted in CA knowledge dissemination. The study proposes that ICTs in CA extension services should be used in combination with conventional approaches of agricultural extension. Combinations may include extension officers + radio+ mobile phone; field days+ mobile phones as suggested by the farmers. However, the type of extension approach is largely determined by the type of information being disseminated.

Table 5. Multinomial logit regression analysis of the relationship between socio-economic variables and ICT knowledge channels

Independent variables	Coefficient	Std. Error	P- Value	Independent variables	Coefficient	Std. Error	P- Value
Mobile phones				TVs			
Age	.008	.012	.526	Age	-008	.013	.544
Gender	-605	.282	.031**	Gender	-697	.291	.017**
Education	-008	.046	.869	Education	-054	.049	.269
Land- Agric. production	.113	.065	.062	Land- Agric. production	.114	.070	.080
Land-CA	-408	.117	.000**	Land-CA	-597	.134	.000**
Radio				Information Kiosk			
Age	.003	.013	.821	Age	.025	.030	.399
Gender	-647	.309	.034**	Gender	-1.003	.723	.168
Education	-064	.048	.181	Education	.275	.113	.014**
Land -Agric. Production	.057	.059	.335	Land- Agric. production	-145	.093	.176
Land –CA	-350	.136	.004**	Land-CA	.175	.271	.488
Newspaper							
Age	.081	.016	-243				
Gender	-142	.366	.021**				
Education	.119	.065	.024**				
Land -Agric. Production	.178	.105	.200				
Land –CA	-844	.172	.298				

Significant at **p < 0.05
Source: Household survey data Laikipia & Machakos, 2016

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