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Analysis of factors that influence smallholder farmers' use of ICTs as enablers for knowledge sharing

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ABSTRACT

Agriculture is becoming highly science driven and knowledge intensive, and farming needs are changing. Yet, rural smallholder farmers have no access to science-based agriculture information. Having a wealth of indigenous agricultural knowledge is not enough. Thus, they ought to expand their knowledge-base and networks, by sharing their knowledge and experiences to a wider farmer community. Also, in academia and agriculture research institutions, there exists a rich knowledge base, much of which does not reach rural smallholder farmers. To bridge this knowledge gap, Information Communication Technologies (ICTs) play a vital role. This study therefore explored factors that facilitate smallholder farmers' use of ICTs as enablers for knowledge sharing. To achieve this, a) a taxonomy of challenges hindering smallholder farmers' use of ICTs and knowledge sharing are identified; and b) A theoretical model for ICT-enabled agriculture knowledge sharing (ICT-AKS) is derived and the identified relationships are examined. Data were collected through a structured questionnaire and literature. The study was conducted in four districts of Uganda (Apac, Lira, Mukura and Bukedea). A total of 156 households engaging in smallholder agriculture particularly cereals (Soy Beans, Maize and Ground nuts) participated, where a total population of 200 smallholder farmers was selected. Results reveal that existence of sharable infrastructure, individual characteristics, willingness to share, usage of ICTs and social cohesion influence rural smallholder farmers' sharing of knowledge.

Keywords: Information Communication Technologies (ICTs), knowledge sharing, smallholder farmers, Uganda

RÉSUMÉ

L'agriculture devient de plus en plus scientifique et intensive en connaissances, et les besoins des agriculteurs changent. Pourtant, les petits exploitants agricoles ruraux n'ont pas accès à l'information agricole basée sur la science. Avoir une richesse de connaissances agricoles indigènes ne suffit pas. Ainsi, ils doivent élargir leur base de connaissances et leurs réseaux, en partageant leurs connaissances et expériences avec une communauté d'agriculteurs plus large. Aussi, dans l'académie et les institutions de recherche agricole, il existe une riche base de connaissances, dont une grande partie n'atteint pas les petits exploitants agricoles ruraux. Pour combler ce fossé de connaissances, les Technologies de l'Information et de la Communication (TIC) jouent un rôle vital. Cette étude a donc exploré les facteurs qui facilitent l'utilisation des TIC par les petits exploitants agricoles

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comme facilitateurs du partage des connaissances. Pour ce faire, a) une taxonomie des défis entravant l'utilisation des TIC par les petits exploitants agricoles et le partage des connaissances a été identifiée; et b) Un modèle théorique pour le partage des connaissances agricoles activé par les TIC (ICT-AKS) a été dérivé et les relations identifiées ont été examinées. Les données ont été collectées à travers un questionnaire structuré et la littérature. L'étude a été menée dans quatre districts de l'Ouganda (Apac, Lira, Mukura et Bukedea). Un total de 156 ménages engagés dans l'agriculture à petite échelle, en particulier les céréales (soja, maïs et arachides) ont participé, où une population totale de 200 petits exploitants agricoles a été sélectionnée. Les résultats révèlent que l'existence d'une infrastructure partageable, les caractéristiques individuelles, la volonté de partager, l'utilisation des TIC et la cohésion sociale influencent le partage des connaissances des petits exploitants agricoles ruraux.

Mots-clés: Technologies de l'Information et de la Communication (TIC), partage des connaissances, petits exploitants agricoles, Ouganda

INTRODUCTION

In developing economies, smallholder farmers live in communities and most belong to community farmer groups. In these community groups, there exist a network of connections and associated social wealth that facilitate knowledge creation (Nahapiet and Ghoshal, 1998); knowledge sharing, and knowledge transfer (Reagans and McEvily, 2003). Sharing of knowledge in these communities mainly occurs through farmer-to-farmer communications; socializing or schmoozing with knowledge experts, extension workers and peers; newspaper/documents; ICTs (mainly radios), etc. The use of mobile phones in these communities is limited (Baumüller, 2016; Musungwini, 2018) yet, a number of mobile applications and technology solution initiatives are being developed to bridge the knowledge gap (Kale *et al*., 2015; Baumüller, 2016; Baumüller, 2018 and Misaki *et al*., 2018). As these technology solutions evolve, they become more pervasive to farmers that find them beneficial. In rustic areas however, leveraging web and mobile based technologies to rural smallholder farmers continues to be a challenge (Iraba and Venter, 2011). Many of these initiatives face difficulty in scaling-up (Baumüller, 2018) due to a number of reasons, among which is; limited proficiency and access to smartphone technology, high internet costs, poor ICT infrastructure, etc. The web and mobile agriculture technology solutions identified mostly run in silos, are not interoperable and have limited uptake among smallholder farmers, causing limitations in information sharing. To counter the low technology solution adoption rates, scholars recommend participatory innovation development or farmer-led experimentation and integration of farming communities into the innovation process (Lwoga *et al*., 20011; Ballantyne, 2009; Pretty *et al*., 2011). In this study, we explore the factors that influence smallholder farmers' use of ICTs as enablers for knowledge sharing.

Agriculture is becoming highly science-driven and knowledge intensive (Jelsma *et al*., 2019), and farming needs are changing. Fundamental to rural smallholder farming, is information asymmetry and shortage of access to key farming information (Hudson *et al*., 2017; Misaki *et al*., 2018; Phiri *et al*., 2018). This may be attributed to a number of factors such as; low education levels, low income, chronic dependence on external support, limited land areas, and limited access to market and credits (Vignola *et al*., 2015). That is why rural smallholder farmers mainly depend on

indigenous and implicit knowledge. This kind of knowledge is highly individualistic and rooted in specific social contexts (Rosskopf and Wagner, 2005). However, having a wealth of indigenous agricultural knowledge is not enough. Smallholder farmers ought to expand their knowledge-base and networks, by sharing their knowledge and experiences to a wider farmer community.

In academia and agriculture research institutions, a lot of scientific agriculture knowledge is generated. This knowledge often ignores the rich home-grown/indigenous local knowledge from smallholder farmers (Rivera-Huerta *et al*., 2011; Zaman *et al*., 2011; Safford *et al*., 2017). This creates a knowledge gap between smallholder farmers and agriculture knowledge experts. Linking researchers (from academia and research institutions) with the community is recognized to foster the materialization of new innovative ideas (Rivera-Huerta *et al*., 2011; Drahota *et al*., 2016; Safford *et al*., 2017). Failure to translate research from these research institutions to "real-world" settings hampers collaboration between researchers and community stakeholders like smallholder farmers (Lasker *et al*., 2001; Drahota *et al*., 2016). The inability to bridge this gap also has an adverse effect on the progress of inclusion in smallholder farming and the ability for knowledge experts to respond to the needs of individual rural smallholder farmers (Rivera-Huerta *et al*., 2011; Drahota *et al*., 2016).

To keep pace with the demands of a rapidly growing modern digital culture, it is essential to take advantage of a) Information Communication Technology (ICT) enabled innovative knowledge sharing tools, and b) engagement opportunities to deliver knowledge to rural smallholder farmers (Howland *et al*., 2015; Dolinska and d'Aquino, 2016; Šūmane *et al*., 2018). ICTs are characterized by a dynamic and haste nature in sharing information which increases efficiency and accelerates growth of knowledge. A key resource to ICT is the Internet, i.e., its availability plays a significant role in sharing knowledge and networking. In Uganda, access to internet has improved and mobile penetration is estimated at 65.4% (MIQ, 2017) of which 16% are smartphones (GSMA, 2019). This offers an opportunity to harness the power of ICT to support smallholder farming in Uganda and other rural developing economies. With a growing smartphone presence, the use and access to mobile-based solutions is expected to increase. The paper proceeds as follows: we review literature to identify challenges hindering rural smallholder farmers' use of ICTs as enablers for knowledge sharing; we present the theoretical background and hypothesize relationships; subsquently we present materials and methods; finally we present results and draw conclusions.

Taxonomy of challenges hindering the use of ICTs by smallholder farmers in rural area. ICTs offer unprecedented potential to deliver information to poor rural communities (Mukhebi *et al*., 2007), and findings from Mukhebi *et al*., 2007 and Misaki *et al*., 2018 indicate that the ability to use and adapt ICTs (especially mobile and web technologies) is critical in generating and accessing wealth, power, and knowledge in smallholder farming communities. Yet, rural smallholder farmers in developing economies still face a number of challenges to access and use these technologies (Milovanovi, 2014; Misaki *et al*., 2018). Pinho and Rego (2012) note that identifying and understanding barriers to Knowledge Management (KM) is critical for enhancing knowledge production and thus, it should be considered as the first stage to improving knowledge flow and production (Heinze and Kuhlmann, 2008; Pinho and Rego (2012). In this study therefore, we found it appropriate to first identify challenges hindering the use of ICTs by rural smallholder farmers in developing economies to better understand the underlying difficulties.

In Table 1, we present a taxonomy of challenges rural smallholder farmers face when using ICTs to share knowledge. This taxonomy is categorized based on Dawson *et al*. (2016) and Long *et al*. (2016) broadly (i.e. socio-economic, behavioral and, policy and institutional). To arrive at the taxonomy, a theoretical approach to literature review was done following Okoli and Schabram (2010). With this approach, the research aim is brought into focus by helping the researcher understand the existing body of knowledge (Okoli and Schabram, 2010; Paré *et al*., 2015).

Table 1. A Taxonomy of challenges hindering the use of ICTs by rural smallholder farmers in developing economies

Categorization of challenges hindering the use of ICTs by rural Smallholder farmers' in developing economies – (Based on Dawson *et al*., 2016 and Long, *et al*., 2016 Publications)	Authors
Socio-economic	
High purchase cost for ICT access tools like Mobile smartphones and computers - C1	Mwangi and Kariuki, 2015; Wyche and Steinfield, 2016; Saidu *et al*., 2017
Limited disposable income - C2	Krell *et al*., 2021; Parikh and Lazowska, 2006; Michailidis *et al*, 2011; Alobo Loison, 2015; Tata and McNamara, 2016; Gneiting and Sonenshine, 2018
Limited technical and learning/literacy levels - C3	Parikh and Lazowska, 2006; Wyche and Steinfield, 2016; Hudson *et al*., 2017; Owusu *et al*., 2018
High internet costs - C4	Kale *et al*., 2015; Deichmann, *et al*., 2016; Phiri *et al*., 2018
Limited awareness/sensitization of information sources and benefits of existing ICT (particularly web and mobile solutions) solutions – C5	Mwaniki, 2006; Milovanovi, 2014; Phiri *et al*., 2018; Phiri *et al*., 2019
Poor Infrastructure E.g. limited ICT infrastructure coverage, intermittent power supply (electricity), limited network coverage - C5	Akpabio *et al*., 2007; Milovanovi, 2014; Kale *et al*., 2015; Deichmann *et al*., 2016; Tata and McNamara, 2016; Wyche and Steinfield, 2016; Mbagwu *et al*. 2017; Saidu *et al*., 2017; Evans, 2018; Misaki *et al*., 2018; Phiri *et al*., 2018; Phiri *et al*., 2019
Limited access to mobile phones - C6	Owusu *et al*., 2018; Phiri *et al*., 2018; Krell *et al*., 2021;
Behavioral	
Limited trust and reluctance of smallholder farmers to adopt existing web and mobile technology solutions - C1	Parikh and Lazowska, 2006; Mwakaje, 2010
Resistance to change due to social and cultural differences among smallholder farmers, beliefs - C1	Mwakaje, 2010; Alobo Loison, 2015
Conflicting smallholder farmers needs and objectives - C1	Mwakaje, 2010; Kante *et al*., 2016; Tata and McNamara, 2016

Lack of e-literacy among smallholder farmers (E-literacy refers to marginalized groups who are unable to make use of information and communication technologies because they are not computer literate). – C3	Parikh and Lazowska, 2006; Kale *et al*., 2015; Saidu *et al*., 2017
Age and gender issues - C3	Mwombe *et al*., 2014; Beuchelt, 2016; Tata and McNamara, 2016; Owusu *et al*., 2018
Communication barriers i.e. most agriculture information is in English not local dialects - C4	Parikh and Lazowska, 2006; Dutta, 2009; Lwoga *et al*., 2010; Kale *et al*., 2015; Phiri *et al*., 2018
Digital divide (the gap between smallholder farmers who have access to the Internet and those who do not). - C5	Owusu *et al*., 2018; Phiri *et al*., 2018; Phiri *et al*., 2019
Policy and Institutional	
Handicapping policies - C1	Mwaniki, 2006; Saidu, *et al*., 2017
Inappropriate ICT policies - C2	Munyua *et al*., 2009; Barakabitze *et al*., 2015; Evans, 2018
Spatially intermittent connectivity: The established Internet connections are slow and frequently disconnected - C3	Parikh and Lazowska, 2006; Milovanovi, 2014; Saidu *et al*., 2017
Limited/poor existing agriculture information content and lack of rural information centers - C4	Kante *et al*., 2016; Phiri *et al*., 2018; Kante *et al*, 2019; Phiri *et al*., 2019
Lack of up-to-date information - C5	Agyekumhene *et al*., 2018
Poor knowledge packaging (inadequate and inappropriate knowledge content) - C5	Mwaniki, 2006
Poor ICT strategies and inefficiency of the current institutional structures - C6	Barakabitze *et al*., 2015; Kante *et al*., 2016
Technology solution complexity and simplicity - C7	Mwangi and Kariuki, 2015; Kante *et al*., 2016; Long, *et al*., 2016;
Key: C: Subcategory	

Designing the ICT-enabled agriculture knowledge sharing (ICT-AKS) model. Having identified the challenges (C1-C7), requirements (R1-R15) and design decisions (DD1-DD15) were derived (see Table 2). Here, we use requirements as high-level abstractions of services that a model provides and constraints under which the model function. The requirements definition process included requirements elicitation, conflict resolution and requirements prioritization as noted by Gupta and Prakash (2001). For each challenge, a requirement(s) was identified and a design decision(s) defined. We use the term design decision in context with van der Ven *et al*.'s definition which states that a design decision is a "description of the choice and considered alternatives that (partially) realize one or more requirements" (van der Ven *et al*., 2006). To arrive at these design decisions, we evaluated possible design options, and selected the most preferred course of action. Thus providing insights into the reasoning process and record the rationale behind the design (Rockwell *et al*., 2010). Validation and selection of the design was based on the acquired/collected information and the researchers' preferences.

Table 2. Challenges, requirements and design decisions

Subcategory	Challenges	Code	Derived Requirements	Code	Design Decisions
C1	High purchase cost for ICT access tools like Mobile smartphones and computers	R1	Devise means for rural smallholder farmers to access affordable ICT tools	DD1	Communal Ownership of scarcely available ICT tools (Avail ICT shareable infrastructure).
C2	Limited disposable income	R2	Create or design structural equity in the supply chains, commodity sectors and policy environments where smallholder farmers operate.	DD2 .1	Web and Mobile solutions that enhance market linkages for smallholder farmers' produce.
				DD2.2	Avail sustainable agricultural supply chains
				DD2.3	Develop sustainable value chains
C3	Limited technical and learning/literacy	R3.1	Create balanced dissemination of learning aids, resources and facilities	DD3.1	Availability of Mobile 2.0 technologies to disseminate information and foster knowledge transfer.
		R3.2	Devise multiple social learning avenues for farmers	DD3.2	Create medium seized farming groups that accelerate social learning.
C4	High internet costs	R4	Devise alternative means to affordable internet connectivity	DD4	Provision of economically sustainable technologies; E.g. Data Caching for offline usage.
C5	Limited awareness/ sensitization of information sources and benefits of existing ICT	R5.1	Build capacity of extension works and agriculture knowledge experts to harness ICT	DD5.1	Create medium sized farming groups to nurture social learning
				DD5.2	Identification of ICT Champions within the community that will train others (KFTs).
		R5.2	Devise creative means to disseminate information		
C1	Limited trust and reluctance of smallholder farmers to adopt existing web and mobile technology solutions.	R6.1	Build web and mobile tools that meet smallholder farmers' needs.	DD6	Offering knowledge solutions that appeal to individual contexts of smallholder farmers.
		R6.2	Include/engage smallholder farmers in the tool development process.		
C5	Poor Infrastructure E.g. Limited ICT infrastructure coverage, intermittent power supply (electricity), limited network coverage	R7	Support strengthening of infrastructure and policies for proper development.	DD7	Enacting public policies that lead to infrastructure development and improvement.

C1	Resistance to change due to social and cultural differences among smallholder farmers, beliefs	R8	The need for web and mobile solutions to be socially inclusive to particular communities	DD8	Diversifying web and mobile solutions to be socially inclusive to particular communities and individual smallholder farmer contexts
C1	Conflicting smallholder farmer needs and objectives	R9.1	Enable good practices, create timely and practical interventions for smallholder farmers	DD9.1	Having a group leader within the medium sized groups who exercises authority in times of conflict and ensure that the knowledge created is effectively shared and used.
		R9.2	Build consensus and involve smallholder farmers in solution identification and building	DD9.2	Availability of shared agriculture information repertoire and
C3	Lack of E-literacy among smallholder farmers	R10	Avail teaching support to smallholder farmers	DD10	Aligning smallholder farming business processes with relevant ICT alternatives.
C3	Age, gender issues and social equity	R11	Promote equality among smallholder farmers.	DD11	Collaboration with existing social groups like women groups, Farming Associations etc.
C4	Language and communication barriers	R12	Devise means to improve communication among smallholder farmers	DD12	Sufficient investments into necessary ICT infrastructure for knowledge sharing
C5	Digital Divide	R13.1	Increase digital literacy	DD13.1	Creation of digital literacy programs/ campaigns
		R13.2	Develop relevant local content in addition telecommunications infrastructure	DD13.2	Creation of knowledge Products in local dialect (Appealing knowledge packaging)
				DD13.3	Fostering Trainers of trainers
C6	Poor ICT strategies and inefficiency of the current institutional structures	R14	Refashion ICT strategies and structures	DD14	Build partnerships with Private Sector, NGOs, farming groups and implementing partners
C7	Technology solution complexity and simplicity	R15	Participatory innovation development or farmer-led experimentation and integration of farming communities into the innovation process	DD15	Social learning and social construction of technology solution

Table 3. The five external enablers derived from the design decisions

Derived variable	Mapped design decision	Description
Existence of Sharable Infrastructure (ESI)	DD1, DD7, DD10, DD12 and DD14	This construct supports ICT driven engagements between smallholder farming communities and Agricultural Knowledge experts
Individual Characteristics (IX)	DD6, DD8 and DD13.3	This variable comprises unique personal attributes that describe or relate to individual smallholder farmers
Willingness to Share (WTS)	DD5.1, DD5.2, DD11 and DD13.2	This construct comprises attributes that support the quality of information shared among smallholder farmers
Ease of Use (EOU)	DD3.2, DD4, DD9.1, DD9.2, DD13.1	This construct is a measure which a particular communication technology can be used without much effort.
Social Cohesion (SC)	DD2.1, DD2.2 DD2.3 and DD15	Defines willingness of smallholder farmers in a social grouping to cooperate with one another in order to improve their produce.

Theoretical Background. Knowledge is a dynamic significant resource for socio-economic growth, created as part of the learning process, highly individualistic and rooted in specific social contexts (Kefela, 2010; Brix, 2017). It is a combination of experience, values, contextual information and expert insights (Davenport and Prusak, 1998). Knowledge is recognized as either implicit (with knowledge of rules/unconscious) or explicit (without knowledge of rules/conscious) (Masters, 1992; Rosskopf and Wagner, 2005; Davies, 2015). Implicit/tacit knowledge is tied to the smallholder farmers who use this knowledge to adjust their practices. Wójcik *et al*. (2019) and Thomas *et al*. (2020) argue that shaping farmers' knowledge is a multi-stranded process and is closely linked to location. Also vital to shaping farmers' knowledge is knowledge sharing. Hence knowledge is useful when processed and shared. Sharing of knowledge and learning is a result of mental construction. Both of these occur when farmers are actively involved in the process of knowledge construction as opposed to passively receiving information (Šūmane *et al*., 2018; García-Almeida and Cabrera-Nuez, 2020).

Knowledge management (KM) is a collaborative and integrated approach dependent upon structures and cultures, i.e., to create, capture, organize, access and use the intellectual asset for long-term sustainability (Martins *et al*., 2019). It is a means to capture and share existing knowledge as well as create new knowledge (Gorelick and Tantawy-Monsou, 2005). Loon (2019) identifies three KM practice systems: "learning and knowledge

creation culture; organizational knowledge architecture for adaptive and exaptive capacity; and 'business model' for knowledge capitalisation and value capture" (Loon, 2019; Martins *et al*., 2019). One of the advantages of KM is that it increases the information exchange among stakeholders, boosting the generation of innovations. Thus, through KM, knowledge sharing is made possible (Martins *et al*., 2019). Hence KM though engrained in organizational management is key in embedding scientific research in smallholder farmer networks of practice (Wood *et al*., 2014). Its environment also heartens both scientists and smallholder farmers to collaboratively work in groups involving joint processes, contributing, negotiating and utilizing knowledge to solve problems, develop new ideas, implement policies and procedures (Srivastava *et al*., 2006; Thomas *et al*., 2020).

In this study, we underpin the theoretical model with the GPO-WM model (Heisig, 2009). The GPO-WM model is a method for integrating KM into business processes. It comprises of three knowledge management layers (i.e. Business focus, Knowledge focus and Enabler focus) that caters for domain specific business processes. A detailed step by step guide and approach on how the framework can be incorporated in domain specific business processes is given in Heisig (2009). To arrive at the five external enablers, the identified design decisions were mapped as presented in Table 3. Thus, the theoretical model in Figure 1 comprises the five (5) identified external variables (Existence of Sharable Infrastructure (ESI), individual Characteristics (IX), Willingness to Share (WTS), usage of ICTs (UOI), Social Cohesion (SC)) and the GPO-WM variables applying knowledge, generating knowledge, storing knowledge and sharing knowledge.

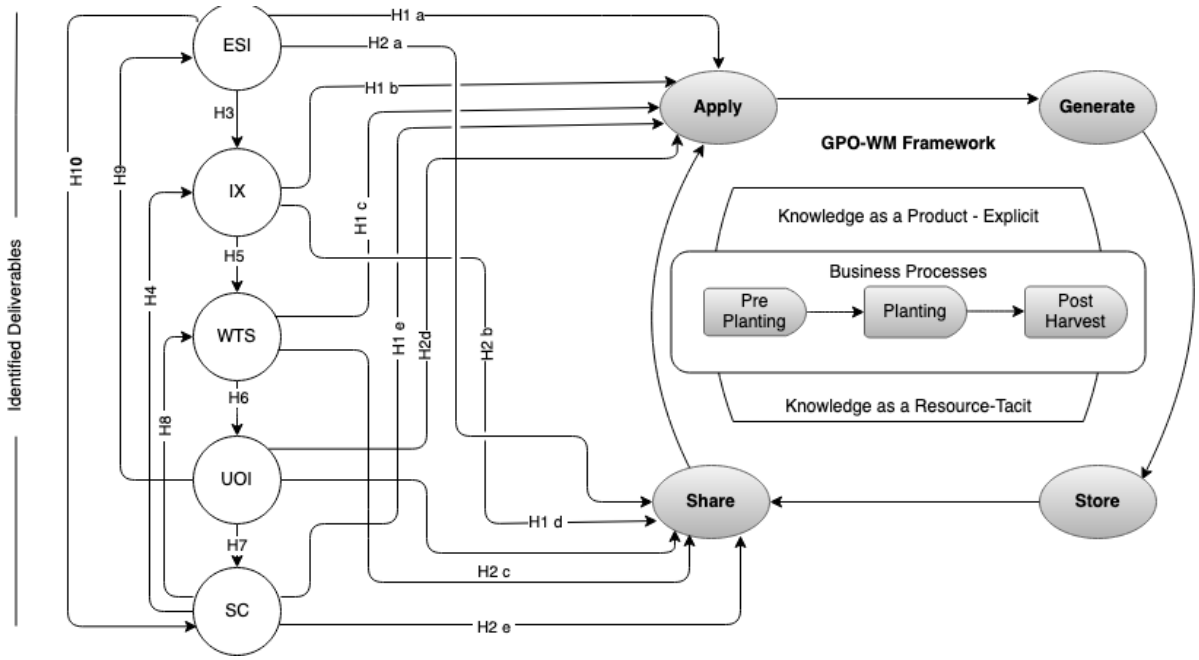

Figure 1. A theoretical model for ICT-enabled agriculture knowledge sharing (ICT-AKS) with identified hypothesizes

HYPOTHESES

To examine relations among variables and covariance, we hypothesize relationships (resultant paths) in Figure 1 as follows: The existence of sharable ICT infrastructure (ESI) encompasses community information centers (CICs), Key Farmer Trainers (KFTs) etc. Having communally owned infrastructure supports knowledge sharing among smallholder farmers, improves access to communication and communal ICT infrastructure.

H1a: ESI has a significant effect on smallholder farmers' ability to apply the shared knowledge.
H2a: ESI has a significant effect on smallholder farmers' ability to share knowledge.
H3: ESI has a significant effect on individual characteristics
H9: ESI has a significant effect on smallholder farmers' usage of ICTs (UOI)
H10: ESI has a significant effect on smallholder farmer's social cohesion.

Individual Characteristics (IX) are personal attributes that allow differences between individuals to be distinguished e.g., age, gender, marital status, level of education, work experience amongst other. Smallholder farmer's individual characteristics greatly determine their constructive input into knowledge sharing activities. We hypothesize relationships between individual characteristics, knowledge sharing and applicability as follows:
H1b: IX have a significant effect on smallholder farmers' ability to apply the shared knowledge.
H2b: IX have a significant effect on smallholder farmer's ability to share knowledge.
H4: IX have a significant effect on smallholder farmer's social cohesion.
H5: IX have a significant effect on smallholder farmers' willingness to share knowledge.

Willingness to share (WTS) was another identified variable. This is an individual's internal drive and attitude towards knowledge sharing activities. Sharing of knowledge includes processes to improve the willingness and ability for smallholder farmers to share what they know. This helps to increase their knowledge base. Van den Hooff and Hendrix (2014) note that people are more willing to collect knowledge than share it. This is attributed to collectivism than individualism. In order to develop smallholder farmers' self-assurance to share and co-operate, WTS is significant. From the derived initual framework we hypothesize relationships between willingness to share; Individual Characteristics (IX), usage of ICTs (UOI), applicability and smallholder farmers' ability to share as follows:
H1c: WTS has a significant effect on smallholder farmers' ability to apply the shared knowledge.
H2c: WTS has a significant effect on smallholder farmers' ability to share knowledge.
H12: WTS has a significant effect on existence of sharable ICT infrastructure.

ICTs play dual roles both as enablers and operant resources for innovation i.e., 1) they establish a value network by allowing sharing and integration of resources and knowledge; 2) They avail opportunities through digitization by allowing technology to be an operant that triggers innovation. The UOI is the measure or degree which a particular communication technology can be used without much effort. There exist relationships between smallholder farmers' usage of ICTs (UOI), applicability and ability to share.
H1d: UOI has a significant effect on smallholder farmers' ability to apply the shared knowledge.
H2d: UOI has a significant effect on smallholder farmers' ability to share knowledge.
H6: UOI has a significant effect on farmers' willingness to share knowledge.
H11: UOI has a significant effect on individual characteristics.

In agriculture, knowledge is regarded as a basis for innovation with influence on sustainability. It is socially constructed and a shared resource that can be valued through social capital (van Reijsen, 2014). The social relationships and interactions help farmers gain from the social capital embedded in them. Social capital is known as a resource entrenched in social structures that are accessed and/or mobilized in purposive actions. Social capital focuses on the availability of social relationships and shared values and trust in farming networks. Thus, the availability of social capital is regarded as a valuable resource that supports smallholder farmers to implement innovative farming practices. Here we identify social cohesion (SC) as a key contributing factor to agriculture knowledge sharing because it depends on accumulated social capital. Note that social capital focuses on social relationships between individuals yet, social cohesion focuses on social interaction and exchange in a group.

H1e: SC has a significant effect on smallholder farmers' ability to apply the shared knowledge.

H2e: SC has a significant effect on smallholder farmers' ability to share knowledge.

H7: SC has a significant effect on smallholder farmers' usage of ICTs (UOI)

H8: SC has a significant effect on smallholder farmers' willingness to share knowledge.

MATERIALS AND METHODS

To supplement literature, a structured questionnaire with both close and open-ended questions was used to collect data from smallholder farmers. In this questionnaire, we explored smallholder farmers' use of ICTs for knowledge sharing and social community grouping. The questionnaire comprised of four sections. Section one had the demographic characteristics; section two comprised smallholder farmers' use of ICTs and their social or community groups; section three focused on how smallholder farmers acquired and shared knowledge; and section four identified the challenges smallholder farmers face when sharing agricultural information.

Questionnaire Reliability: To minimize the effect of human errors, a reliability test was conducted. The questionnaire was examined by three agricultural knowledge experts from Makerere University at the College of Agriculture and Environmental Sciences. As a result, five major variables were identified and tested for internal consistency. Internal consistency was examined using Cronbach's values. Tavakol states that Cronbach's alpha is expressed as a number between 0 and 1. Tavakol *et al*. (2011) note that internal consistency should be determined before a research test to ensure validity. The acceptable values of Cronbach's alpha (α) range from 0.70 to 0.95 (Bland and Altman, 1997). Results obtained in Table 4, indicate that all constructs had Cronbach values greater than 0.75 which is higher than the threshold value of 0.70. This therefore indicates a high internal consistency with corresponding measurement indicators.

Table 4. Questionnaire Reliability Analysis (coefficients)

Theme	SD	Cronbach's (α)
Individual Characteristics	0.645	0.752
Usage of ICTs	0.783	0.850
Social Connections	0.754	0.735
Existence of sharable Infrastructure	0.732	0.798
Willingness to Share	0.751	0.772

Questionnaire administration. The questionnaire was administered in five regions in the northern part of Uganda, i.e., Chegere sub-county in Apac, Boroboro in Lira District, Kachede sub-county (at Popular Knowledge Women's Initiative) in Bukedea district, Mukura in Ngora district and Bala Subcounty in Kole District. Several challenges were encountered among which was the inability to interpret questions by some smallholder farmers (respondents). To successfully complete the data collection exercise, an aide (translator) was hired to assist respondents interpret questions to smallholder farmers' local dialect.

A total of 156 households engaging in smallholder agriculture particularly cereals (maize and legumes, (soy beans and ground nuts) were selected and a total population of 200 smallholder farmers were identified. To attain a sample size of 162 smallholder farmers, a confidence interval of 95% and an error margin of 5% was used. Applying the sample size formula below:

$$\textit{Formula for sample size} = \frac{\frac{z^2 \times p(1-p)}{e^2}}{1+\left(\frac{z^2 \times p(1-p)}{e^2 N}\right)}$$

Equation to obtain sample size

Where the population size = N, Margin of error = e and z-score = z. The z-score is expressed as a number of standard deviations that a certain proportion is away from any given mean (Chubb and Simpson, 2012).

Data Analysis. The questionnaires were administered in groups. There was 100% response rate with a total of 162 questionnaires distributed and returned. Of the 162 questionnaires, 89 were valid. Using proportionate sampling, 15(16.95%) smallholder farmers were selected from Chegere Sub-county in Apac, 23(25.94%) smallholder farmers from Kachede sub-county (at Popular Knowledge Women's Initiative) in Bukedea district, 18(20.04%) smallholder farmers were selected from Bala Sub-county in Kole District, 14(15.73%) smallholder farmers were selected from Boroboro in Lira District and 19(21.34%) smallholder farmers were selected from Mukura in Ngora district. To successfully analyze the collected data, we used an inductive approach. With this approach, analysis is guided by specific objectives and the procedure is systematic (Thomas, 2003). The analysis phase comprised of a number of activities e.g. coding, classifying or categorizing of raw data, transcribing of data from video and audio recorder, looking for emerging patterns, etc. The most time consuming activities were transcribing and merging collected data from different sources e.g. audio recorded data, questionnaire data and notes taken by the researcher during the sessions. For data coding and theming, we first used a statistical analysis software called JASP but due to its limitations to create syntaxes and expressions, we resorted to using SPSS because of its versatility and wide usage in the academic sphere (Arkkelin, 2014). Here, we focused on finding measures of central tendency, variation, standard deviations and where necessary correlational analysis. Descriptive statistics were used to compare and explore relationships between variables under contention.

RESULTS

In this section, we first present questionnaire results followed with results from video and audio recording.

Smallholder farmers' demographic information. From the demographic characteristics presented in Table 5, the gender composition of respondents was 50.6% (45) male and 49.4% (44) female. This indicates a fair representation from both genders. 2.3% (2) of the responded were aged between 15 and 20 years, 8.0% (7) were aged between 20 and 25 years, 14.9% (13) were aged between 25 and 30 years, 21.8 %(19) were aged between 30 to 35 years and 52.9% (46) were 35 years and above. This implies that smallholder farming is practiced by relatively middle aged persons. Out of 89 respondents, 28.1% (25) attained secondary education, 16.9% (15) tertiary education, 48.3% (43) Primary and 6.7% (6)

were uneducated. This implies that majority of the respondents had attained sufficient education to enable them answer the questions asked. The uneducated (6.7%) were aided by both the translator and moderator to interpret the questions to their local dialect and filling in the questionnaires.

Smallholder farmers' social community grouping. Cohesion and association between farmers affect their willingness to share, communicate, and interact with other community members. Thomas *et al*. (2020), note that it is crucial to understand the importance of farmer social context and social relations to knowledge sharing. Zboralski's research on work teams also emphasizes the importance of strong intergroup relations on team effectiveness (Zboralski, 2009). The evolving social connections support transfer and generation of knowledge. It was therefore important for this study to establish whether smallholder farmers' belonged to a community social farmer group. These social or community groups help farmers obtain agricultural information, collaborate/synergize on farm practices, share experiences and stories, and expedites access to useful information.

Table 5. Smallholder farmers' demographic frequencies

Measurement	Item	Frequency	Percentage (%)	
Gender	Male	45	50.6	
	Female	44	49.4	
Age	15-20	2	2.3	
	21-25	7	8.0	
	26-30	13	14.9	
	31-35	19	21.8	
	35-Above	46	52.9	
Highest level of Education	Bachelors	0	0	
	Tertiary	15	16.9	
	Secondary	25	28.1	
	Primary	43	48.3	
	Uneducated	6	6.7	
Statement/Question	Option/Answer	Frequency	Percentage	Cumulative %
I get agricultural advisory information through	Community information centers (CICs)	11	12.0	12
	Extension worker	16	18.0	30
	Demonstration gardens (Model farms)	4	5.0	35
	Newspapers	2	2.0	37
	Television	4	5.0	42
	Phone	7	7.5	49.5
	Radio	45	50.5	100
I own a smartphone	No	77	86.5	86.5
	Yes	12	13.5	100
I buy data bundles	Daily	12	13.5	13.5
	Monthly	23	25.8	39.3
	Never	46	51.7	91.1
	Weekly	8	9.0	100

Table 6. Smallholder farmers and their farmer groups

Farmer Group	Frequency	Farmer Group	Frequency
Abarata	1	Katama Women farmers	1
Adul Joint Farmers	1	Kokota Pkwi	1
Aipecitoi	2	Kusudea	7
Aminanaros	1	Kamodokima Pokori	1
Amoru Ican	1	Katama Farmers (Pkwi)	1
Anyambasi A, Women	10	Mukura Farmers	3
Aijen Farmer Group	1	None/No Social group	2
Apur Pe-Tur Farmers	9	Okota Farmers	1
Basere	1	Opyo-Icen Farmers	1
Bate(P'kwi)	8	Orib Cing	21
Inomu Agric	1	Okuma Farmers (P'kwi)	2
Irarak / Buteka	2	P'kwi FC	1
Kachede Intergrated Youth	1	Puna Farmers	1
Kakunguri	2	Rapad Farmers	2
Kareu Doyoro Farmers	2	Rebes Aputoon (P'kwi)	1

The farmer groups were founded on basis of gender, location, type of crops grown and age brackets. Results in Table 6 indicate that 97.8% (87) of the respondents belong to a community farmer group.

Factors influencing smallholder farmers' use of ICTs as enablers for knowledge sharing. In Table 7, it is indicated that 45 (50.5%) of the smallholder farmers depend on Radio programs for advisory information; 11 (12%) depend on Community Information Centers (CICs); 16 (18%) depend on extension workers; 4 (5.0%) on model farms; 4 (5.0%) demonstration gardens (Model farms); and 2 (2.0%) smallholder farmers use newspapers especially for knowledge acquisition. For newspapers, farmers noted that they mostly depend on archaic (Out dated) newspapers because they are cheaper. In these newspapers, they look out for special pullouts and editorials that focus on local and international market prices of commodities, agricultural columns, etc. It was also revealed that extension workers take long to visit CICs thus, cannot be relied on for timely agricultural information (C1: lack of timely agriculture information). Other means through which smallholder farmers share knowledge are model farms. Farmers visit model farms to learn about new farming practices and new seed varieties. Despite the existence of model farms, extension workers are seen as a more popular means for knowledge sharing.

On whether smallholder farmers own a smartphone, a dichotomous nominal scale of "No" and "Yes" was used to establish the number of smallholder farmers that owned smart phones. Results indicated that 12 (13.5%) respondents owned a smart phone and 77 (86.5) did not own a smartphone. This creates a gap in use of mobile applications for agriculture knowledge sharing (C2: Limited smartphone presence). The findings indicate that 74 (83.1%) smallholder farmers had no smartphone but had access or have used one before. Out of those who did not own smartphones, 28 (32%) strongly agreed to operating a smartphone

without seeking help; 15(17.2%) agreed to operating a smartphone with minimum support; 41 (48.1%) disagreed to highlighting problems with sight and complexity in maintaining and operating a smartphone, and 2 (2.3%) were neutral. We further established mobile internet data consumption patterns and 23 (25.8%) of the respondents indicated that they subscribe to a monthly data package, 8 (9.0%) subscribe to weekly a package; 12 (13.5%) subscribe to a daily data package; and 46 (51.7%) never subscribe to any data package.

Existence of Information Technologies. In Table 7, it is indicated that 58.4% (52) smallholder farmers strongly agreed to having knowledge of existing information technologies (e.g. computers, mobile phones) through which they can share agricultural information with experts/researchers; 37.1% (33) agreed; 2.2% (2) were neutral; and 2.2% (2) disagreed. This implies that a big percentage of smallholder farmers have knowledge of the existing information technologies. With more skilling and sensitization, farmers' adoption of these technologies will improve. On whether there were online facilities through which farmers can readily share information regarding pre-plant, planting, harvesting and post harvesting handling, 39.3% (35) strongly agreed to having online facilities in their area through which they can readily share agriculture information, 49.4% (44) agreed, 6.7% (6) were natural and 3.4% (3) disagreed. These facilities are mainly in trading centers. From these results, it is evident that smallholder farmers have challenges in sharing agricultural information through online (internet supported) facilities (C3: Inadequate ICT Facilities).

Television. The findings indicate that 5 (5.7%) of these respondents strongly agreed to having specific TV programs from which they acquire knowledge regarding agriculture, 15 (17.2%) agreed, 32 (36.8%) were neutral, 23 (26.4%) disagreed and 12 (13.8%) strongly disagreed. These results reveal that majority of the smallholder farmers do not use Television to access agricultural advisory knowledge. Responses attributed this to lack of hydroelectricity power in rural communities (C7). The other challenge with this mode of knowledge sharing is that TV programs are designed in a specific language (C4: communication and Language barriers) and are a "One size fits all" manner which does not take into consideration specific farmer contexts and need (C4: Inappropriate Knowledge packages). Results further indicate that 84.2% (75) of the respondents use radio for agricultural advisory information, 89.3% (67) of these respondents agreed to listening to specific radio programs for agricultural advisory information, 8% (6) were neutral and 2.7% (2) disagreed to listening to any specific radio program. Thus, the most commonly used ICT is radio. The use of radio is complimented by mobile phones whereby farmers call-in to ask specific questions.

Community Information Centers (CICs) for knowledge sharing. The CICs are run by knowledge workers or key farmer trainers. Three out of the four districts under study had CICs (Apac district (Kubeere Information Center managed and owned by Women of Uganda Network (WOUGNET)), Ngora district (Mukura Information Center established by Professor Francis Omaswa) and Bukedea (Popular Knowledge Women's Initiative (P'KWI)). Out of 53 (60%) smallholder farmers who use CICs for knowledge sharing, 58 (65.9%) of these respondents strongly agreed to having CICs in their area where they share knowledge; 19 (21.3%) agreed; 7 (8.0%) disagreed and 5 (5.7%) strongly disagreed. Thus CICs provide a fertile ground for knowledge sharing and social learning.

Table 7. Descriptive statistics

Code	Item	Measurement frequencies (%value)				
		1	2	3	4	5
	Existence of Sharable Infrastructure (ESI)					
ESI-1	There is good network connectivity in my area	33 (37.08)	24 (26.96)	27 (30.34)	5 (5.62)	0 (0.00)
ESI-2	There is a community information center (CIC) in my area (Parish, county or sub-county) where we share knowledge	59 (66.29)	18 (20.22)	0 (0.00)	7 (7.87)	5 (5.62)
ESI-3	The community information center in my area shares agriculture knowledge with smallholder farmers	35 (39.33)	49 (55.06)	0 (0.00)	5 (5.61)	0 (0.00)
ESI-4	There are information technologies facilities like Inter-net café, Kiosks that support sharing of agriculture knowledge	52 (58.43)	33 (37.08)	2 (2.25)	2 (2.25)	0 (0.00)
	Individual Characteristics (IX)					
IX-1	I interact with other individual farmers and farmer groups in my community	78 (87.64)	11 (12.36)	0 (0.00)	0 (0.00)	0 (0.00)
IX-2	I have an independent way of looking at things in my community and farmer group	41 (46.07)	8 (8.99)	26 (29.21)	10 (11.24)	4 (4.49)
IX-3	I easily develop social relationships with other smallholder farmers in my community	35 (39.33)	59 (66.29)	2 (2.25)	0 (0.00)	3 (3.37)
IX-4	I pay attention to the needs of other smallholder farm-ers in my community	69 (77.53)	15 (16.85)	5 (5.62)	0 (0.00)	0 (0.00)
	Willingness to Share (WTS)					
WTS-1	I am willing to share my expertise with other smallholder farms near my farm	34 (38.20)	15 (16.85)	25 (28.09)	10 (11.24)	5 (5.62)
WTS-2	I am willing to share agriculture knowledge through a mobile phone	60 (67.42)	28 (31.46)	1 (1.12)	0 (0.00)	0 (0.00)
WTS-3	I am willing to share agriculture knowledge with the community information center	62 (69.66)	20 (22.47)	2 (2.25)	5 (5.62)	0 (0.00)
	Usage of ICTs (UOI)					
UOI-1	I find using a smartphone phone very difficult	28 (31.47)	15 (16.85)	4 (4.49)	29 (32.58)	13 (14.61)
UOI-2	There is airtime service with in my neighborhood	40 (44.94)	24 (26.97)	22 (24.72)	2 (2.25)	1 (1.12)
UOI-3	In my area, there are online facilities through which I can share agriculture knowledge	35 (39.33)	44 (49.45)	6 (6.74)	3 (3.37)	0 (0.00)
UOI-4	There are radio programs through which I receive agriculture knowledge/information	51 (57.30)	28 (31.46)	8 (8.99)	2 (2.25)	0 (0.00)
UOI-5	There are TV programs through which I receive agriculture knowledge/information	5 (5.62)	15 (16.85)	32 (35.96)	23 (25.84)	12 (13.48)
UOI-6	Using a mobile phone to share agriculture knowledge experts is important	74 (83.15)	5 (5.62)	8 (8.99)	0 (0.00)	2 (2.25)
UOI-7	Translating agriculture knowledge in different dialect will increase my use of the mobile phone	44 (49.45)	18 (20.22)	0 (0.00)	12 (13.48)	15 (16.85)

	Social Cohesion (SC): This is social interaction and exchange in a group					
SC-1	The farmer groups use knowledge shared through ICTs	12 (13.48)	3 (3.37)	30 (33.71)	25 (28.09)	40 (44.94)
SC-2	In our farmer group, we interact and exchange knowledge	38 (42.70)	13 (14.61)	22 (24.72)	3 (4.49)	12 (13.48)
SC-3	The farmer groups are essential for knowledge sharing	15 (16.85)	23 (25.84)	45 (50.56)	0 (0.00)	6 (6.74)
SC-4	The key farmer trainers share agriculture knowledge with farmer groups	65 (73.03)	24 (26.97)	0 (0.00)	0 (0.00)	0 (0.00)

Key: (1) Strongly Agree, (2) Agree, (3), Neutral, (4) Disagree, (5) Strongly Disagree

DISCUSSION

The relationships established in the framework were validated as well as the inter-correlations between the variables.

In Table 8, the significance levels of the path coefficients are indicated as ***p < 0.001, **p < 0.01 and *p < 0.05. i.e. the correlation coefficient (r) ranges between 1 and 1. If r is positive, it indicates there is a positive relationship between the two variables, if r is negative, it indicates negative relationship, and if it is zero, it indicates that there is no relationship. The P on the other hand is the level of significance (error margin). If P is below 0.005, that means that the error margin is too small thus the relationship is significant and it stands otherwise and if P is above 0.005, it shows that the error margin is big therefore the relationship is insignificant and thus the relationship cannot stand (Kothari, 2009). The full results of the path model analysis are depicted in Figure 2.

The correlation matrix in Table 9 indicates that existence of sharable ICT infrastructure showing the effect of existence of sharable ICT infrastructure on smallholder farmers' ability to share agriculture knowledge (H2a), apply the shared agricultural knowledge (H1a), individual characteristics (H3), social cohesion (H10) and usage of ICTs (H9). Existence of sharable ICT infrastructure had no significantly positive effect on applying of the shared knowledge (r=0.450, p= 0.030), individual characteristics (r=0.066**, p=0.740) and social cohesion (r=0.335, p=0.001) so H1a, H3 and H10 were not supported. But, it was found to be positively influenced by smallholder farmer's ability to share knowledge (r=0.048, p=0.080) and usage of ICTs (r=0.748**, 0.000), so H2a and H9 are supported. These results are consistent with those of Van Der Velden (2002); Hinds and Pfeffer (2003) and Van den Hooff *et al*. (2004) who argue that the social context in which developed ICT-based tools are to be applied should guide their design and development. Hinds and Pfeffer, further claim that ICT-based support tools built in face-to-face meetings with stakeholders establish trust and relationships needed to share knowledge (Hinds and Pfeffer, 2003). Smallholder farmers' usage of ICTs was found to be positively influenced by smallholder farmers' ability to apply the shared knowledge (r=1.000**, p=0.031), smallholder farmers' ability to share knowledge (r=0.832**, p=0.000), willingness to share knowledge (r=0.900**, p=0.002) and individual characteristics (r=0.813, p=0.000), so H1d, H2d, H6 and H11 are supported. The resulting influence between individual characteristics and smallholder farmers' usage of ICTs is consistent with Feder and Umali (1993)'s study. In their study, they state that rural smallholder farmers adopt simple and cheaper technologies, and adoption of new technologies is positively correlated with their level of education, technology usability (ease of use, flexibility, durability and how beneficial) and interoperability. To identify viable solutions and bring diversity in content/ideas, it is recommended that smallholder farmers are involved in the development process.

Table 8. Correlation among five constructs

	GPO-WM Share	GPO-WM Apply	IX	ESI	SC	WTS	UOI
GPO-WM Share	1						
GPO-WM Apply	.325*	1					
IX	.350*	.843**	1				
ESI	.048	.450	.066**	1			
SC	.841**	.614**	. 704**	.335**	1		
WTS	.038	.220	.811*	.079	.174	1	
UOI	1.000**	.832**	.813**	.748**	.402**	.900**	1

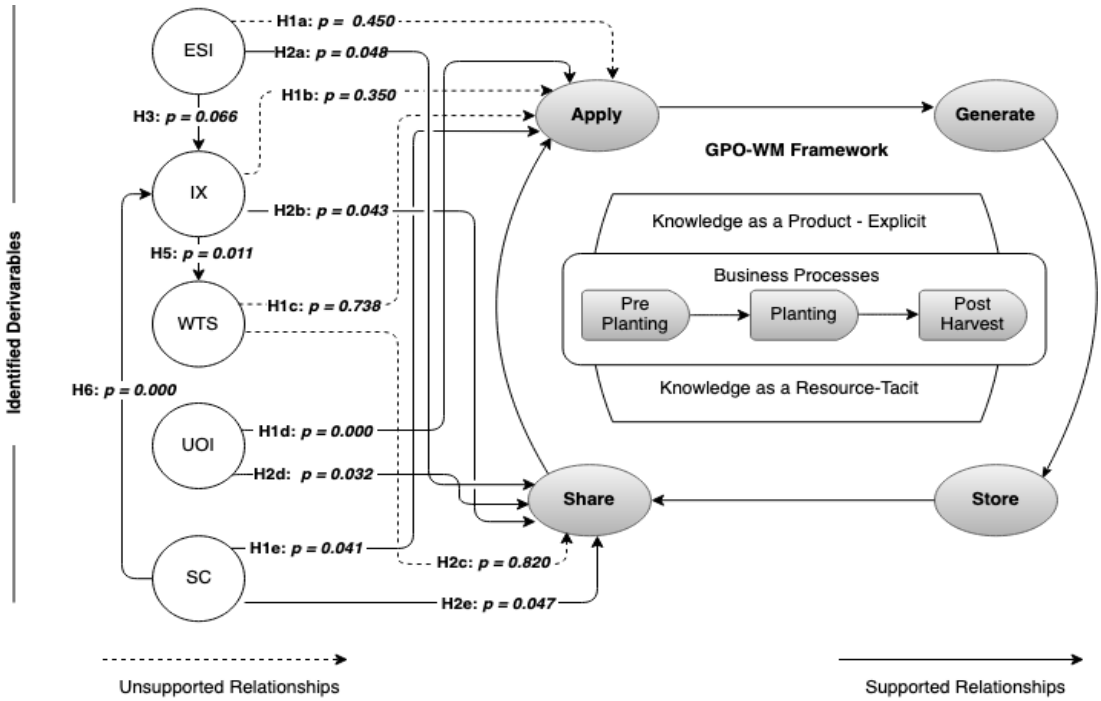

Figure 2. Path coefficients of the ICT-ASK framework

From the resulting path coefficients in Figure 2, individual characteristics were found to be positively influenced by smallholder farmers' ability to apply the shared knowledge (r=0.843*, p= 0.000), social cohesion (r=0.704*, p=0.020), and willingness to share (r=0.811*, p=0.034). Thus, relationships H1b, H4 and H5 are supported. These results are consistent with Hinds and Pfeffer (2003) findings who argue that cognitive limitations are related to an individual's ability to share knowledge. Smallholder farmers are characterized by low education/literacy levels, low income etc. (Vignola *et al*., 2015). These factors affect their confidence levels and competence to share knowledge. Wang and Noe (2010) identified individual confidence as a contributing factor to one's sharing of useful knowledge. In this study,

individual characteristics had no significantly positive effect on smallholder farmers' ability to share knowledge (H2b: r=0.350*, p=0.090 so was not supported). This may also be attributed to their characteristics as stated in Vignola *et al*. (2015).

Farmers' social relations are crucial to their sharing of knowledge and knowledge development. The farmers' social interactions are formed by farmers' adherence to locally-recognized practices, implementation of good farming practices and social relations (Sutherland and Burton, 2011; Fisher, 2013; Thomas *et al*., 2020). Results from this study indicate that social cohesion was positively influenced by smallholder farmers' ability to apply the shared knowledge (r=0.614**, p=0.001) and smallholder farmers' ability to share knowledge (r=0.841**, p=0.000), so H1e and H2e are supported. This is coherent with Abenakyo *et al*. (2008) findings where they argue that belonging to a farmer group builds the farmers' use of available resources to achieve desired objectives. Results also indicate that social cohesion had no significantly positive effect on smallholder farmers' willingness to share knowledge (r=0.174, p=0.105) and smallholder farmers' usage of ICTs (r=0.402, p= 0.000) so H8 and H7 are not supported.

There are a number of factors that contribute to one's decision to share knowledge. Chiu *et al*. (2006) identifies social ties, a shared language, trust, identification with the community, its goals, mission and vision etc. as some of the factors that determine one's willingness to share knowledge with other members of the community. Results from this study indicate that the effect of smallholder farmers' WTS knowledge has no significant positive effect on applying of the shared knowledge (r=0.220*, p= 0.831), ability to share the knowledge (r=0.038, p=0.064) and existence of sharable ICT infrastructure (r=0.079, p= 0.66). Thus, H1c, H2c and H12 are not supported. This may be attributed to the 'kind' of knowledge shared. Thomas *et al*. (2020) note that farmers are more willing to share knowledge passed on to them than one acquired by them (direct from their experiences). The authors further note that farmers' unwillingness to share knowledge is attributed to its perceived competitive value, trust and cultural capital (Thomas *et al*., 2020).

Table 9. Correlation Matrix

Hypothesis	Correlation (r)	Implication (P)	
H1a: Existence of sharable ICT infrastructure has a significant effect on smallholder farmers' ability to apply knowledge.	0.450	.030	Unsupported
H2a: Existence of sharable ICT infrastructure has a significant effect on smallholder farmers' ability to share knowledge.	0.048	.080	Supported
H3: Existence of sharable ICT infrastructure has a significant effect on individual characteristics.	0.066**	.740	Unsupported
H9: Existence of sharable ICT infrastructure has a significant effect on smallholder farmers' usage of ICTs.	0.748**	.000	Supported
H10: Existence of sharable ICT infrastructure has a significant effect on smallholder farmer's social cohesion.	0.335	.001	Unsupported
H1b: Individual characteristics has a significant effect on smallholder farmers' ability to apply the shared knowledge.	0.843*	.000	Supported

H2b: Individual characteristics has a significant effect on smallholder farmers' ability to share knowledge.	0.350*	0.090	Unsupported
H4: Individual characteristics have a significant effect on smallholder farmer's social cohesion.	0.704*	.020	Supported
H5: Individual characteristics have a significant effect on smallholder farmers' willingness to share knowledge.	0.811*	.034	Supported
H1c: Willingness to share has a significant effect on smallholder farmers' ability to apply the shared knowledge.	0.220	.831	Unsupported
H2c: Willingness to share has a significant effect on smallholder farmers' ability to share knowledge.	0.038	.064	Unsupported
H12: Willingness to share has a significant effect on existence of sharable ICT infrastructure.	0.079	.066	Unsupported
H1d: Smallholder farmers' usage of ICTs has a significant effect on smallholder famers' ability to apply the shared knowledge.	1.000**	.031	Supported
H2d: Smallholder farmers' usage of ICTs has a significant effect on smallholder farmers' ability to share knowledge.	0.832**	.000	Supported
H6: Smallholder farmers' usage of ICTs innovation has a significant effect on farmers' willingness to share knowledge.	0.900**	.002	Supported
H11: Smallholder farmers' usage of ICTs has a significant effect on individual characteristics	0.813	.000	Supported
H1e: Social cohesion has a significant effect on smallholder farmers' ability to apply the shared knowledge.	0.614**	.001	Supported
H2e: Social cohesion has a significant effect on smallholder farmers' ability to share knowledge.	0.841**	.000	Supported
H8: Social cohesion has a significant effect on smallholder farmers' willingness to share knowledge.	0.174	.105	Unsupported
H7: Social cohesion has a significant effect on smallholder farmers' usage of ICTs	0.402	.000	Unsupported

CONCLUSION

The purpose of this study was to explore the factors that facilitate smallholder farmers' use of ICTs as enablers for knowledge sharing. Results indicate that smallholder farmers' sharing of knowledge through ICTs (particularly mobile and web technologies) is influenced by five key constructs: 1) existence of sharable ICT infrastructure, 2) individual characteristics, 3) willingness to share, 4) smallholder farmers' usage of ICTs, and 5) social cohesion. Four of these were found to have a significant effect on smallholder farmers' ability to apply and share knowledge (see results in Table 9).

Numerous challenges hinder smallholder farmer's use and sharing of knowledge through ICTs (see Table 1). A number of web and mobile technology solutions have been developed to improve farming practices and share information. However, most of these work in silo and do not cover a wider scope

of farmer needs. During this study, academic agriculture knowledge experts were involved in addressing smallholder farmers' queries. The process of query identification, packaging and responding was time consuming. To quicken and support this process, community question answering tools should be developed (Shah and Pomerantz, 2010).

Secondly, in academia, knowledge experts have intersubjective understanding of agricultural knowledge with multiple realities and is therefore context-specific. This constrains knowledge capturing, building and sharing. The experiences (reading, academic, collaborations) of an expert are hard to codify and electronically translate to the smallholder farmer. This requires physical visitation to the farm as cases may differ from one farm to another or one crop to another. Although ICTs offer a dynamic and flexible means to share knowledge, they miss out on the nitty-gritties of socialization. For example, smallholder farmer's previous farming learnings and experiences are hard to remotely tap into without physical interaction. Academic institutions should find innovative ways to update and integrate their knowledge systems with indigenous knowledge to better aid Farmers (end users) in their day-to-day tasks by preventing them from becoming knowledge-flooded or knowledge-starved.

STATEMENT OF NO-CONFLICT OF INTEREST

The authors declare that there is no interest of conflict in this paper.

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