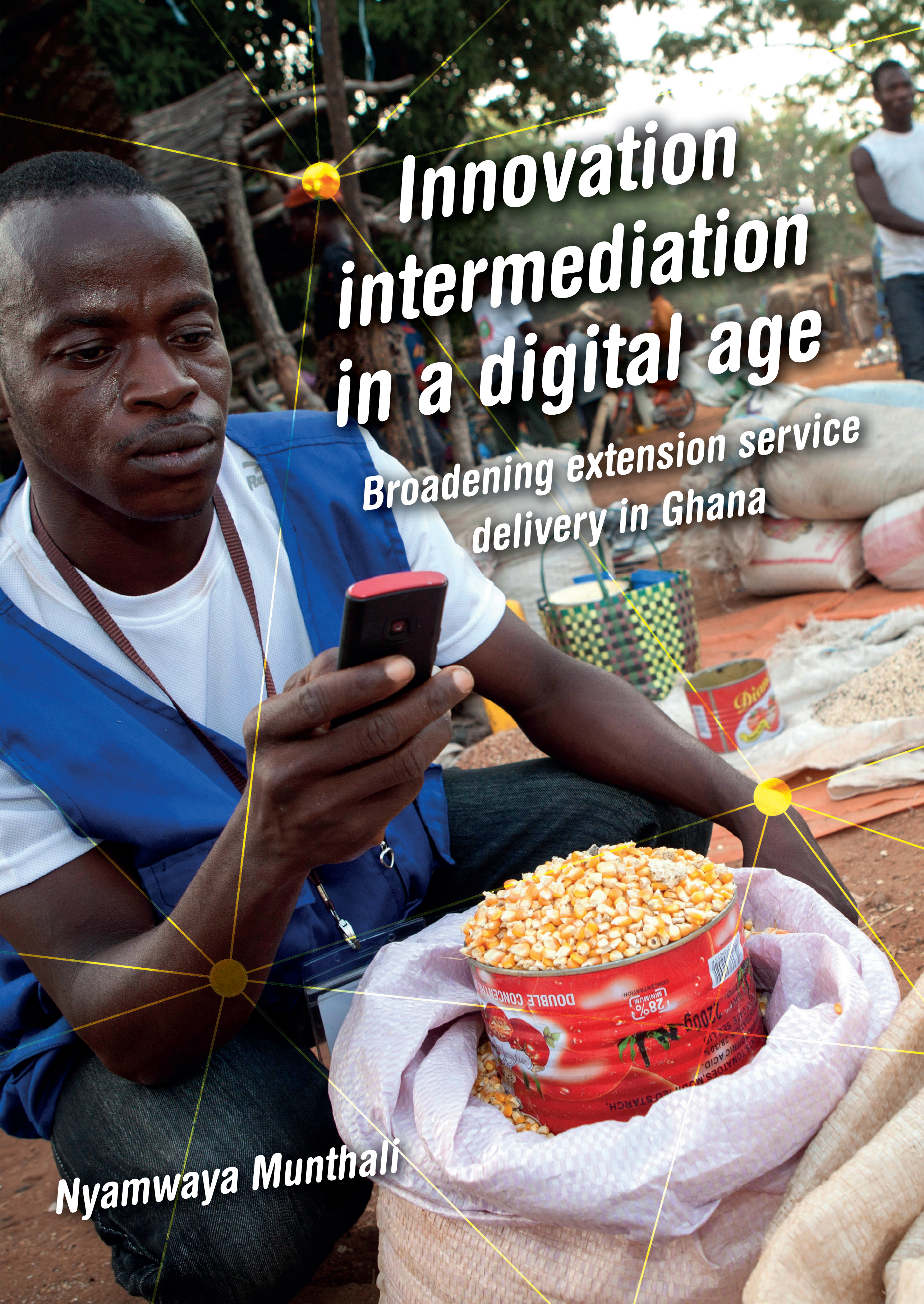

Innovation intermediation in a digital age

Broadening extension service delivery in Ghana

Nyamwaya Munthali

Innovation intermediation in a digital age: broadening extension service delivery in Ghana

Nyamwaya Munthali

Thesis committee

Promotor
Prof. Dr C. Leeuwis
Professor of Knowledge, Technology and Innovation
Wageningen University & Research

Co-promotor
Dr R. Lie
Assistant professor, Knowledge, Technology and Innovation
Wageningen University & Research

Dr A. van Paassen
Associate professor, Knowledge, Technology and Innovation
Wageningen University & Research

Dr R. J. A. van Lammeren
Associate professor, Laboratory of Geo-Information Science and Remote Sensing
Wageningen University & Research

Other members
Prof. Dr A. R. P. J. Dewulf, Wageningen University & Research
Dr C. Freeman, University of Ghana, Accra, Ghana
Dr S. Cardey, University of Reading, Reading, United Kingdom
Dr J. Brouwers, Wageningen Centre for Development Innovation

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Nyamwaya Munthali

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Dedicated to my mum - MHSRIP

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Abbreviations

ACDI/VOCA - Agricultural Cooperative Development International/ Volunteers in Overseas Cooperative Assistance

AEA - Agricultural Extension Agent

AIS - Agricultural Innovation System

AIS - Achieving Impact to Scale project

AKIS - Agricultural Knowledge and Innovation System

BBC - British Broadcasting Cooperation

CABI - Centre for Agriculture and Bioscience International

COCOBOD – Ghana Cocoa Board

CTA - Technical Centre for Agricultural and Rural Cooperation

DAES - Directorate of Agricultural and Extension Services

DaM - Data Management technology

DAO - District Agricultural Officer

DFAD - District Food and Agriculture Department

DoM - Document Management technology

EU - European Union

EVOCA - Environmental Virtual Observatories for Connective Action

FBO - Farmer Based Organisation

FGD - Focus Group Discussion

GAP - Good Agricultural Practices

GF - Grameen Foundation

GNSS - Global Navigation Satellite System

GPS - Geographical Positioning System

ICT - Information and Communication Technology

ICT4Ag - Information and Communication Technologies for Agriculture

ICT4D - Information and Communication Technologies for Development

ITU - International Telecommunication Union

IVR - Interactive Voice Response technology

MEST - Meltwater Entrepreneurial School of Technology

MMS - Multimedia Messaging Service

MOFA - Ministry of Food and Agriculture

NGO - Non-Governmental Organisation

NSP - National Service Personnel

OECD - Organisation for Economic Co-operation and Development

PPRSD - Plant Protection and Regulatory Services Department

SME - Small and Medium Enterprise

SMM - Social Media Messaging technology

SMS - Short Message Service

SNA - Social Network Analysis

t/ha - tonne per hectare

UN - United Nations

USSD - Unstructured Supplementary Service Data

VOA - Voice of America

YEA - Youth Extension Agent

Abstract

Classical extension focuses on linear transfer of technology. Globally, and in Ghana particularly, we have seen attempts to address the linearity of classical extension with the shift to broader extension service delivery approaches. From an innovation systems perspective innovation intermediation is suggested for extension organisations to function more effectively and respond to wider agricultural system constraints. This involves three broad facilitation roles which are demand articulation, matching demand and supply, and innovation process management. Both public and private extension service providers in Ghana are transitioning towards broader extension approaches, but these efforts are hampered by human and financial resource constraints. At the same time there is emphasis on exploring new Information and Communication Technologies' (ICTs) potential to improve and upscale extension service delivery. However, there is limited knowledge on new ICTs' potential and contribution to facilitating innovation intermediation. Taking in account that new ICTs can enable new ways of connecting people and sharing information, the thesis investigates the opportunities and role of new ICTs in supporting innovation intermediation in the Ghanaian extension system using a socio-technical perspective and a mixed methods research approach. The study finds that of the types of technologies functioning in the Ghanaian agricultural system there are opportunities for Interactive Voice Response (IVR) outbound, Data Management (DaM) and social media messaging technology to support innovation intermediation. Through interviews with extension organisation staff and observing field agents, the study finds DaM technologies can facilitate location-based farmer database development and support farmers' (tacit) needs identification as well as intervention planning and advice tailoring. Beyond these organisations, an experts' consensus building survey and interviews with farmers show that private sector led IVR interventions can provide farmers with immediate access to information (advice, weather, prices, pest threats). Further, by observing and interviewing actors on more informal social media messaging platforms it was established that these platforms can support the coordination of extension activities, timely pest and disease monitoring and knowledge sharing among extension staff and subject matter specialists to enable individual-centred learning and problem solving. Despite this potential, the study also shows that new ICTs' inherent technical features do not determine their application, but social factors (human abilities and preferences, identity management, socio-political influences and the wider institutional environment) shape their use. Therefore, the potential of DaM and IVR outbound technologies are not realised, and the technologies identified have the potential to or contribute to innovation intermediation activities as they complement human intermediaries (public extension agents) and conventional communication mechanisms (face-to-face settings and radio). The implications of these findings for extension practice and policy are that contextual considerations are made, and participatory technological design engaged to foster technological access and realise new ICTs' potentials. Another recommendation is that combinations of new and classical media, face-to-face settings and human intermediaries are explored such that new ICTs are integrated into the existing communication landscape of extension systems based on where they add value - as this is where huge opportunities for facilitating innovation intermediation lie.

Keywords: Information and Communication Technology (ICT), social media, mobile technology, innovation intermediation, information seeking behaviour, agricultural extension, knowledge processes, Agricultural Knowledge and Innovation Systems (AKIS), network analysis, fall armyworm, Ghana.

Contents

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Chapter 1

General introduction

1. Introduction

Despite agriculture's potential to contribute to the growth of the Ghanaian economy (Aker, 2011; Barimah, Doso and Twumasi-ankrah, 2014) agricultural production remains less than optimal (McIntrye *et al.*, 2009; Sova *et al.*, 2014). For the major food crop, maize, the potential yield is estimated at 5.0 tonnes/ha, while production has not exceeded 2.0 t/ha between 2008-2014 (World Bank, 2017). Factors explaining these production levels include not only rainfall variability and environmental degradation, but also a range of socio-political and institutional conditions (McIntrye *et al.*, 2009; Pretty, Toulmin and Williams, 2011), including limitations in agricultural extension service delivery mechanisms (Leeuwis, 2004; Davis, 2008; Swanson and Rajalahti, 2010; DAES, 2011). The current understanding of agricultural extension transcends technology transfer from scientists to farmers (Leeuwis, 2004; Davis, 2008). Recent perspectives presume that extension involves coordinating the set of organisations[1] that support value chain actors[2] in emergent problem solving, facilitating business linkages between these actors and facilitating their access to localised information (technology) and skills, (Christoplos, 2010; Davis, 2008). In addition, these perspectives of extension involve facilitating the integration of scientific and other knowledge to produce appropriate technologies for value chain actors (Leeuwis, 2010). The drawbacks of national extension systems to adapt to such approaches, and effectively serve a range of actors whose needs that relate to their constantly changing environments are broader than knowledge and also interwoven, have hampered production (Leeuwis, 2004).

Besides the shift in extension perspectives, Africa is experiencing an Information and Communication Technologies (ICT) revolution[3] (World Bank, 2011). New ICTs[4] are a

[1] Research institutions, educational institutions, non-governmental organisations, development organisations, other government institutions, credit providers, weather service providers, transporters, private extension service providers.

[2] Farmers, input suppliers, processors, exporters, traders, retailers, wholesalers, packaging and other manufacturers.

[3] The revolution was/is primarily driven by the shift from analogue to digital technology, and more recently within the digital age there has been the emergence and focus on networking digital technology. Therefore, reference is sometimes also made to the networked digital age (Van der Haak, Parks and Castells, 2012).

[4]. The term new ICT is used in this study to refer not only to new media, media preceding analogue broadcasting and printed media that are more interactive and digital (Lister *et al.*, 2003), but also technology such as unstructured supplementary service data, short message services, interactive voice response (mobile technologies

feature of this revolution. These ICTs that precede analogue broadcasting and printed media, non-interactive and non-digital media (Lister *et al.*, 2003), enable the exchange of textual, audio, video and pictorial information between two or more actors (Qiang *et al.*, 2012; Barber, Mangnus and Bitzer, 2016). These technologies include social media[5] (e.g., Facebook, WhatsApp), Short Message Service (SMS), Unstructured Supplementary Service Data (USSD), Interactive Voice Response (IVR), and data collection and storage technologies (e.g., Open data kit). Based on their capacity to enable new ways of sharing information and connecting people (World Bank, 2011; Bennett and Segerberg, 2012; Klerkx and Gildemacher, 2012; Qiang *et al.*, 2012; Bell, 2015), these technologies present opportunities to improve communication-related service delivery. Given these opportunities, new ICTs feature on the international development agenda including the Sustainable Development Goals (United Nations, 2020), and on the research agenda in the ICT-for-development (ICT4D) field and scientific domain of development informatics (Walsham, 2017; Heeks, 2018; Sein *et al.*, 2019). Globally and in Ghana, (new) ICTs are considered one of the driving forces of agricultural reform (Swanson and Rajalahti, 2010; McNamara *et al.*, 2012). While with ICT-for-agriculture (ICT4Ag) they represent an opportunity to address the limitations of classical extension approaches (Chapman and Slaymaker, 2002; Swanson and Rajalahti, 2010).

This thesis investigates the contribution of new ICTs to supporting broader extension service delivery - namely innovation intermediation - in Ghana's maize farming system. Innovation intermediation as an Agricultural Innovation Systems (AIS) approach to extension involves three broad facilitation roles, which are demand articulation, matching demand and supply, and innovation process management. The study takes a socio-technical perspective to understand new ICTs' capabilities to support innovation intermediation, considering technology has contingent effects in any social context (Toyama, 2011; Heeks, 2018). In the next sections the study's significance is highlighted

also considered relatively new (Gershon *et al.*, 2013)) that are not classical media nor necessarily digital oriented either.

[5] "Social media refer to technology artefacts that support various actors in a multiplicity of communication activities for producing user-generated content, developing and maintaining connections and social relationships, or enabling other computer- mediated interactions and collaborations," (Osch and Coursaris, 2013:700).

and the resulting research objective is stated. Then the study's conceptual underpinning and main as well as sub-research questions are outlined, followed by a brief description of the focus of each sub-question. The final section of this chapter outlines the study's overall methodological approach.

Ghana's shift in extension approaches

Classical extension, largely associated with the dominant public extension system, has been criticised for having a narrow technology transfer focus that is limited in responding to wider constraints in agricultural systems[6] (Davis, 2008; DAES, 2011; Leeuwis and Aarts, 2011). It is characterised by inefficiencies in coordinating agricultural stakeholders in problem solving and facilitating value chain linkages (Kilelu *et al.*, 2011; Klerkx and Gildemacher, 2012). Further, classical extension falls short in integrating scientific and other knowledge to produce appropriate technologies as well as localise agronomic advice for farmers (Leeuwis, 2010; Lambrecht *et al.*, 2015; Karpouzoglou *et al.*, 2016). This extension approach is not suited to the complexity of the current agricultural landscape. A landscape characterised by multiple interdependent actors (value chain actors and their service providers) that need to interact to operate as they simultaneously adapt to changes in their socio-economic contexts, and need to respond to climate change related constraints (e.g., new pests or rainfall variability) that have disoriented traditional farming systems (Klerkx and Leeuwis, 2009; McIntrye *et al.*, 2009). Further, this landscape is characterised by these emergent, locality specific biophysical and socio-economic constraints that require updated knowledge, location specific strategies and immediate action to mitigate (Klerkx and Leeuwis, 2009; McIntrye *et al.*, 2009). Fall armyworms' emergence in Ghana's maize farming systems, in the 2016/2017 farming season, is an example of such constraints (Day *et al.*, 2017).

The Ghanaian Ministry of Food and Agriculture's (MOFA) - Directorate of Agricultural and Extension Services (DAES) has attempted to address the problems of classical

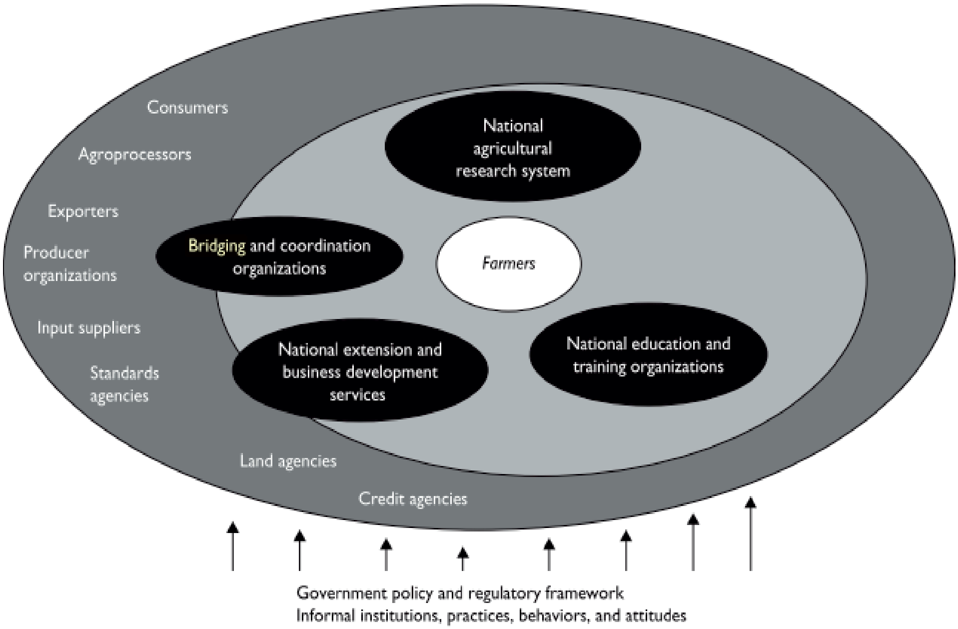
[6]The agricultural system is agricultures' operational unit comprising all actors and organisations at different levels, from local to national level, involved in producing, processing and commercialising agricultural commodities, alongside bio-physical, cultural and economic, and other non-human elements of agriculture (Geng, Hess and Auburn, 1990).

extension. This has involved a shift to extension approaches that transcend technology transfer and include facilitation roles for extension staff (Anderson, 2008; Davis, 2008; DAES, 2011). Starting from the 1970s the extension ideology has moved from top-down, one-size-fits-all approaches (training and visitation approach) to include participatory and bottom-up approaches (farmer field schools) in the 1990s (Davis, 2008; DAES, 2011). More recently, Ghanaian extension is transitioning to an integrated pluralistic system (Davis, 2008; DAES, 2011; Sova *et al.*, 2014; Sigman, 2015). The current approach encompasses stronger research-extension linkages and a broader range of service provision and providers, including the private sector, to meet farmers' and other value chain actors' demand for extension services (DAES, 2011).

Ghana's present extension approach is based on the AIS perspective. To foster innovation[7], the AIS perspective focuses on influencing the relationships of multiple actors and the conditions that affect their collective operations (Figure 1)(Leeuwis, 2004; Klerkx and Leeuwis, 2008; Swanson and Rajalahti, 2010). The broad categories of actors comprise knowledge and technology providers (research, extension and education institutions) and users (value chain actors), and organisations that facilitate interaction and strengthen linkages between these actors (bridging organisations). For the AIS perspective, the focus on these actors' relationships is necessary as innovation occurs when interaction among these diverse agricultural stakeholders is increased (open), resulting in improved knowledge exchange and access to appropriate knowledge and technologies (Swanson and Rajalahti, 2010; Koutsouris, 2012). For this perspective, the actors also need to network to form partnerships, access business development opportunities, and engage in coordinated, collective action to respond to system changes (Koutsouris, 2011; World Bank, 2012). Ghana's integrated pluralistic system focuses on enhancing interaction and linkages in the extension system, a segment of the AIS. More specifically, it focuses on actors in the immediate network of public extension

[7] "Innovation can be defined as a new way of doing something, ranging from changes in the way we think, to the way we produce new products or use new processes or procedures. It also includes institutional innovations that change the way an organization carries out new or different functions, for example, shifting toward a bottom-up rather than a top-down extension system; or moving toward a more market-driven rather than a technology-driven extension system," (Swanson and Rajalahti, 2010: 181).

organisations comprising researchers, Non-Governmental Organisations (NGOs), private extension organisations and value chain actors.



Source: World Bank, 2012

Figure 1. Agricultural innovation system

New ICTs and the Agricultural Innovation Systems' perspective of extension

Despite the national agricultural policy direction to transition to an AIS-based extension approach, facilitating this remains a challenge for both public and private extension organisations due to human and financial resource constraints (McIntrye *et al.*, 2009; Bell, 2015). At the same time the emergence of new ICTs in Africa and the emphasis on exploring these technologies to improve extension service delivery and respond to wider constraints in agricultural systems has intensified (Qiang *et al.*, 2012; Barber, Mangnus and Bitzer, 2016). Studies show that new ICTs can enhance information exchange and interaction in extension service delivery based on their capabilities to enable decentralised information sharing and collection that is timely and location-specific as well as facilitate two-way, open and networked communication in virtual communities (Chapman and Slaymaker, 2002; Davis, 2008; Swanson and Rajalahti, 2010; Aker, 2011;

Amadu and McNamara, 2014; Mccole *et al.*, 2014; Wright *et al.*, 2016). However, little is known of new ICTs' capacity to support AIS-based extension approaches.

New ICTs as innovation intermediaries

Klerkx and Gildemacher (2012) have made a start at connecting new ICTs to AIS-based extension service delivery. They develop a typology of innovation intermediaries in the Dutch agricultural sector – innovation intermediaries being organisations, persons or entities that facilitate interaction and linkages among AIS actors to foster innovation (Klerkx and Gildemacher, 2012). Klerkx and Gildemacher (2012) identify seven types of intermediaries: internet-based portals and platforms; consultants targeting individual farmers and Small and Medium Enterprises (SMEs) in the agri-food sector; consultants targeting farmer collectives and agri-food SMEs; peer network brokers; education brokers; systemic intermediaries; and research councils (Klerkx and Gildemacher, 2012) - putting forward that these types of intermediaries often exist in combinations, for instance ICT and organisation configurations (Materia, Giarè and Klerkx, 2015; Randhawa, Wilden and Gudergan, 2018). In addition to these seven types of intermediaries extension organisations, NGOs, farmer-based organisations, research institutions are also known to assume intermediary roles (Kilelu *et al.*, 2011). While, in many developing countries, it is argued that extension organisations are best suited to function and easily assimilated as innovation intermediaries (Kilelu *et al.*, 2011).

Despite new ICTs identification as a type of intermediary, more studies on innovation intermediaries explore the functioning and influence of other types of intermediaries in innovation systems (Winch *et al.*, 2007; Kilelu *et al.*, 2011; Kivimaa *et al.*, 2019). Nonetheless, some studies indicate that new ICTs have the potential to function as intermediaries by passive matching of demand and supply and as information sources (Klerkx and Gildemacher, 2012; Randhawa, Wilden and Gudergan, 2018). Overall existing studies on innovation intermediaries, including Klerkx and Gildermacher's (2012) study and a European study that assesses the capacity of new ICTs to support agricultural innovation processes (Hansen *et al.*, 2014), lack insights on the role of specific new ICTs functioning in Africa to support innovation intermediation on the continent.

Despite the limitations of the studies identified in the previous section, it is also important to point out that existing literature on new ICTs and innovation intermediation in Africa is fragmented. The literature lacks insight into the relationship of different types of new ICTs and innovation intermediation as a whole (Gakuru, Winters and Stepman, 2009; Misaki, Gaiani and Tedre, 2018). It [the literature] focuses on evaluating specific new ICT applications or platforms that provide market, technical and weather information to farmers (Aker, Ghosh and Burrell, 2016) or rather the literature focuses on research related to the demand and supply side matching role of innovation intermediation. Even so, a recent review on the challenges of smallholder farmers in accessing information via mobile phones in Africa, by Misaki et al (2018), only identified seven such new ICT platforms.

New ICTs, knowledge sharing and other forms of collaboration

In a similar vein, a number of articles connect new ICTs to another aspect of innovation intermediation, knowledge sharing. A recent systematic review identifies substantial literature on the use of social media in knowledge sharing in different geographies and fields (Ahmed *et al.*, 2019). The review provides evidence of social medias' positive influence on open knowledge exchange among academic researchers and in disaster management as a real-time communication and monitoring tool. Although this emergent research area presents considerable research opportunities (Phillips, Klerkx and Mcentee, 2018; Ahmed *et al.*, 2019), there is an emphasis on Facebook use and less attention is paid to agricultural or African contexts. The review highlights research opportunities on the topic 'organisation social media'[8], which has received little attention to date, despite the potential and growing use of social media for professional activities (Van Osch and Coursaris, 2013). These opportunities relate to understanding how organisations use social media to meet their goals and how social media platforms have an impact on broader forms of collaboration than knowledge sharing. These other forms of collaboration and professional organisational uses include marketing, lobbying,

[8] Social medias' effects on communication and collaboration processes in organisations (Van Osch and Coursaris, 2013).

relationship building, learning, knowledge co-production and innovation (Van Osch and Coursaris, 2013; Hansen *et al.*, 2014; Kane *et al.*, 2014a; Ahmed *et al.*, 2019).

Additionally, a selection of the studies on knowledge sharing contribute to a better understanding of why the combination of ICT and non-ICT intermediaries exist. Materia *et al.* (Materia, Giarè and Klerkx, 2015) show that new ICTs play a complementary role of providing input for or supporting face-to-face interaction to facilitate knowledge sharing and learning between agricultural advisors and researchers (Perez-Perdomo, Klerkx and Leeuwis, 2010; Sulaiman *et al.*, 2012). This is because face-to-face interaction is better suited for complex knowledge exchange processes (e.g., knowledge integration or co-creation) as it allows for in-depth interaction (Krone, Schumacher and Dannenberg, 2014; Aker, Ghosh and Burrell, 2016). Sulaiman *et al.* (2012) further suggest (as Materia *et al.* (2015) imply) that the combination of conventional communication mediums and new media that could enhance knowledge sharing in agricultural (innovation) systems include user-driven media, such as Facebook that are emerging as powerful tools of information sharing (and collective action (Bennett and Segerberg, 2012)). Sulaiman *et al.* (2012) suggest user-driven ICT tools to enhance knowledge sharing, as opposed to organisation driven (expert or top-down) tools, based on their findings that most organisations in South Asian agricultural systems are largely engaged in a technology transfer extension approach and their use of ICTs reinforces this approach rather than broader stakeholder engagement. In other words, and according to amplification theory, ‘technology cannot substitute for missing institutional capacity and human intent’ (Toyama, 2011: 75).

Studies on new ICTs and collaboration suggest that these technologies, in combination with conventional communication methods have the potential to facilitate certain aspects of innovation intermediation, particularly when new ICTs are user-driven, like social media. The new ICTs can contribute to knowledge sharing and learning among researchers, and between researchers and extension staff, and information dissemination and monitoring in disaster management (Van Osch and Coursaris, 2013; Ahmed *et al.*, 2019). However, the studies lack insights into which type of new ICTs may be promising and appropriate for improving knowledge sharing and broader forms of collaboration (relating to innovation intermediation) in Africa.

Research objective

Based on the knowledge gaps outlined above, the overall study objective is to identify the opportunities for new ICTs to resolve information and interaction related problems in the Ghanaian agricultural system, and identify and assess the specific roles that new ICTs can play in supporting innovation intermediation.

2. Conceptual Framework

The concept of extension has evolved since the 1970s from the conventional function of providing knowledge to fulfilling a variety of new facilitation roles (Davis, 2008). From an innovation systems perspective, - a perspective that “recognises that innovation is more than simply the adoption of new technologies [but] it involves the co-evolution of technologies, societies, economies and institutions” (Fielke, Taylor and Jakku, 2020: 3), Klerkx *et al*. (2009) suggests innovation intermediation is needed for extension service providers to function more systemically and respond to wider constraints in agricultural systems. Innovation intermediation involves three intermediary roles for these organisations (Table 1).

Table 1. Innovation intermediaries' roles and associated limitations of classical extension

Role	Components | Activities	Limitations
Demand articulation	Locality-specific stakeholders needs identification Systemic problem diagnosis Participatory problem assessment	Limited multi-actor engagement in demand articulation
Matching demand and supply	Tailored knowledge provision Weather services linkage Transport and tractor services linkage Credit options and linkage Input prices and linkage Market prices and linkage	Limited context specific, socio-economic and biophysical data to tailor advice
		Value chain actors' limited access to business linkage information and facilitation
Innovation process management	Coordination and joint problem solving Maintaining and strengthening relationships Facilitating learning, knowledge integration and co-creation	Limited multi-actor engagement and coordination in problem solving
		Limited partnership development and business development for agricultural stakeholders
		Limited synthesis of scientific and other knowledge to embed appropriate technologies in agriculture

Source: author with insights from Klerkx et al., 2009

First, demand articulation involves the engagement of sector stakeholders in needs identification, participatory problem assessment and making interdependencies explicit (Klerkx and Gildemacher, 2012). Second, matching demand and supply involves establishing sector contacts and developing mutually beneficial relationships (Howells, 2006). Third, innovation process management comprises the creation of a discussion and negotiation space for actors to jointly mitigate constraints, maintain relationships and engage in knowledge sharing for continuous innovation (Leeuwis, 2010; Vitos *et al.*, 2013).

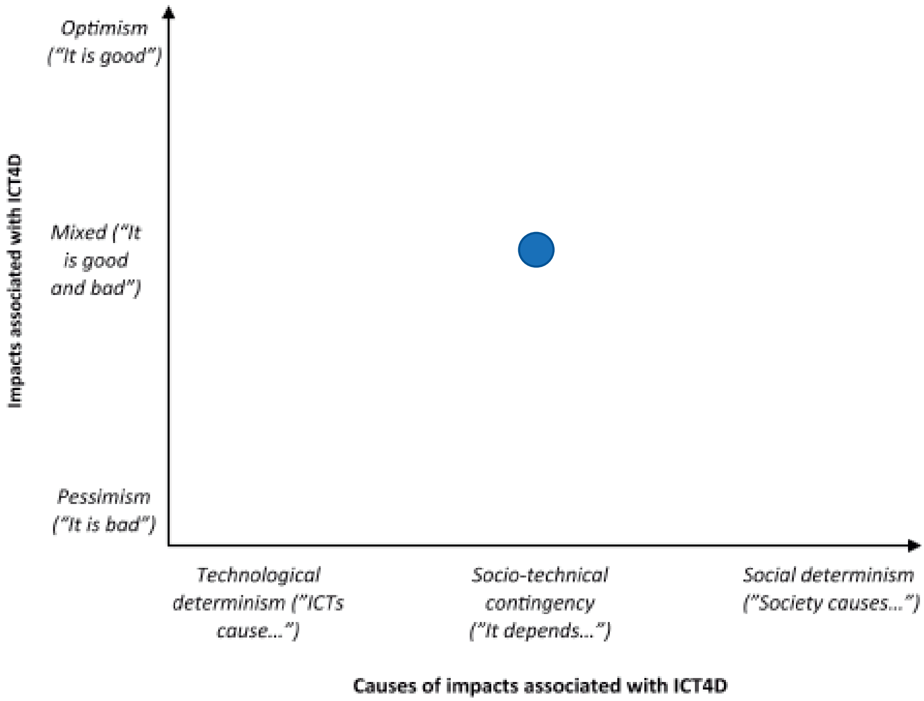
In sub-Saharan Africa, including Ghana, extension organisations' adaptation to innovation intermediation are hampered by human and financial resource constraints (McIntrye *et al.*, 2009; Swanson and Rajalahti, 2010). Currently, new ICTs are being explored to respond to these challenges as there are indications that new ICTs can act as bridging mechanisms and upscale extension service delivery (Qiang *et al.*, 2012; Bell, 2015; Barber, Mangnus and Bitzer, 2016). As bridging mechanisms, new ICTs can act as virtual intermediaries facilitating interaction and business linkages between agricultural stakeholders (Kilelu *et al.*, 2011; Klerkx and Gildemacher, 2012). They can act as bridging mechanisms based on possessing intermediation capabilities that range from linear to networked communication: disseminating, retrieving,, harvesting, matching, networking, coordinating and co-creating (adapted from Hansen *et al.* (2014) with insight from Leeuwis (2004) and Howells (2006)). Given these capabilities are communication and networking functions relevant to facilitating innovation intermediation, new ICTs present opportunities to support this extension approach.

In relation to the intermediation role of demand articulation, new ICTs can facilitate engagement, discussion and networking between demand and supply-side stakeholders in different locations through virtual platforms to share information that clarifies their needs and constraints (Klerkx and Gildemacher, 2012; Hansen *et al.*, 2014). Whereas forms of decentralised data sharing, including crowdsourcing, afford opportunities for the collection of locality specific information (e.g., soil data, pest infestation) for tailoring agronomic advice and also for use in strengthening value chain linkages by improving access to information on markets, weather, agronomic advice and financial services (Qiang *et al.*, 2012; Barber, Mangnus and Bitzer, 2016). Both opportunities mentioned being areas in which new ICTs could support the matching demand and supply role of innovation intermediation.

For the innovation process management role, new ICTs can potentially enhance information sharing and interaction for knowledge sharing and joint problem solving. They may foster online networks that can support open communication spaces, alongside formal organisational communication structures. These spaces may function as multi-actor discursive spaces that support intra- and inter-organisational linkages through free information sharing and equal access to information to enhance knowledge dissemination, integration and joint problem solving (Bennett, 1996; Sexton and Lu, 2009; Abouzeedan and Hedner, 2012). The term open communication space is derived from the open innovation concept. Open innovation is a firm's process of re-combining knowledge or co-creating it with a variety of external stakeholders to accelerate inter-organisational innovation, and expand external use of innovation (Chesbrough, Van Haverbeke and West, 2006). Further, new ICTs offer opportunities for developing "early warning systems" that support the detection of emerging issues, such as drought or pest occurrences in the field, allowing extension service providers or value chain actors to respond promptly (Mccole *et al.*, 2014). These early warning systems are based on data crowdsourcing that is closely linked to the concept of citizen science, namely the involvement of ordinary people in data collection and or analysis within scientific projects (Van Vliet, Bron and Mulder, 2014). Additionally, new ICTs' opportunities for the innovation process management role lay in re-organising extension service delivery towards connective action. Connective action refers to informal, inclusive self-organisation often facilitated by social media (e.g., Facebook) and driven by personal motivations to engage with others (network) to put forward agendas, share view points and coordinate in pursuit of collective goals (e.g., the 'Arab Spring')(Bennett and Segerberg, 2012; Cieslik *et al.*, 2018).

In spite of the inherent capabilities and expectations of new ICTs to resolve problems in agricultural systems, it is important to avoid technological determinism because technology and society mutually shape each other (Williams and Edge, 1996; Boczkowski, 1999; Sein *et al.*, 2019). New ICTs are socially embedded such that social[9] influences shape their use and at the same time ICTs shape society. This interplay comes with the high probability of partial technology adoption and impact, and in certain cases comes with unanticipated negative impacts (Stilgoe, Owen and Macnaghten, 2013). Therefore, avoiding social or technological determinism this study takes a socio-technical (contingent) perspective when studying technology in context. Whilst also taking into account that technology can have positive and negative effects or impacts (see Figure 2 – the blue dot marks this thesis' underlying perspective to understand and explain new ICTs relationship to innovation intermediation).

[9] Social - influences: personal factors such as human abilities, preferences and motivations (Marchewka and Kostiwa, 2007; Toyama, 2011), socio-political influences (e.g., actors with interests in maintaining the status quo, power dynamics in information exchange or sharing) and the wider institutional environment (policies, incentive systems, funding arrangements, prevailing communication cultures, etc.) (Ipe, 2003; Leeuwis, 2013; Cieslik *et al.*, 2018).



Source: Heeks, 2018

Figure 2. Worldviews on ICT4D impacts and causes

Further, given that new ICTs are socially embedded, it is important to understand farmers' predispositions to accessing agricultural information and services. This serves the purpose of scrutinising the assumptions of new ICT and AIS-based extension approaches to establish how farmers, as key actors in extension, plug into these approaches.

Research questions and description of empirical chapters

The overarching research question that links into the broader research objective emerges from the conceptual framework: what roles do new ICTs play in supporting innovation intermediation in the Ghanaian extension system? The sub-questions of this question that correspond with the thesis' empirical chapters are discussed further below.

1) What are experts' views on the intermediation capabilities of new ICTs in Ghana's agricultural system?

2) What are new ICTs' roles in supporting innovation intermediation in public and private extension organisations?

3) What is the contribution of social media messaging platforms to enhancing interaction for collaboration at the interface of research and extension?

4) What are farmers' information source choices in accessing information for managing new pests (fall armyworm), and the role of mobile technology in this process?

The first question focuses on the assumed capabilities of new ICTs (Figure 3) and corresponds to Chapter two. The chapter identifies specific communication and networking functions (intermediation capabilities) that new ICTs functioning in the Ghanaian agricultural system can support, taking into account that few studies discuss the inherent capabilities (what technology is capable of doing) of such technologies (Van Osch and Coursaris, 2013). The chapter further gives indications of the opportunities for particular new ICTs to connect farmers and other agricultural stakeholders in innovation intermediation processes.

Chapter three, based on the second research question, considers the extension-technology interface in Ghana. The chapter delves into a public and private extension organisation to investigate their use of new ICTs to support innovation intermediation (Figure 3). The study connects two topical research areas, namely new ICTs' inherent capabilities and innovation intermediation in Africa.

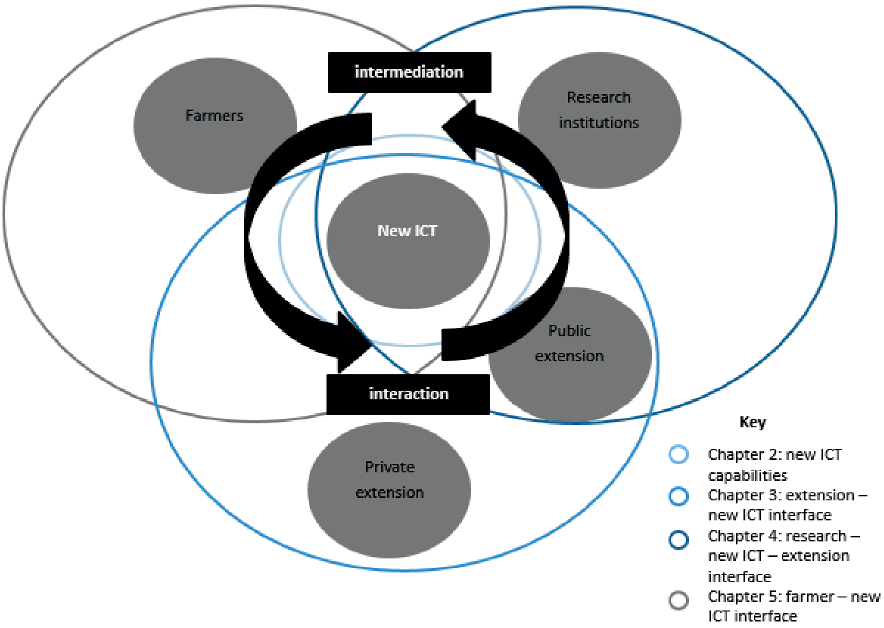


Figure 3. Description of empirical chapters

The fourth chapter relates to the research - technology - extension interface (Figure 3), and research question three. It focuses on social media's contribution to facilitating open information sharing and interaction between researchers and extension staff in innovation process management during the emergence of fall armyworm (a new pest). The study contributes to the emerging research area that relates social media (other than Facebook) to knowledge sharing (Phillips, Klerkx and Mcentee, 2018; Ahmed *et al.*, 2019) and other forms of collaboration in Africa (Van Osch and Coursaris, 2013).

Finally, chapter five is connected to the last research question, and reflects on the farmer - technology interface (Figure 3). The chapter provides understanding of farmers' predispositions to accessing knowledge and information for problem solving (fall armyworm management), with a specific interest in the application of mobile technology in this process. The relevance of this focus is to show how these technologies are made useful by farmers, the primary targets of extension (Martin and Hall, 2011), to engage in innovation intermediation processes.

Overall the studies as a collective are relevant to extension service providers as they point to possible areas in which new ICTs could broaden extension service delivery. They provide a deeper understanding of new ICTs' capacity to facilitate these augmentations and the social influences that hamper or enable them. This is essential to consider in the development of agricultural interventions with higher potential for success in the changing landscape of agricultural production (Crane, 2010; Hansen *et al.*, 2014).

3. Methodological Design

The methodological design is guided by an interpretivist perspective that places "human meaning-making at the centre of the research endeavour" and understanding phenomenon from the perspective of the respondent(s) (Schwartz-shea, 2014: 1); and to achieve rich, contextualised understanding of phenomenon (Polit and Tatano, 2010). The methodological approach was suitable for the research based on the choice of theory. A socio-technical perspective was used to understand how respondents (experts, extension staff, organisations and farmers) found and made new ICTs useful to achieve organisational or individual goals related to extension activities (innovation intermediation), and establish the social factors in their contexts enabling and limiting the exploitation of these technologies' inherent capabilities for such purposes.

To achieve this objective qualitative data collection methods were a major feature of the study. However, while interpretive approaches often seek to understand a particular subject through qualitative data collection methods (e.g., in-depth interviews, participant observation), this study takes a pragmatic approach to data collection and its associated analysis. The study largely relies on qualitative data, but applies other quantitative methods where appropriate to answer the research question effectively and comprehensively. This mixed method approach served two purposes: 1) to explain the findings of quantitative data using qualitative data (question 1) and vice versa (question 3); 2) to elucidate more information and collect comprehensive data that one method could not provide (questions 1 and 3) (Creswell and Plano Clark, 2011). Data collection and analysis methods used to answer each research question are described in Table 2, and further details are provided in the empirical chapters.

Table 2. Summary of data collection and analysis methods

Question	Data collection	Data analysis
1	Experts' honey comb evaluation	Aggregation and averaging individual evaluations
	Experts' survey	Descriptive statistical analysis
	Experts' focus group discussion	Thematic analysis
2	Characterisation of new ICT platforms interface functions	Content and functionality analysis
	In-depth interviews with extension organisation staff	Thematic content analysis
	Observation (extension) agents in the field	Thematic analysis
3	Observation interaction social media platform actors	Thematic content analysis
		Social network analysis
	Social media platforms actors' survey	Descriptive statistical analysis
4	Semi-structured interviews with farmers	Descriptive statistical analysis
		Thematic content analysis

<u>Question 1: What are experts' views on the intermediation capabilities of new ICTs in Ghana's agricultural system?</u>

To answer the first question, a scoping exercise and expert consensus building exercise were conducted. For the scoping exercise, ICT4Ag literature on Ghana was reviewed and organisations in the Ghanaian ICT4Ag community discovered in the literature were engaged to develop an inventory of new ICT ag-platforms functioning in Ghana (Gakuru, Winters and Stepman, 2009; Qiang *et al.*, 2012; World Bank, 2014; Aker, Ghosh and Burrell, 2016). The inventory (see Appendix 1: 57) was then examined to categorise the types of new ICTs the platforms comprised (e.g., SMS push, social media, IVR outbound).

Using the categories, a Delphi-inspired consensus building study was conducted with varied experts (scientists, researchers and practitioners). A Delphi study is a "group facilitation technique, which is an iterative multistage process, designed to transform opinion into group consensus" (Hasson, Keeney, and McKenna 2000: 1) . This experts' consensus building study involved two rounds and a focus group discussion with purposively sampled experts of varying configurations. The first round was a five-point Likert scale assessment by each member of the research team of communication and innovation scientists on the intermediation capabilities of the types (categories) of new ICTs identified. The individual results of the evaluation were aggregated and averaged, and then used to develop propositions on the extent to which specific new ICTs could support communication and networking functions relevant to innovation intermediation processes. The second round was a survey based on the same propositions that was conducted via Google Forms. The survey targeted a broader external panel of experts that ascertained consensus and dissensus over the propositions. The experts were identified from a list of invitees for an ICT4D workshop organised by a research programme the research team was affiliated to (list available upon request). Further, researchers and practitioners outside the workshop were also identified as potential respondents. They were selected from journal publications based on the search function '(mobile technology or ICT) AND (extension or agriculture) AND (Ghana)' (research results available upon request).

Descriptive statistical analysis was applied to data from this round (round 2). While the focus group discussion involved a small external expert panel, one of the working groups of the workshop mentioned, to establish the factors behind propositions associated with consensus and dissensus. Thematic analysis was used to identify these factors that emerged from the focus group discussions.

Question 2: What are new ICTs' roles in supporting innovation intermediation in public and private extension organisations?

For question two, a comparative case study analysis of two new ICT platforms was conducted. The platforms were selected from the new ICT platform inventory mentioned above based on being embedded in a public and a private extension organisation broadening extension service delivery. The private extension organisation was specifically working in the maize farming system and both platforms were functioning in the Techiman area (Brong-Ahafo Region), and therefore this farming system and area were included as part of the context for this research and the entire study.

Data collection involved characterising the content and functionality of the platforms. Additionally, in-depth interviews were conducted with purposively sampled key informants (e.g., top and middle managers, specialised officers, platform developers) from both organisations to determine the innovation intermediation roles they are engaged in and the (ICT-based) mechanisms for facilitating these roles. In-depth interviews and field observation were also conducted with randomly sampled (extension) agents attached to both organisations to determine the actual intermediation roles they engaged in and their platform (user) experiences. Data from the interviews and field notes from observations were analysed using content and thematic analysis.

Question 3: What is the contribution of social media messaging platforms to enhancing interaction for collaboration at the interface of research and extension?

Data collection related to question three focused on two social media platforms. One platform was a WhatsApp[10] group initiated by a public extension organisation, functioning at the district level, for staff members. The other platform (a Telegram[11] group) was associated to a research institution that linked the district extension organisation to a broader external network of extension agents in other districts and subject matter specialists. The platforms were selected based on being bottom-up initiatives, hence promising for free information exchange. They were also selected based on their capacity to facilitate multi-actor engagement and networked communication - conditions that are useful for supporting open interaction for complex innovation process management activities. These processes including, knowledge integration and joint problem solving that were relevant in the response to fall armyworm, a new pest that emerged in Ghana around 2016 and caused devastation to maize crops.

[10] WhatsApp Messenger is an instant messaging (mobile and desktop) application that enables the of exchange text, images, video and audio messages between individuals and in actors in groups. See https://www.whatsapp.com/?lang=en for more information.
[11] Telegram is also an instant messaging application that enables the same functions as WhatsApp. See https://telegram.org/ for more information.

As part of data collection, platform interaction data was exported into text files using the export functions on both WhatsApp and Telegram applications. The text files were subject to content analysis and processing for social network analysis. Content analysis was used to establish the type of content exchanged on the platforms. While social network analysis was applied to determine the platforms' network and communication structure: how actors connect (interact) with each other given the capacity of the platforms to support free information exchange and networked communication.

A platform user survey was also conducted with actors who voluntarily responded to a questionnaire via Google Forms. The survey aimed to gain insights into social factors influencing the type of interaction taking place on the platforms. The survey data was analysed to produce descriptive statistics.

Question 4: What are farmers' information source choices in accessing information for managing new pest (fall armyworm), and the role of mobile technology in this process?

Semi-structured interviews were conducted with farmers to establish their information sources for different types of information required (information dimensions) to manage a new pest, fall armyworm. Farmers' responses were marked and captured in a matrix. The matrix' vertical axis fielded farmers' potential information sources developed from literature (Dutta, 2009; Ajani, 2014; Bernard, Dulle and Ngalapa, 2014; Rahman, Lalon and Surya, 2016; Acheampong *et al.*, 2017), while its horizontal axis reflected the information dimensions of FAW management. The data in the matrices were analysed to produce descriptive statistical outputs that showed the number of times a source was cited as an information source for the different information dimensions of fall armyworm management. The interviews also served to establish the factors determining farmers' preferences for engaging with specific information sources. The factors considered were based on characteristics of good information sources (Starasts, 2004). These factors were synonymous with themes used for the content analysis of the interview data (notes).

Farmers were included in the sample based on three considerations. Firstly, they had experienced a fall armyworm infestation. Secondly, they were affiliated to an active maize farming group of either a public or a private extension organisation. Farmers were selected and differentiated by these affiliations as it was assumed that they might have different information source choices for fall armyworm management, given that the extension organisations had different service delivery approaches. Thirdly, farmers were included in the sample based on established determinants of ICT adoption (age, sex, education level etc.) (Ali, 2012). The third consideration was made in sampling because the study also aimed to establish farmers' mobile phone and new ICT usage in fall armyworm management, and needed farmers with these characteristics represented in the sample to capture diversity. The farmers interviewed were selected through multiple stage sampling. They were randomly selected, based on the ICT-adoption determinants, from a purposive sample of maize farming groups affiliated to each type of extension organisation.

2

Chapter 2

Intermediation capabilities of new information and communication technologies in Ghana's agricultural system

Nyamwaya Munthali, Rico Lie, Annemarie van Paassen,
Ron van Lammeren, Richard Asare and Cees Leeuwis

To be submitted

Abstract

New Information and Communication Technologies (ICTs) present opportunities for enhanced intermediation between actors, and related information exchanges in Ghana's agricultural extension system. To understand these opportunities, this study investigates the capabilities of new ICTs to support seven forms of intermediation: disseminating, retrieving, harvesting, matching, networking, coordinating and co-creating. Firstly, we identified the types of new ICTs currently functioning in Ghana's agricultural system. Secondly, we applied a Delphi-inspired research design to determine scientists', researchers' and practitioners' consensus or dissensus over which new ICTs can support each of the seven intermediation capabilities. The outcomes show that experts see opportunities for Interactive Voice Response (IVR) technologies to support action-oriented and linear intermediation such as disseminating, retrieving, harvesting and matching. As to the other intermediation capabilities, experts agreed that Social Media Messaging (SMM) technologies can support coordination to a certain extent. However, there was no consensus among experts on which new ICTs can currently support networking or co-creating.

Keywords: Information and Communication Technology (ICT), intermediation, agricultural extension, Ghana.

1. Introduction

Productivity growth in Ghana to bridge the gap between potential and actual production of food and cash crops is partly hampered by the historic and prevailing approach to extension service delivery (Alemna and Sam, 2006; MOFA, 2007; McNamara *et al.*, 2012; World Bank, 2017). This approach is typified by extension being limited to technology transfer rather than taking on broader roles (e.g., knowledge brokering, facilitating access to credit, and supporting market linkages) to help meet farmers' multi-faceted production needs. The prevailing extension approach also fails to adequately facilitate interaction among agricultural stakeholders (farmers and the various actors involved in agricultural research and development). Such interaction could support knowledge sharing, joint problem solving and coordinated action to provide farmers with appropriate knowledge to respond efficiently to emerging farming challenges such as the impacts of climate change (McNamara *et al.*, 2012; Asiedu-darko, 2013).

National agricultural policy objectives in Ghana from 1996 onward have consistently stated that re-organisation and improved coordination in the sector are key to agricultural development and adaptation strategies (DAES, 2011; Sova *et al.*, 2014; Sigman, 2015; World Bank, 2017). Based on this policy direction, structural changes in the Ghanaian extension delivery system have included accommodating private extension organisations to meet the high demand for extension services and a transition towards Agricultural Innovations Systems (AIS) based extension approaches (McNamara *et al.*, 2012; Van Paassen *et al.*, 2013; Adekunle and Fatunbi, 2014). In view of fostering innovation (new ideas and improvements) in agriculture, the AIS perspective focuses on influencing the relationships of multiple actors and on the conditions (e.g., policies) that affect their (collective) operations (Leeuwis, 2004; Klerkx and Leeuwis, 2008; Swanson and Rajalahti, 2010). Extension approaches based on this perspective involve three broad intermediary roles which are demand articulation, matching demand and supply, and innovation process management. Demand articulation involves the engagement of sector stakeholders in needs identification, participatory problem assessment and making interdependencies explicit (Klerkx and Gildemacher, 2012). Matching demand

and supply involves establishing sector contacts and developing mutually beneficial relationships (Howells, 2006). Lastly, innovation process management comprises the creation of a discussion and negotiation space for actors to jointly mitigate constraints, maintain relationships and engage in knowledge sharing for continuous innovation (Leeuwis, 2010; Vitos *et al.*, 2013).

Despite the efforts of public and private extension organisations to successfully transition to such approaches, some factors still stand in the way. These factors include financial constraints (untimely and limited funding), human resource constraints (freezes in hiring staff; limited numbers of staff) and skill-set related constraints (limited adaption on the part of educational institutions to develop the facilitation capabilities of extension staff) (MOFA, 2007; Sova *et al.*, 2014).

At the same time, Africa is experiencing an Information and Communication Technology (ICT) revolution (Alemna and Sam, 2006; Bell, 2015) and Ghana is emerging as the West African ICT hub (Alemna and Sam, 2006; Mccole *et al.*, 2014). New ICTs form part of this revolution. These ICTs precede analogue broadcasting and printed media (Lister *et al.*, 2003), they include Interactive Voice Response (IVR), Short Message Service (SMS), Unstructured Supplementary Service Data (USSD), social media (e.g., WhatsApp, Facebook), and document and data management systems (e.g., Open data kit). New ICTs present new opportunities for connectivity to enhance service delivery (Qiang *et al.*, 2012; Bell, 2015), and are currently being explored by scientists, researchers and development practitioners to respond to the limitations of classical extension and interaction constraints in Ghana’s agricultural system (Gakuru, Winters and Stepman, 2009; Qiang *et al.*, 2012; Cieslik *et al.*, 2018; MEST, 2019).

Currently, there is limited scientific literature assessing the capability of different types of new ICTs to drive agricultural innovation processes and simultaneously highlight the opportunities for organisations to use these technologies to support these processes (Van Osch and Coursaris, 2013). This is the case even though there are indications that new ICTs can act as bridging mechanisms between actors (Kilelu *et al.*, 2011; Munthali *et al.*, 2018). These technologies can connect actors and facilitate their interaction (intermediate) based on supporting communication functions such as coordination, information retrieval and dissemination (Martin and Hall, 2011) as well as supporting networking functions such as engagement, discussion, crowdsourcing, networking, co-production and cooperation (Hansen *et al.*, 2014). One such rare study presents an expert assessment of the capability of social media and other web based platforms, Facebook, Twitter, ResearchGate, LinkedIn, YouTube, SlideShare, Organic e-prints, Word press, Blogger, NING, ERFALAND, Yammer, Crowdsourcing and Wikipedia, to act as drivers of agricultural innovation (Hansen *et al.*, 2014). The study finds that a number of the platforms (mostly social media) have high capacity to support specific social networking functions that support innovation: discussion (Facebook, NING, ERFALAND and Yammer); networking (Facebook, LinkedIn and NING); crowdsourcing (ResearchGate and Crowdsourcing), cooperation (Yammer, ResearchGate and Wikipedia) and co-production (ResearchGate and Wikipedia). However, this European study assesses forms of media that are currently inaccessible in the African agricultural context, where key actors (such as farmers) are typically located in rural settings with limited access to the internet and to mobile devices that support internet services (Aker, 2011). Thus, the opportunities for new ICTs presented in this study cannot be leveraged in many African agricultural systems. Further consideration of the study's applicability to Africa reveals that it lacks a picture of the types of new ICTs that are currently available in Africa and that could facilitate AIS-based extension service delivery. Additionally, the study fails to consider how different experts, from academic-oriented to more location-specific and practice-oriented experts, currently look at the opportunities for specific new ICTs to augment extension service delivery.

In this study we address these knowledge gaps and aim to identify opportunities for new ICTs to support intermediation capabilities, which are essential communication and networking functions for facilitating AIS-based extension service delivery in Ghana. The study identifies these opportunities based on the perspectives of Ghana-focused communication and innovation scientists, development informatics researchers and ICT4Ag practitioners.

2. Analytical framework

In this section we start by discussing bridging mechanisms as an overarching concept that incorporates the core concept of this study, which is intermediation capabilities. We highlight the possibility of new ICTs to function as bridging mechanisms and in doing so support extension organisations in facilitating AIS-based extension service delivery. Further, we delve into the types of intermediation relevant to this facilitation process and simultaneously present the intermediation capabilities that new ICTs may facilitate. We finish the section by formulating the research questions.

New ICTs functioning as bridging mechanisms

Farmers operate in multi-faceted production environments. Enhancing the performance of the Ghanaian agricultural sector therefore requires improved information (knowledge) flows among agricultural stakeholders and improved business linkages. The major stakeholders in the agricultural system are knowledge technology providers and users. Their interaction and knowledge exchange needs to be enhanced, along with other value chain actors who reportedly have loose linkages (McNamara *et al.*, 2012; Asiedu-darko, 2013). The other actors in the system are bridging organisations that are involved in facilitating interaction and linkages between stakeholders (Kilelu *et al.*, 2011; World Bank, 2012). Bridging organisations are defined by Berkes *et al.* (2003) as organisations that provide an arena for knowledge co-production, trust building, sense making, learning, vertical and horizontal collaboration, and conflict resolution.

From an innovation systems perspective, bridging organisations are associated with intermediaries, which are “persons or organisations that, from a relatively impartial third-party position, purposefully catalyse innovation through bringing together actors and facilitating their interaction” (Klerkx and Gildemacher 2012: 221). For many developing countries it is argued that these bridging functions are best suited to and easily assimilated by public extension organisations, even though other organisations (private extension organisations, non-governmental, farmer-based organisations and research institutions) have been involved in the role (Kilelu *et al.*, 2011). In the case of

Ghana, to assimilate this role (MOFA, 2001; DAES, 2011), "extension organisations are required to expand their role from that of a one-to-one intermediary between research and farmers," to that which "creates many-to-many relationships to facilitate access to knowledge, skills, services, and goods from a wide range of organisations," (Kilelu *et al.* 2011: 89).

However, various other actors in agricultural systems can also take on bridging functions. These include networks, trade associations, special programmes, consultants, input suppliers and ICT (Kilelu *et al.*, 2011; Klerkx and Gildemacher, 2012). New ICTs can therefore also engage as bridging mechanisms (World Bank, 2012; Hansen *et al.*, 2014), and can be leveraged by extension organisations to function better as bridging organisations and simultaneously engage in AIS-based extension service delivery.

Intermediation capabilities

Intermediation is performed by bridging organisations and new ICTs can function as bridging mechanisms through their capabilities to mediate. Hansen *et al.* (2014) assess these capabilities to drive agricultural innovation based on six social networking functions: engagement, crowdsourcing, discussion, networking, co-production and cooperation. As part of their study, different forms of social media and web-based platforms (e.g., YouTube, ResearchGate, LinkedIn, Facebook, Twitter) were assessed by innovation systems experts to establish the extent to which they support particular social networking functions that may facilitate collaboration for sharing ideas, and mobilising knowledge and resources circulating in other arenas (Granovetter, 1973; Kaushik *et al.*, 2018).

In the African context, new ICTs also have the capability to catalyse innovation. Specifically, they can facilitate aspects of AIS-based extension service delivery. They do this by enabling multi-actor networks for joint needs identification, knowledge integration and problem solving to meet information needs in farming systems (Ajani, 2014). Mobile applications have also been recognised for their ability to improve value chain linkages (Martin and Hall, 2011; World Bank, 2012; Ajani, 2014), to build timely monitoring systems (with geo-referenced data) on environmental issues and production and to provide timely advice to enable farmers to respond to farming challenges (Alemna and Sam, 2006; McNamara *et al.*, 2012; Ajani, 2014). That said it is important to note that in general most studies on new ICT extension initiatives focus on the application of specific mobile applications (new ICT platforms) to provide market, technical and weather information to farmers or rather on these platforms' impact on the matching demand and supply role of AIS-based extension (Aker, Ghosh and Burrell, 2016; Misaki, Gaiani and Tedre, 2018). Further, existing literature does not clarify which new ICTs, of those available in the Ghanaian or wider African context, are most capable of supporting the specific types of intermediation required to facilitate AIS-based extension service delivery. Additionally, there has been little consideration of how different experts, academically-oriented to more location-specific and practice-oriented experts look at the opportunities for new ICTs to augment extension service delivery.

To address these knowledge gaps, we investigate what communication and innovation scientists, development informatics researchers and ICT4Ag practitioners see as the opportunities for new ICTs to enhance interaction in extension service delivery in Ghana. More specifically, we build on the social network functions articulated by Hansen *et al.* (2014) to engage experts in an assessment of the capability of new ICTs to support specific types of intermediation that are essential for facilitating AIS-based extension service delivery in Ghana (see Table 1 for a list of these intermediation capabilities). We modify the work of Hansen *et al.* (2014) that tables these social networking functions: engagement, discussion, crowdsourcing, networking, co-production and cooperation to create a clear distinction between functions by merging and embedding overlapping functions (engagement, discussion, cooperation) into a broader function (coordinating and co-creation). We also include additional functions relevant to facilitating AIS-based extension delivery (harvesting, matching, coordinating) and we categorise all the functions according to three levels of interaction, from linear to more networked communication. Overall, we broaden the work of Hansen *et al.* (2014) to reflect networking as well as communication functions relevant to facilitating AIS-based extension service delivery. We refer to these functions collectively as intermediation capabilities.

Table 1. Intermediation capabilities

Level of interaction	Intermediation capability	Description
ACTION	Disseminating	Enabling content to be spread widely, alerting or attracting the interest or raising awareness of a large group of geographically dispersed actors
	Retrieving	Enabling actors to retrieve information (e.g., price, weather) from a central database or retrieve documents out of a central repository
	Harvesting	Enabling the gathering of feedback, ideas, opinions through the contributions of a large group of geographically dispersed actors e.g., crowdsourcing or polling
INTER-ACTION	Matching	Enabling supply and demand linkages – actors are able to query, consult or search information systems and connect to advice or services
	Networking	Enabling contact between actors such that they make direct connections and are able to interact to form new (business) relationships or reinforce existing relationships
TRANS-ACTION	Coordinating	Facilitating virtual multi-actor engagement to provide open and live communication channels that enable discussion for coordinated action e.g., acting together towards a common purpose or engaging in joint problem solving
	Co-creating	Facilitating a common working space for multiple actors to combine and contribute contextual knowledge or information, engage in document sharing and information storage towards a tangible output

Source: adapted from Hansen *et al.,* 2014 with insights from Leeuwis, 2004 and Howells, 2006

Taking the intermediation capabilities listed in Table 1 as a reference, this study answers the following research questions:

1) How do experts assess the extent to which different new ICTs support specific intermediation capabilities?

2) What type of consensus or dissensus do experts reach over which new ICTs can support which specific intermediation capabilities?

3) What factors are contributing to consensus and dissensus among experts over which new ICTs can support which specific intermediation capabilities?

3. Methods

This methodology section starts by reporting on the scoping exercise which was conducted to identify the new ICTs currently being used in the Ghanaian agricultural system. The scoping study forms the base for the research. The section also explains the set-up of the Delphi-inspired study which was designed to establish experts' consensus on the intermediation capabilities of the different types of new ICTs that were identified through the scoping exercise.

The scoping exercise

We reviewed ICT4Ag literature on Ghana and engaged with organisations rolling out new ICT initiatives discovered in the literature to identify the new ICTs being used in the Ghanaian agricultural sector (Gakuru, Winters and Stepman, 2009; Qiang *et al.*, 2012; World Bank, 2014; Aker, Ghosh and Burrell, 2016). Through these scoping activities we developed an inventory of new ICT platforms (see Appendix 1 page 57). We then examined the inventory to identify the different categories of new ICTs that the platforms comprised (see Table 2). Detailed descriptions of these types of new ICTs can be found in Appendix 2 page 63[12].

[12] For the purposes of this study we describe new ICTs from the front-user perspective, despite applications being part of a broader information system with front-end and back-end users.

Table 2. Types of new information and communication technologies

Type		Interface	Data format	Communication	Mobile device needed	Minimal network needed
Short Message Service (SMS)	SMS pull	SMS request typing	text	one-to-one	all phones	2G
	SMS push	SMS based reading	text	one-to-many	all phones	2G
Interactive Voice Response (IVR)	IVR inbound	request-based talking and listening	audio	one-to-one	all phones	2G
	IVR outbound	request-based talking and listening	audio	one-to-many	all phones	2G
Unstructured Supplementary Service Data (USSD)		request-based typing and reading	text	one-to-one	all phones	2G
Social Media Messaging (SMM)		request-based typing and reading	text, audio, pictorial, video	one-to-many	smart phone	4G
Data Management (DaM)		data gathering	text, audio, pictorial, Global Navigation Satellite System (GNSS)	one-to-one or one-to-many	smart phone	4G
Document Management (DoM)		document sharing	text, audio, pictorial, video, GNSS	one-to-many	smart phone	4G
Spatial (Spa)		mapping	GNSS	one-to-one or one-to-many	smart phone	4G

<u>Delphi-inspired expert consensus-building study</u>

Building on the scoping study, we developed an expert consensus-building method that was inspired by the Delphi study approach. A Delphi study is defined by Delbecq as "a method for systematic solicitation for judgements on a particular topic through a set of carefully designed sequential questionnaires interspersed with summarised information and feedback of opinions derived from earlier responses" (Chu and Hwang 2008: 2828). It involves a "group facilitation technique, which is an iterative multistage process, designed to transform opinion into group consensus" (Hasson, Keeney, and McKenna 2000: 1) among experts (Benitez-Capistros, Hugé and Koedam, 2014). Benitez-Capistros *et al.* (2014) define an expert as a person who is competent as an authority on particular facts. The use of experts and avoidance of data collection in a group setting where more dominant actors' opinions may be captured enhances the content validity of the Delphi

(Hasson, Keeney and McKenna, 2000). The multiple rounds of questionnaires also increases concurrent validity of the method (Hasson, Keeney and McKenna, 2000). Because consensus building is the objective of the Delphi approach, the number of rounds is undefined and dependent on when consensus emerges or increases among participants (Benitez-Capistros, Hugé and Koedam, 2014). According to Hasson *et al.* (2000) and de Franca Doria *et al.* (2009), acceptable majorities in a Delphi-derived consensus can range from basic majority (50-59%) to low (60-69%), medium (70-79%) and high (≥ 80%) majority.

There are variations in the set-up of Delphi studies (Chu and Hwang, 2008; Allen *et al.*, 2019). Our Delphi-inspired expert consensus-building method involved two rounds, and for each round the expert panel composition varied to fit a particular purpose (see Figure 1).

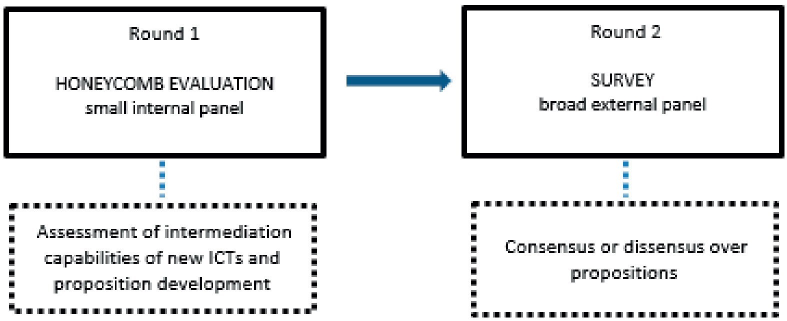


Figure 1. Summary expert consensus-building method

Round 1: Honeycomb evaluation. The first round involved the research team: four internal experts in the domain of communication and innovation sciences. The experts individually engaged in a honeycomb evaluation to assess the intermediation capabilities of the various new ICTs (see Figure 2) and ranked the different new ICTs in relation to the seven intermediation capabilities. The ranking was based on a Likert scale ranging from '0' (no capability to support) to '5' (strong capability to support). Based on the individual honeycomb evaluations, we calculated the average rank assigned by the experts to each type of technology for each type of intermediation capability.

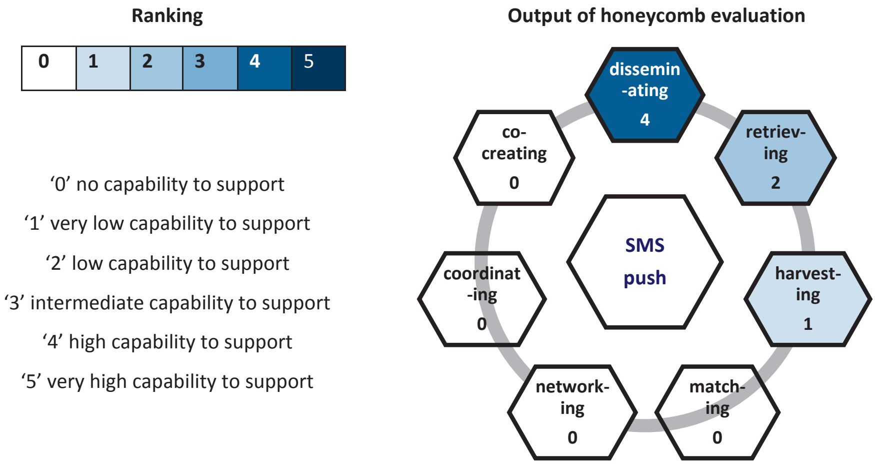


Figure 2. Example of honeycomb evaluation output

The aggregated and averaged results of the honeycomb evaluation were then presented to the internal panel to facilitate a convergence forum. The convergence forum gave the experts the opportunity to reflect on the aggregated results in relation to their individual responses, discuss areas of divergence and ultimately reach agreement on the indicative intermediation capabilities of the different new ICTs. The forum also enabled the experts to identify the significant results of the honeycomb evaluation from which propositions were developed for the second round of the expert consensus-building method (see Table 4 for the propositions).

Round 2: Survey. In the second round the propositions were packaged into a questionnaire format using a five-point Likert scale that ranged from '1' (strongly disagree) to '5' (strongly agree). The questionnaire was presented to a broader expert panel made up of Ghana-focused development informatics researchers and ICT4Ag practitioners. The questionnaire was administered via the web-based platform Google Forms to capture responses from the geographically dispersed respondents.

Potential respondents were identified from a list of invitees for a workshop that took place in April 2019 and targeted Ghanaian agricultural stakeholders[13]. The workshop was organised by a research programme (Environmental Virtual Observatories for

[13] List available upon request.

Connective Action – EVOCA) that the research team was affiliated to. Researchers and practitioners outside the workshop were also identified as potential respondents. They were identified from journal publications in SCOPUS in two steps: 1) a search using the function '(mobile technology or ICT) AND (extension or agriculture) AND (Ghana)' (available upon request) and; 2) screening of articles captured in the search to establish if they were on topic and the main authors could be invited to participate in the survey[14]. The review was conducted on SCOPUS the world's largest abstract and citation database of peer-reviewed research literature (Ballew, 2009). In total, 22 potential respondents, 13 researchers and nine ICT4Ag practitioners were identified and sent an email invitation to engage in the study. Of these invitees, 11 (five researchers and six practitioners) responded to the questionnaire in the two weeks period given for them to respond.

For round two, the descriptive statistics analysed for each proposition included the mean (*qi*), the median (*Q2*) and the frequency of ranking for each point on the Likert scale. Based on these statistics we arrived at whether there was positive (agreement) or negative (disagreement) consensus over a proposition or whether there was dissensus (varied ranking or polarisation) over a proposition. We considered three criteria to determine whether consensus was reached and the direction of the consensus for each proposition (Table 3). These were i) the position of the mean on the Likert scale (Chu and Hwang, 2008), ii) the position of the mean in relation to the median in the data distribution (Chu and Hwang, 2008), and iii) the significant percentage of participants ranking a proposition on the Likert scale – ranging from low to medium, high and very high (Hasson, Keeney and McKenna, 2000; Doria *et al.*, 2009).

[14] Search results available upon request.

Table 3. Criteria determining consensus over a proposition

	Rule	Positive consensus	Dissensus	Negative consensus
1	Position of mean on Likert scale	$qi > 3.5$	$2.5 > qi < 3.5$	$qi < 2.5$
2	Position of mean in relation to median of data distribution	$qi <$ Q2, indicating there is a right-skewed distribution	Q2 $< qi <$ Q3, indicating there is a normal distribution	$qi >$ Q2, indicating there is a left-skewed distribution
3	Position of majority ranking on Likert scale	very high consensus: ≥80% agree; high consensus: 70-79% agree; medium consensus: 60-69% agree	low consensus: 50-59% dis(agree) or <60% dis(agree)	very high consensus: ≥80% disagree; high consensus: 70-79% disagree; medium consensus: 60-69% disagree

Abbreviations: qi, mean; Q2, median; Q3, "middle" value in the second half of the rank-ordered data

Focus group discussion. In addition to the expert consensus-building method a focus group discussion was conducted to establish factors contributing to consensus and dissensus over the propositions. The focus group discussion took place during the EVOCA programme's Ghana workshop. The workshop attracted 19 participants and as part of the workshop proceedings the participants were selectively split into four working groups that each comprised all the categories of participant present at the event, which were mainly targeted users of the technologies. One of the working groups comprised five workshop participants who took part in the focus group discussion: two public extension staff members, two ICT-based Non-Governmental Organisation (NGO) representatives and a small-scale farmer. We presented the aggregated questionnaire results to the focus group, and they reflected on the results and discussed whether or not they agreed with them, and why. The discussion was recorded to facilitate thematic analysis of the factors behind propositions associated with consensus and dissensus.

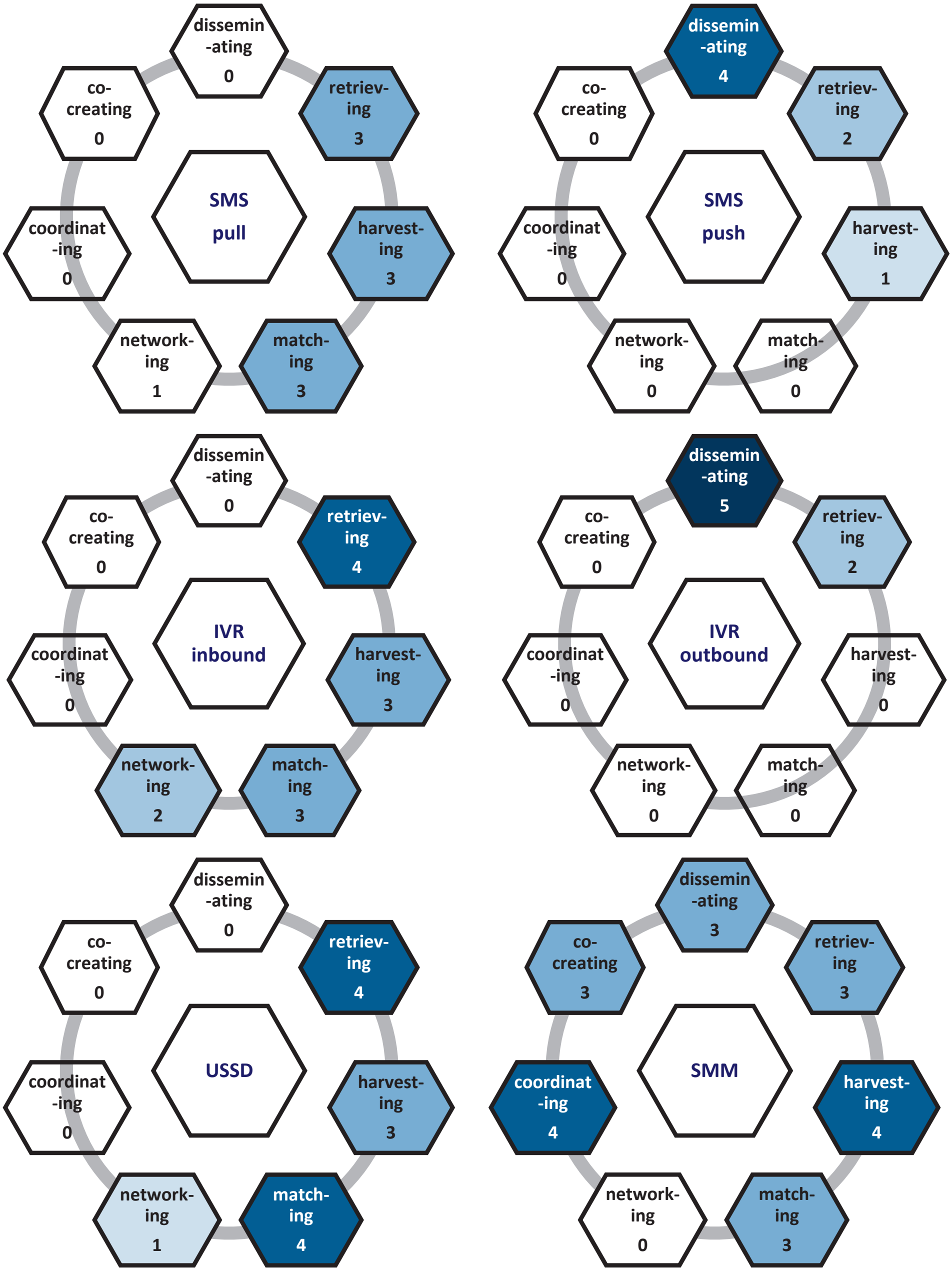
4. Findings

In this section we describe the results of the two rounds of the expert consensus method we developed to assess the intermediation capabilities of the new ICTs. We also show the type of consensus reached on the intermediation capabilities of the different new ICTs and outline factors that contributed to propositions associated with consensus and dissensus.

Indications of new ICTs' capabilities to support intermediation

The first round of the expert consensus-building method involved the honeycomb evaluation conducted by the internal expert panel. This round provided an indication of the intermediation capability (high to low) of each type of new ICT (see Figure 3).

In terms of the new ICTs with a high capability to support the intermediation capabilities (ranking > 3), the aggregated results of the honeycomb evaluation showed that IVR outbound technologies had very high capability to support disseminating, and IVR inbound technologies had high capability to support retrieval. SMS push technologies had a high capability to support disseminating, and USSD technologies had a high capability to support retrieval and to match actors. Further, the aggregated results showed that social media messaging technologies had a high capability to support information harvesting and coordinating, and an intermediate capability to support all the other intermediation capabilities, excluding networking.


SMS pull
dissemin -ating 0
retriev- ing 3
harvest- ing 3
match- ing 3
network- ing 1
coordinat -ing 0
co- creating 0
SMS push
dissemin -ating 4
retriev- ing 2
harvest- ing 1
match- ing 0
network- ing 0
coordinat -ing 0
co- creating 0
IVR inbound
dissemin -ating 0
retriev- ing 4
harvest- ing 3
match- ing 3
network- ing 2
coordinat -ing 0
co- creating 0
IVR outbound
dissemin -ating 5
retriev- ing 2
harvest- ing 0
match- ing 0
network- ing 0
coordinat -ing 0
co- creating 0
USSD
dissemin -ating 0
retriev- ing 4
harvest- ing 3
match- ing 4
network- ing 1
coordinat -ing 0
co- creating 0
SMM
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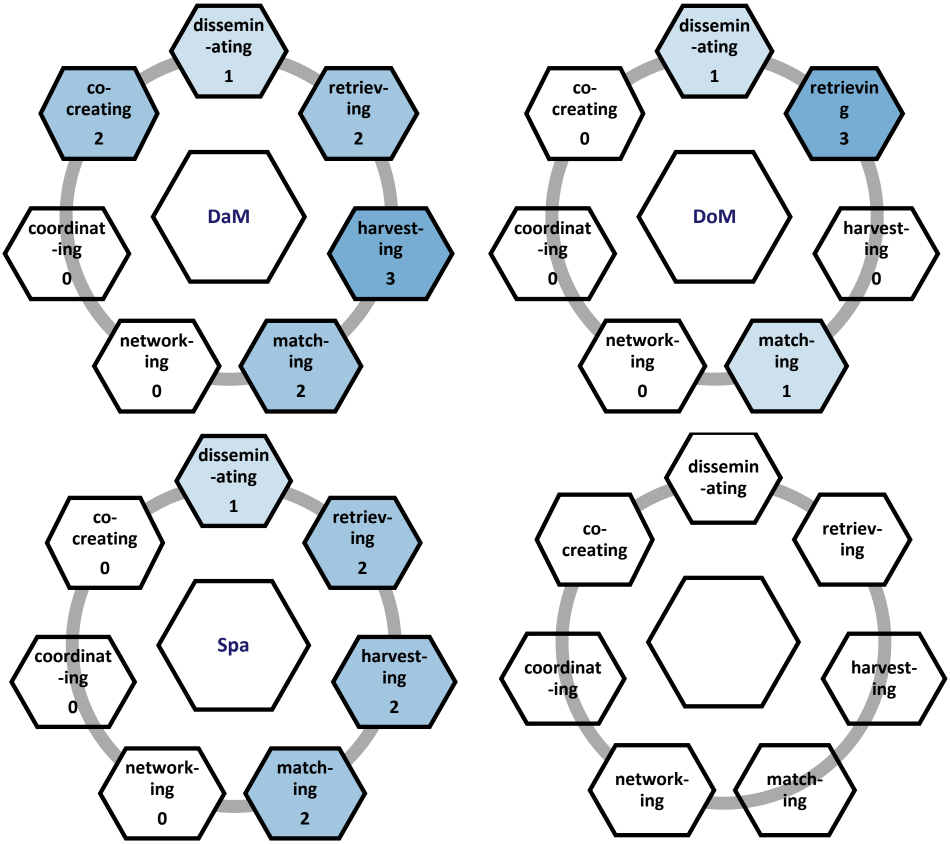


Figure 3. Aggregated results of honeycomb evaluation

In relation to the technologies with a low capability to support specific intermediation capabilities (ranking < 3), the panel of internal experts assessed that spatial (Spa) technologies generally had a low capability to support all the intermediation capabilities. The panel assessed that SMS pull technologies, DaM and DoM technologies also did not rank highly (ranking > 3) in terms of their capability to support any intermediation. The assessment also found that all new ICTs had a low capability to support networking.

The internal expert panel developed propositions based on the aggregated results (see Table 4). Sixteen out of the 22 propositions were presented to a broader set of experts as part of the second round of the consensus-building method. The reason for discounting some propositions was that they were speculative: they were either loosely based on the results of the aggregated honeycomb evaluation or they duplicated another proposition pointing to similar results.

Table 4. List of 16 propositions

Intermediation capability		Proposition
Disseminating	P1	At present IVR outbound technologies have the highest capability for disseminating information to rural farmers than the other types of technologies
	P2	At present IVR outbound technologies have higher capability than SMS push technologies for disseminating information to rural farmers
	P3	SMM technologies have high potential to facilitate disseminating information to rural farmers in the next 10 years
Harvesting	P4	At present IVR inbound technologies have the highest capability for harvesting information from rural farmers than the other types of technologies
	P5	At present IVR inbound technologies have higher capability than USSD technologies for harvesting information from rural farmers
	P6	SMM technologies have higher potential than IVR inbound technologies for harvesting information from rural farmers in the next 10 years
Retrieving	P7	At present IVR inbound technologies have the highest capability for rural farmers to retrieve information than the other types of technologies
	P8	At present USSD technologies have the highest capability for rural farmers to retrieve information than the other types of technologies
	P9	SMM technologies have high potential for rural farmers to retrieve information in the next 10 years
Matching	P10	At present USSD technologies have the highest capability to match rural farmers to services than the other types of technologies
	P11	At present IVR inbound technologies have higher capability than USSD technologies to match rural farmers to services
Networking	P12	At present all the types of technologies have low capability to facilitate networking between rural farmers and other agricultural stakeholders
	P13	SMM technologies have high potential to facilitate networking between rural farmers and other agricultural stakeholders in the next 10 years
Coordinating	P14	At present SMM technologies have the highest capability to facilitate coordination between rural farmers and other agricultural stakeholders than the other types of technologies
Co-creating	P15	At present SMM technologies have intermediate capability to facilitate co-creating among rural farmers and other agricultural stakeholders
	P16	SMM technologies have high potential to facilitate co-creating among rural farmers and other agricultural stakeholders in the next 10 years

The propositions were also developed within a specific context to help the panel of external experts in assessing which new ICTs are best suited to facilitate certain communication and networking functions in extension activities. The internal panel therefore required the external panel to envision themselves as district extension staff tasked by the "Ministry of Agriculture – Headquarters" to ground truth a preliminary assessment of the current capability and future potential of specific new ICTs to improve extension service delivery involving rural farmers.

Experts' consensus and dissensus over propositions

The results of round two showed that half of the 16 propositions presented to experts of the external panel were marked by consensus and the remainder marked by dissensus. Additionally, the questionnaire results showed there was no negative consensus among experts over any of the propositions.

In terms of the propositions associated with positive consensus, there was consensus among experts that IVR outbound technologies had the highest capability for disseminating information to farmers (P1). Experts also agreed that IVR inbound technologies had the highest capability to harvest information from farmers (P4) and for farmers to retrieve information (P7) as well as link them to advice and services (P11). Further social media messaging technologies were found to have the highest capability to support coordination among agricultural stakeholders (P14), including farmers, but had an intermediate capability score to facilitate co-creation among these stakeholders (P15).

Table 5. Propositions associated with positive consensus

Type of new ICT		Proposition	Criterion for positive consensus		
			Criteria 1	Criteria 2	Criteria 3
			***qi* > 3.5**	***qi* < *Q2***	**(strongly) Agree %**
IVR inbound	P4	At present IVR inbound technologies have the highest capability for harvesting information from rural farmers than the other types of technologies	3.55 > 3.5	3.55 < 4	63.64
	P7	At present IVR inbound technologies have the highest capability for rural farmers to retrieve information than the other types of technologies	3.73 > 3.5	3.73 < 4	72.73
	P11	At present IVR inbound technologies have higher capability than USSD technologies to match rural farmers to services	3.73 > 3.5	37.3 < 4	81.82
IVR outbound	P1	At present IVR outbound technologies have the highest capability for disseminating information to rural farmers than the other types of technologies	3.64 > 3.5	3.64 < 4	72.73
	P2	At present IVR outbound technologies have higher capability than SMS push technologies for disseminating information to rural farmers	3.73 > 3.5	3.73 < 4	72.73
SMM	P14	At present SMM technologies have the highest capability to facilitate coordination between rural farmers and other agricultural stakeholders than the other types of technologies	3.82 > 3.5	3.82 < 4	72.73
	P15	At present SMM technologies have intermediate capability to facilitate co-creating among rural farmers and other agricultural stakeholders	3.82 > 3.5	3.82 < 4	90.91

Abbreviations: qi, mean; Q2, median

Experts did not reach consensus on eight of the 16 propositions. There was no clarity on whether experts agreed or disagreed on these propositions, meaning the propositions failed to meet all three criteria. More importantly, the propositions showed that experts had varied views on the potential of social media messaging technologies to facilitate disseminating, harvesting and retrieving of information targeted at or involving farmers in the next 10 years (see P3, P6 and P9 in Table 6). Experts also had varied views on the future potential of social media messaging technologies to support networking and co-creation among agricultural stakeholders (see P13 and P16).

Table 6. Propositions associated with dissensus

Type of new ICT		Proposition	Criteria for dissensus					
			Criterion 1	Criterion 2		Criterion 3		
			2.5 > q*i* < 3.5	*Q2* < qi	qi < Q3	(strongly) Disagree %	Neutral %	(strongly) Agree %
IVR inbound	P5	At present IVR inbound technologies have higher capability than USSD technologies for harvesting information from rural farmers	2.5 > 3.36 < 3.5	4 > 3.36	3.36 < 4	18.18	27.27	54.55
USSD	P8	At present USSD technologies have the highest capability for rural farmers to retrieve information than the other types of technologies	2.5 > 2.73 < 3.5	2 < 2.73	2.73 < 4	54.55	9.09	36.36
	P10	At present USSD technologies have the highest capability to match rural farmers to services than the other types of technologies	2.5 > 2.73 < 3.5	2 < 2.73	2.73 < 4	54.55	9.09	36.36
SMM	P3	SMM technologies have high potential to facilitate the dissemination of information to rural farmers in the next 10 years	2.5 > 3 < 3.5	3 ≥ 3.00	3.00 < 3.5	36.36	36.36	27.27
	P6	SMM technologies have higher potential than IVR inbound technologies for harvesting information from rural farmers in the next 10 years	2.5 > 3.18 < 3.5	3 < 3.18	3.18 < 4	18.18	36.36	45.45
	P9	SMM technologies have high potential for rural farmers to retrieve information in the next 10 years	2.5 > 3.18 < 3.5	4 > 3.18	3.18 < 4	36.36	9.09	54.55
	P13	SMM technologies have high potential to facilitate networking between rural farmers and other agricultural stakeholders in the next 10 years	2.5 > 3.27 < 3.5	3 < 3.27	3.27 < 4	36.36	18.18	45.45
	P16	SMM technologies have high potential to facilitate co-creating among rural farmers and other agricultural stakeholders in the next 10 years	2.5 > 3.55 > 3.5	4 > 3.55	3.55 < 4	18.18	27.27	54.55
All	P12	At present all the types of technologies have low capability to facilitate networking between rural farmers and other agricultural stakeholders	2.5 > 2.55 < 3.5	2 < 2.73	2.55 < 4	54.55	0.00	45.45

Abbreviations: qi, mean; Q2, median; Q3, "middle" value in the second half of the rank-ordered data

The propositions marked by dissensus showed that experts had polarised views on the current capability of all the technologies to support networking among rural farmers and other agricultural stakeholders (P12). There was also variation in the experts' ranking of the current capability of USSD technologies to facilitate information retrieval by rural farmers or for them to access advice (P8) and other agricultural services (P10).

Factors contributing to consensus and dissensus over propositions

The focus group discussion revealed factors contributing to consensus and dissensus among experts over particular propositions. In relation to the propositions associated with consensus, the focus group revealed two factors contributing to experts' agreement on the high capabilities of IVR inbound and outbound technologies as described above. One factor was that IVR technologies operated on basic and feature mobile phones that were accessible to farmers. The second factor was that IVR technologies, unlike SMS or USSD technologies, generated audio as opposed to textual content. This made them more compatible with farmers' lower literacy levels. Discussing the factors, a middle manager of an ICT-based NGO stated: "*At the moment, IVR is known widely and used because it is programmed in a language that the end user understands. It does not involve text messages and is available on any kind of phone."*

We also established the reasons behind experts' agreement on the high capability of social media technologies to support coordination among agricultural stakeholders at present. One reason behind the consensus was that social media messaging technologies, in comparison to the other new ICTs, facilitated interaction and feedback with the most ease and immediacy. Another reason was that most farmer group leaders who connect farmers to service providers (e.g., extension agents) are currently able to use these technologies due to the fact that these farmers have a high literacy level and greater financial means than the average farmers to access cheap smartphones that have infiltrated the Ghanaian market. Discussing the reasons behind the experts' consensus on the capability of social media messaging technologies mentioned above, a senior manager of a commercial new ICTs platform said: *"Social media applications are the medium of swift information exchange and facilitation at the moment*" and *"[...]*

because of the infiltration of cheaper smartphones [...] most lead farmers have this platform [WhatsApp], which makes them easily facilitate meetings and solicit for assistance and information from each actor when need be." We also established that experts' positive consensus on the intermediate capability of social media messaging technologies to facilitate co-creation among farmers and other agricultural stakeholders was due to the capability of social media messaging technologies to facilitate interaction easily and speedily. However, social media messaging technologies were not considered to have a very high capability to support co-creation. On this point, experts took into consideration that the average farmer currently lacked access to smartphones that supported these technologies. They also considered how limited literacy affected farmers' ability to engage intensively (discuss) on or with social media messaging technologies. In relation to these findings, some experts pointed to alternative communication mechanisms such as face-to-face meetings currently being more useful for facilitating co-creation.

Where propositions were associated with dissensus, we established the factors behind experts' varied views. Specifically, we established the factors behind experts' varied views on social media messaging technologies capabilities to support disseminating, harvesting and information retrieval involving and/or targeting farmers in the future. The variation was due to different levels of optimism among experts on rural farmers' access to smartphones in the next 10 years. The more optimistic experts were confident about farmers' increased access to mobiles that supported social media technologies and the increase in farmers' literacy. An example of the less optimistic view was expressed by a senior manager from a commercial new ICTs platform who said: *"[...] right now it has been tagged that you need a lot of money to get a smartphone [by farmers], let alone the [poor] internet connectivity within rural areas."* A middle manager of an ICT-based NGO added another less optimistic view: *"I am not even looking at the costs of bundles. Let's look at how old the active rural farmers will be and what their educational level will be. When you talk about the farmers now, most of them are within the range of 30-35 and they will be 40-50 in the next 10 years. In the next 10 years we* *will be dealing with the same crop of farmers. Therefore, I do not expect to see significant changes in relation to their adoption of such new technology [SMM technologies]."* While a middle management staff member at the Directorate of Agricultural and Extension Services countered the preceding statement, stating: *"[...] but it [the situation] is not static, maybe in 10 years the youth will become more active farmers and be more inclined to use WhatsApp."*

5. Analysis and discussion

In this section we discuss the results of the research by comparing the findings of the honeycomb evaluation undertaken by the panel of internal experts (round 1) and the findings of the questionnaire administered to the panel of broader experts (round 2). We identify instances of alignment and misalignment in the experts' rankings of the intermediation capabilities of the new ICTs between the two rounds and explain these instances with reasoning provided in the focus group discussion. We also point out opportunities that emerge from the expert consensus between the two rounds for specific new ICTs to support certain communication and networking functions required to facilitate AIS-based extension service delivery. Finally, this section highlights areas for future research and reflects on the Delphi-inspired research design.

In the results section of this study we see that rankings of the intermediation capabilities of new ICTs between the first and second round of the study aligned in certain instances. For the first and second rounds experts agree that IVR inbound and outbound technologies currently have a high capability to support action-oriented communication functions targeted at rural farmers. These communication functions – disseminating, retrieving, harvesting and matching – do not require intensive interaction. Experts in both rounds also indicated that social media messaging technologies currently have a high capability to support coordination between farmers and other agricultural stakeholders.

In relation to these observations we see that experts reached positive consensus over certain propositions and the factors behind the consensus are clear. More specifically, as other authors have found IVR technology to have huge potential to reach farmers directly (McNamara *et al.*, 2012; Dittoh, Van Aart and De Boer, 2013), it is clear that scientists, researchers and practitioners view IVR technologies as being appropriate for supporting action-oriented communication involving rural communities. This is because these technologies are audio-based to fit rural farmers' literacy levels and because they are supported by mobile phones that most rural farmers can access (basic and feature phones) (Schmidt *et al.*, 2010; Dittoh, Van Aart and De Boer, 2013; Munthali *et al.*, 2018). It is also clear that various experts see opportunities for social media messaging technologies to support the coordination of activities involving farmers and other agricultural stakeholders – as suggested by (Fabregas, Kremer and Schilbach, 2019), but specifically between farmers and traders. This consensus is due to the ability of social media messaging technologies to provide speedy information dissemination and immediate feedback (Bennett and Segerberg, 2012; Stevens *et al.*, 2016). Beyond the technological aspect of social media messaging technologies, we also see that they can support coordination in extension systems as they align with the current extension service delivery structure in which human intermediation remains relevant (Bailur and Masiero, 2012). Farmer group leaders – positioned as intermediaries between farmer groups and other agricultural stakeholders – are often more educated and financially solvent than other farmers. Moreover, they may have the means to access a smartphone and use these technologies for their intermediary role. However, we also see that the capacity of social media messaging technologies to create multi-actor discursive spaces is underutilised. This is because farmer group leaders confine their use to speedier linear communication with service providers to support aspects of coordination in their intermediary role – e.g., organising meetings (as Martin and Hall (2011) also report) as opposed to multi-stakeholder problem solving.

We also identified instances of misalignment in the experts' ranking of the intermediation capabilities of new ICTs. In round one, the internal panel of communication and innovation scientists was of the view that alongside IVR technologies, SMS pull technologies and USSD technologies also have a high capability to support disseminating and retrieving information. The internal panel also felt that social media messaging technologies were more capable than IVR technologies when it comes to supporting information harvesting. The internal panel also agreed that USSD technologies have more potential than IVR technologies to match farmers to advice and services. In contrast, the panel in round two strongly agreed that IVR technologies have the highest capability regarding the functions matching as well as for harvesting. Based on the focus group discussion, it appears that IVR technologies are best suited to support action-oriented communication functions directed at farmers as they support audio content and operate on basic mobile phones (Aker, Ghosh and Burrell, 2016).

Beyond these instances of misalignment in experts' rankings of the intermediation capabilities of new ICTs between the first and second round, there were also propositions on which development informatics researchers and ICT4Ag practitioners did not reach consensus. There was also no clarity on which new ICTs are best suited to support certain intermediation capabilities. Specifically, it was not clear which technologies can currently support networking and co-creating. This was because the propositions related to the capability of the technologies to support networking were marked by varying views (dissensus) and the propositions related to the capability of the technologies to support co-creation had an intermediate ranking. This is in spite of the fact that there were indications that social media messaging technologies could support other functions that require multi-actor engagement (i.e. coordinating). These findings on the low capability of the social media technologies to support networking and co-creation contradict the EU-focused Hansen study (Hansen *et al.*, 2014). These mixed findings point to two issues that require consideration. The first issue is that at present these intermediation capabilities could best be supported by alternative communication mechanisms, such as conventional face-to-face meetings that remain relevant in the functioning of agricultural systems for intensive interaction (Materia, Giarè and Klerkx, 2015; Leeuwis *et al.*, 2018), and have been cited as trusted social networking methods in the African context (Molony, 2006) that are more appropriate modes of interaction considering farmers, and other rural agricultural actors, literacy and types of mobile phones (Dittoh, Van Aart and De Boer, 2013). Secondly, the findings point to the need for research to understand the role of social media messaging technologies in supporting intermediation capabilities that require multi-actor discursive spaces. Experts have mixed views on social media messaging technologies, which they see as having a high capability to support coordination but not networking and co-creation. At the same time, it is unclear which technologies or communication mechanisms have a high capability to support networking and co-creation. This justifies the need for further research.

Further research could also shed light on the practical application and role of the new ICTs identified in supporting broader (AIS-based) extension service delivery. This study has provided evidence of opportunities for new ICTs to improve information sharing and interaction in agricultural systems that need to be tailored to specific needs, situations and contexts. Therefore, the study cannot predict which new ICTs can successfully enhance specific AIS-based extension activities, though the study reveals positive and negative indicators for some possibilities. The positive indicators are that IVR technologies may support the broadcasting of knowledge and early warning alerts to rural stakeholders as part of coordination efforts in problem solving, and enable them to retrieve knowledge and other information (weather, prices) (Aker, Ghosh and Burrell, 2016). These applications can also match farmers with service providers and suppliers, as well as allow for the harvesting of information from farmers and other rural stakeholders (viamo, 2020) as inputs for systemic problem diagnosis. The negative indicators are that the new ICTs identified may not support stakeholder engagement, including rural farmers, for collaborative problem diagnosis and problem solving or combining knowledge.

Finally, we want to reflect on the validity of the expert consensus-building method that we applied in comparison to a Delphi study. In line with Delphi's general principles, our expert consensus-building method involved multiple rounds of individual responses by experts (Hasson, Keeney and McKenna, 2000). However, our approach deviated from a standard Delphi as it did not require that the same experts be involved in the two rounds to foster concurrent validity. For our method, each set of experts was engaged for the distinct purpose of each round, such that we fostered concurrent validity by aggregating the views of a small group of experts in the first round and then presenting these views to a broader expert panel in a following round to be affirmed or refuted. We developed this approach to validate the views of the internal expert panel (communication and innovation experts) with the views of experts that were more engaged with the Ghanaian context, and respond to the challenge of establishing consensus on new ICTs' potential amongst a wide range of experts. A Delphi study can be considered valid based on the input of 16 to 60 experts (Hasson, Keeney and McKenna, 2000); however, lower numbers of experts have been reported in other Delphi studies (Benitez-Capistros, Hugé and Koedam, 2014). Therefore, in this study the 15 experts that assessed new ICTs' opportunities for intermediation (in round 1 and 2) is not a misnormer and still provides valuable insights based on the study design fostering concurrence validity.

6. Conclusion

The starting point of this study is that new ICTs have the capability to respond to information and interaction related problems hampering productivity growth in Ghana's agricultural sector, and simultaneously to improve extension service delivery. Through a total of 15 varied experts in two rounds, we assessed the capability of nine types of new ICTs operating in Ghana to support specific communication and networking functions (intermediation capabilities) that are required to facilitate AIS-based extension service delivery.

Overall, we established that experts see opportunities for new ICTs, specifically IVR technologies, to support linear communication when a significant number of AIS-based extension service delivery activities require multi-actor engagement and interaction. This was due to these technologies being easily accessible to the average farmers. For intermediation capabilities that require more intense interaction among agricultural stakeholders (networking, coordinating, co-creating) there was evidence of dissensus among experts over the capabilities of social media messaging technologies – the only technology enabling multi-actor engagement – to support these functions and type of interaction. The dissensus was due to these technologies being inaccessible to most farmers. Additionally, the study revealed that social media messaging technologies can support coordinating to a certain extent, but there was no consensus among experts on which new ICTs can currently support networking or co-creating involving farmers and other agricultural stakeholders.

Appendices

Appendix 1. New Information and Communication Technology platform inventory

Platform description and services	Constituent new ICTs
E-agriculture www.e-agriculture.gov.gh Direct to farmer: ○ E-farm – farmer audio agricultural information library ○ Call centre – access to subject matter specialists ○ Farmer engagement platform Extension providers: ○ Web portal - repository of value chain actors, service providers and stakeholders; and dissimenation of new technologies and agrictural current affairs ○ E-extension - to collect farmers geo, bio and crop data; and digitise field and pest and disease monitoring reports ○ E-subsidy – electronic registration of farmers with GPS integration and unique ID generator to faciliate efficient fertiliser subsidy distribution	IVR inbound DaM SMM Spa
SmartEX https://grameenfoundation.org/resource/appraisal-agro-tech-smart-extension-model-ghana-payment-options-and-challenges-ict-enabled Traders and outgrower schemes: ○ Farmer discovery and enrolment with GPS intergration - farmer registration, and records of farm practices and credit activities ○ Farmer management - protocol of agent routine tied to key crop growth stages of farm operations to deliver timely support ○ Value chain and service linkages - access to agribusiness service providers and value chain actors ○ Information and knowledge repository: collection of technical information on crop production, processing and marketing ○ Monitoring, evaluation and learning - analysed farmer data to learn their needs and requirements, and track their performance. Additonally, tracking of agents activities through a dashboard	DaM DoM Spa
ESOKO https://www.esoko.com/ Direct to farmer: ○ Market prices and weather ○ Agronomic tips ○ Buy and sell marketplace – reach agent through call centre, sorted by location, commodity, quantity and grade, and place offer that is SMS to buyer(s) ○ Call centre - access to agri-extension experts, market prices and weather forecast Extension providers: ○ Knowledge plus - knowledge respository templates ○ Insyts - digitised reporting templates and real-time analytics ○ Real-time message alerts Business to business - Government institutions, NGOs, social projects: ○ Buy and sell marketplace - reach agent through call centre and place offer that is sent to farmers via SMS ○ Targeted marketing messages, announcements and alerts ○ Polling and feedback ○ Knowledge respository templates	SMS push IVR inbound IVR outboud SMS pull DoM DaM Spa

○ Digitised reporting templates	
ImageAd/MFARMS http://www.mfarms.org/solutions/ Direct to farmers: ○ Commodity and agri-input prices ○ Presision agriculture ○ M-Xtension - provides good agricultural practices ○ Farmer to market – facilitates linkage between farmers, and input and ouput markets through human agents Business to service providers - extension providers, agro-dealers, seed producer, off takers: ○ Field agent management - agent database development and service provision/activity tracking ○ Farm-level monitoring - farmer database development with farm mapping and farming activity Business to business - NGOs, FBOs, agro-dealers, logistics or warehousing companies, aggregators, processing companies: ○ Targeted advertising and messaging with instant delivery reports and dashboards ○ Targeted short surveys and polling for organisations (NGO, input suppliers e.t.c) to track their performance ○ Warehousing, and stock and sales tracking systems ○ Loan management systems ○ Fleet management systems	SMS pull SMS push DaM IVR outbound Spa
Plantwise https://www.plantwise.org/KnowledgeBank/Home.aspx Plant health and protection institutions and extension providers: ○ Plantwise factsheet - repository of crop based pest and disease management advice ○ Plantwise data collector - digitised "prescription form" to record farmer's biodata and plant health problem diagnosis' and prescriptions ○ Plantwise plant doctors platform - pest and disease alert and knowledge sharing platform	DoM DaM SMM Spa
Scientific animations without borders (SAWBO) https://sawbo-animations.org/home/ Extension providers: ○ Video library - extension information accessible as 2D, 2.5D and 3D animations with voice overlay	DoM
Complete farmer https://www.completefarmer.com/ Farmers: ○ Builds and manages farms for individuals and provides real-time monitoring sensor and drone feed data through an online dashboard	DaM Spa
Qualitrace http://qualitracegh.com/ Input buyers: ○ Anti-counterfeiting solution – enabling input buyers to confirm the authenticity of farm inputs by dialling the barcode of the purchased product through a USSD application prompt	USSD

AgroInnova - Akokotakra http://akokotakra.com/app Farmers: ○ Mobile and web-based management system that enables poultry farmers to record, monitor, and track their operations	DaM Spa
Ghalani https://ghalani.com/#/ Farmers and agri-businesses: ○ Eletronic management of farm records	DaM Spa
Tro tro tractor http://www.trotrotractor.com/ Farmers: ○ land preparation, planting, spraying, threshing, shelling and transportation services requested	USSD IVR inbound
MTN ISKA http://www.ignitia.se/ Direct to farmer: ○ Localition specific weather updates - daily, monthly and seasonal rain forecasts	SMS push
Farmerline http://farmerline.co/ Direct to farmer: ○ Weather forecasts ○ Agronomy tips – customised to location (GPS) and production stage ○ Market prices ○ Market place - access to farm inputs, water, solar energy, and financial services – aggregated demand for inputs (type and location) for Farmerline to supply goods Business to business - off takers, input dealers, global food companies, Government institutions, research organisations, NGOs, financial institutions: ○ Polling and short surveys ○ Engagement platform – send customised bulk messages ○ Data collection, management and analytics – including farm-level monitoring, field monitoring, farmer profiling, and farm mapping through delivery ○ Building credit history to access advanced financial services through a mobile money payment platform ○ Mobile payments and savings platform ○ Plant health and vegetation change monitoring using satellites	SMS push USSD IVR inbound IVR outbound DaM Spa
MoringaConnect Extension providers: ○ Inhouse electronic data collection form and analytics, paired with GIS mapping system to monitor plant growth and trace moringa from planting to processing	DaM Spa
MTN mobile money (e-wallet) https://www.mtn.com.gh/personal/mobile-money/about-mobile-money Direct to farmer: Mobile banking - payments, loans and savings, micro insurance Business to business: ○ Mobile banking - payments, loans and savings, micro insurance	USSD

Votomobile www.votomobile.org https://viamo.io/services/information-sharing/ Direct to farmer: ○ Mass-messaging on good agricultural practices ○ Mass-messaging on price information and weather forecasts Business to business: ○ Mobile data collection - track field activities, monitor disaster response, report on stock levels, measure attendance, follow-up on referrals ○ Polling priorities, needs and feedback from farmers or stakeholders ○ Mass-messaging to advertise and inform farmers or stakeholders	SMS push USSD IVR outbound DaM Spa
Farm Radio http://www.farmradio.org/ Direct to farmers: ○ Access to messages, alerts, radio programme segments, and abiility to leave audio message ○ Commodity based farm tips Radio stations and businesses: ○ Conduct surveys using audio messages ○ Farmer feedback on radio broadcasts ○ Uliza polling – voting by beeping/flashing to two phone numbers desginated for a 'yes' or 'no' response – liseners use basic phone to vote on IVR system, view results and recording. Number annouced on radio station – call number and answer with number or record, flash call back ○ Automated callback or SMS with market information	IVR outbound IVR inbound SMS pull SMS push
Manobi http://www.manobi.net/en/index.php?M=56& Direct to farmer: ○ Listing and precise georeferencing of farming plots ○ Marketplace (offers and demands) between large and small producers, and traders, buyers and importers ○ Real-time monitoring of prices of agricultural products in wholesale and retail markets ○ Epidemic alerts, weather forecast, calculation yields Extension providers: ○ Data collection – digitised monitoring data on agricultural operations during crop production Business to business: ○ Collaborative platforms – facilitate multi-actor engagement for cooperatives, associations, etc.. ○ Data collection – surveys and advanced monitoring and evaluation ○ Inventory management system	DaM SMS push Spa
Hershey's CocoaLink https://cocobod.gh/coco_link.php Direct to farmer: ○ Farmers can send in (photo) inquiries directly to experts and other farmers ○ Farmers receive weekly messages (farming practices, farm safety, child labour, crop disease prevention, post-harvest production and marketing) from COCOBOD ○ Digital access to educational content – planting tips, correct input usage and descriptions of best practices	SMS push DaM DoM Spa IVR outbound

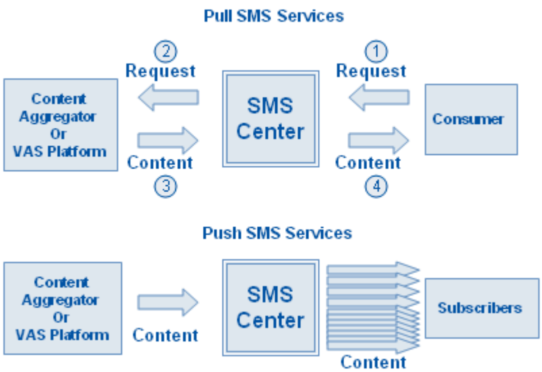
Extension providers: o Electronic farmer data collection	
Farmforce **http://farmforce.com/** Out-grower schemes and NGO (groups or cooperatives or exporters) : - agent o Crop growth stage, pest scouting and monitoring results, bio-data, input usage and recording or estimating harvests / yields o Manage micro-loans and perform audits o Historicla information of where crop came from at supermarket levelTracking specific produce through the value chain o Bulk messaging to field staff and farmers o Electronic (field audit) survey	 SMS push DaM Spa
Freedom fone **http://booki.flossmanuals.net/freedom-fone/what-does-freedom-fone-do** Direct to farmer: o Sharing audio information with an audience - educational dramas, market information, recorded radio programmes or short news items Businesses: o Polling - enable audience to vote on an issue using their phone o Collect SMS feedback from audience - updates about specific news events, alerts or time critical information o Get your audience to leave audio messages to share their opinion on a particular topic or make reports in their own language (IVR inbound)	 SMS pull IVR outbound IVR inbound
Savanet **http://savanet-gh.org/?q=content/what-we-do** Direct to farmers: o Farmer group linkage to extension agents, ICT professional and researchers e.t.c (conference using mobile phone and portable external speakers) o Farm area mapping and analysis o Soil testing and analysis o Record keeping o Market access and weather forecasts	 Spa DaM
Syecomp **http://syecomp.com/projects-and-services/** Business to business and NGOs: o Farmland surveying o Farm mapping o Certification support and traceability	 Spa
Farmer Helpline Direct to farmers: o Weather forecasts, agronomic tips, financial tips and funding news (IVR inbound and SMM)	 IVR inbound SMM
Geotraceability **http://geotraceability.com/products-and-services/** Extension service provider: o Tailored business plans - processing field data and agronomic practices to generate appropriate recommendations for business plans Business to business or project: o Survey design tools and electronic data collection	 SMS push DaM Spa

○ Mapping production areas and relevant infrastructure ○ Treacibility tools ○ Tailored messages to targeted groups of producers ○ Interoperating data from multiple platforms and data sources onto one database ○ Cloud-based data management structure to securely store and recall unlimited amounts of data	
Anitrack and Animat https://www.anitrackgh.com/ Direct to farmers: ○ Anitrack: a web application that enables animal identification, and health tracking of livestock using sensors (wearable tracking devices around the neck of the animal) to monitor vitals such as temperature and report when necessary sensors go off - sending a message to a registered veterinarian ○ Animat : a website for livestock producers to place their stock online for buyers to see	SMS push DaM Spa

Appendix 2. Types of new Information and Communication Technologies

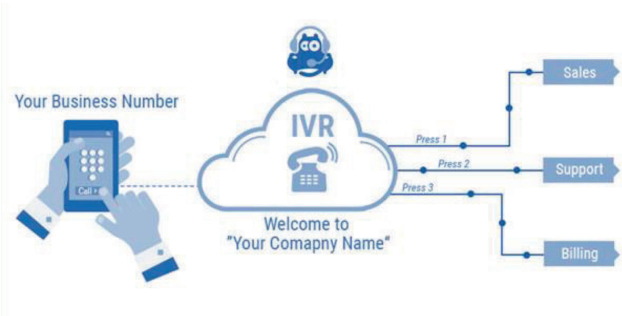
<table>
<tr><th>Type of new ICT</th><th>Description</th></tr>
<tr><td>Short Messaging Service (SMS)</td><td>These applications fall into two categories, SMS push and pull applications. Pull (or incoming) SMS messages, this is any content sent to a subscriber upon request on a one-time basis. The subscriber sends a request, a text message to a specific phone number (e.g., send ‘MAIZ PLSK’ to ‘4455’ for maize prices) belonging to a service provider or organisation, and receives a response. Push messages on the other hand are text messages and mobile alerts that a service provider or organisations sends out to a registered customer's or receiver’s mobile phone without the customer initiating a request for the information.

Front-end engagement with system/mobile device: SMS via basic, feature or android phone
Internet connectivity: not required
System workflow: see below



Source: https://www.medianama.com/2008/10/223-teething-troubles-for-googles-sms-channels-in-india-battle-at-the-smsc/push-sms-services-chart/</td></tr>
<tr><td>Interactive Voice Response (IVR)</td><td>IVR is a technology that allows a computer to interact with humans using voice input via a keypad (calling). IVR systems can respond with pre-recorded audio to provide the caller information or further direct users on how to proceed (e.g., dial a number to listen to specific information, record a message or talk to an agent). These are inbound IVR capabilities, whilst outbound IVR capabilities facilitate the distribution of communications to multiple customers through automated voice calls. Outbound IVR capabilities are used to call multiple people simultaneously and then enable them to listen to a pre-recorded audio message.

Front-end engagement with system/mobile device: calling standard phone number via basic, feature or android phone
Internet connectivity: not required
System workflow: see below</td></tr>
</table>

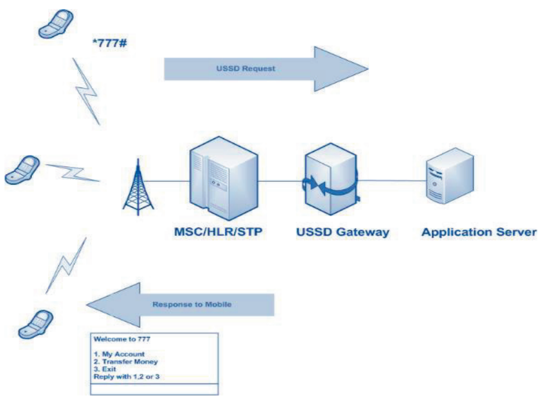


Source: https://callhippo.com/blog/intelligent-ivr-system

Unstructured Supplementary Service Data (USSD)

Similar to SMS applications USSD is a messaging function on mobile phones used to query information and trigger services. However, unlike regular text messages, USSD messages are initiated through "calling". Therefore, in order to query a USSD information system the primary user calls a short code (e.g., *115#), after which a menu appears on their mobile screen, and then the user is required to press a number from the menu that corresponds to the action they desire to take. An example of the application of USSD are the protocols mobile phone subscribers use to load phone credit.

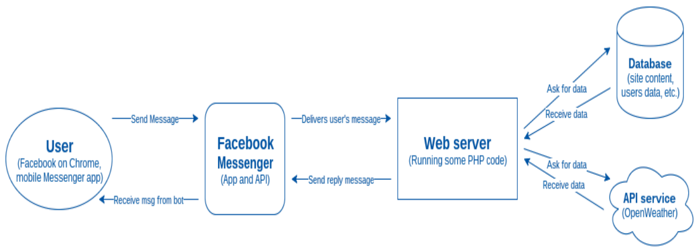
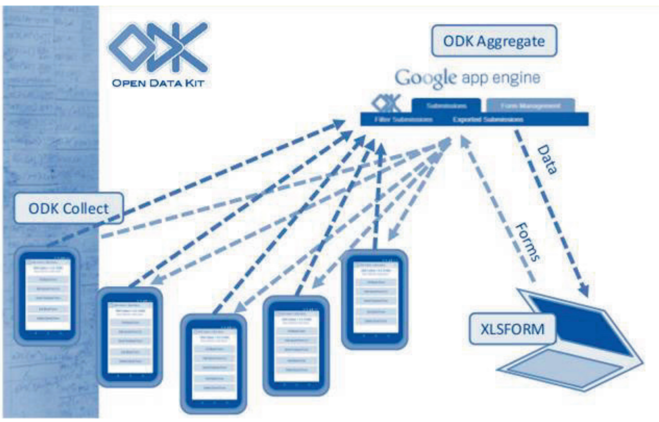
Front-end engagement with system /mobile device: dialling short code via basic, feature or android phone
Internet connectivity: not required
System workflow: see below

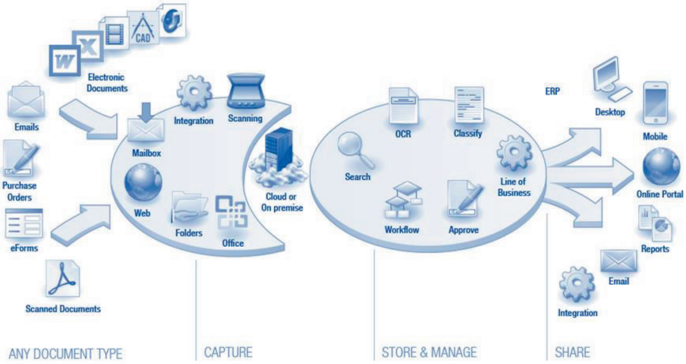


Source: http://www.edwardpopoola.com/category/technology-deep-dive/

Social media messaging (SMM)

These are instant messaging services run on an android system. They allow users to exchange text, image, video and audio messages from one user to another or in a group (e.g., WhatsApp). This technology builds on and extends the core capability of Multimedia Messaging Service (MMS) technology that enables the sending of messages than do not exceed 160 characters in length, 40 seconds of video and audio recordings and one image.

	Front-end engagement with system/mobile device: text; audio; pictorial; video messaging or GNSS location sharing via android phone Internet connectivity: required System workflow: see below  Source: https://chatbotnewsdaily.com/developing-your-facebook-messenger-chatbot-in-php-e06918da1685
Data Management (DaM)	These are tools which help organisations collect, field, and manage data more efficiently than paper-based systems. They provide solutions for users to: build a data collection form or survey with GNSS locations and images; collect data on a mobile device and send it to a server; and aggregate the collected data on a server (e.g., google drive) and extract it in useful formats. Front-end engagement with system/mobile device: access data electronic data form to input data via android phone Internet connectivity: required to sync data to central (aggregated) database, but offline data input supported System workflow: see below  Source: https://www.slideshare.net/fieldwork_ntf/revisiting-open-data-kit-for-fieldwork-teachingefl-workshop-8th-september-2017
Document Management (DoM)	This is a computer-based system used to store documents in digital form, track and manage them. Front-end engagement with system/mobile device: open digital document repository (multiple organised files) on an android phone Internet connectivity: not required System workflow: see below

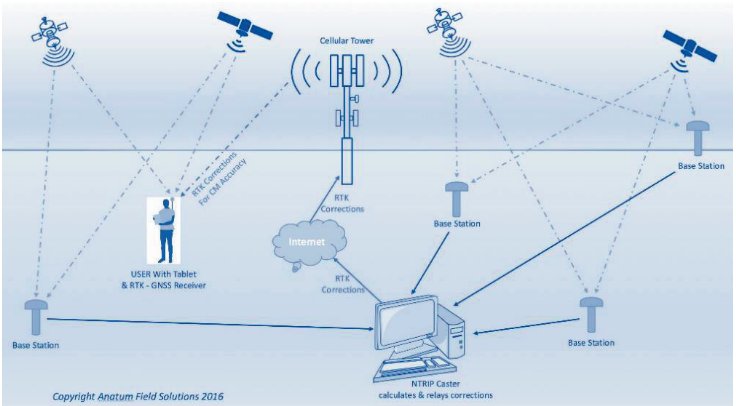


Source: https://www.orsgroup.com/news/document-management/document-management-systems-explained

Spatial (Spa)

These types of applications enable the creation of an electronic field map, by pinning coordinates and automatically connecting them to create a geo-reference shape on a base map. Additionally, such applications enable the calculation of the area of the geo-referenced shape. However, these applications are often embedded in other application such as DaM applications.

Front-end engagement with system/mobile device: GNSS receiver to facilitate pinning of coordinates on an android phone
Internet connectivity: required
System workflow: see below



Source: https://www.anatumfieldsolutions.com/RTK-GPS-Explained_b_6.html

Abbreviations: VAS, Value Applications Server; MSC, Mobile Switching Centre; STP, Signalling Transfer Point; HLR, Home Location Register; API, Application Programme Interface; ODK, Open Data Kit; PHP, Hypertext Pre-processor; XLS form, EXCEL Spreadsheet; OCR, Optical Character Reader; ERP, Enterprise Resource Planning; GNSS, Global Navigation Satellite System; CM accuracy, Relative Accuracy; RKT, Real-time kinematic; NTRIP, Networked Transport of RTCM via Internet Protocol.

3

Chapter 3

Innovation intermediation in a digital age. Comparing public and private new ICT platforms for agricultural extension in Ghana

Nyamwaya Munthali, Cees Leeuwis, Annemarie van Paassen, Rico Lie, Richard Asare, Ron van Lammeren and Marc Schut

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Abstract

Agricultural extension in sub-Saharan Africa has often been criticised for its focus on linear knowledge transfer and limited attention to broadening extension service delivery - transition to extension approaches that include facilitation roles for extension staff to respond to wider agricultural system constraints. Currently, the region is experiencing an ICT revolution and there are high expectations of new Information and Communication Technologies (ICTs) to enhance interaction and information exchange in extension service delivery. Using an innovation systems perspective, we distinguish three roles for extension organisation to assume and function as innovation intermediaries, demand articulation, matching demand and supply side actors, and innovation process management. The study explores literature on how new ICT may support these roles, with specific interest in the possibilities of environmental monitoring and new forms of organisation enabled by enhanced connectivity. In order to contribute to the understanding of this area, the paper reports on a comparative study of two new ICT platforms embedded in Ghanaian public and private extension organisations respectively. We assess the roles that these platforms (aim to) support, and document achievements and constraints based on interviews with extension staff and farmers, and observation of extension agents in the field. The findings indicate that while both platforms aim to support innovation intermediation roles the focus areas and level of detail differ due to diverging organisational rationales to service delivery. In addition, we see that new ICTs' potential to support innovation intermediation roles is far from realised. This is not due to (new) ICTs lacking the capacity to link people in new ways and make information accessible, but due to the wider social, organisational and institutional factors that define the realisation of their potential. Therefore, more conventional modes of interaction around production advice and also credit provision continue to be dominant and better adapted to the situation.

However, beyond the two platforms that were developed specifically by and for the extension organisations, there were indications that more informal and self-organised new ICT initiatives can transform and enhance interaction patterns in extension systems to achieve collective goals through social media platforms such as WhatsApp and Telegram.

Keywords: Information and Communication Technology (ICT); ICT4D; ICT4Ag; agricultural extension; innovation intermediation.

1. Introduction

Despite agriculture's potential to contribute to the growth of sub-Saharan African economies (Aker, 2011), agricultural production in the region remains less than optimal (McIntrye *et al.*, 2009; Aker, 2011). Factors explaining low levels of productivity include not only rainfall variability and environmental degradation, but also a range of socio-political and institutional conditions (McIntrye *et al.*, 2009; Pretty, Toulmin and Williams, 2011), including limitations in agricultural extension service delivery mechanisms (Leeuwis, 2004; Davis, 2008; Swanson and Rajalahti, 2010). Agricultural extension has often been criticised for its focus on linear knowledge transfer (Daane, 2010; Leeuwis and Aarts, 2011) and limited attention to approaches to service delivery that would include broader innovation intermediation roles such as process facilitation and knowledge brokering (Howells, 2006; Swanson and Rajalahti, 2010).

Specifically, classical extension has been criticised for its poor capacity to engage multiple interdependent actors (farmers, credit and input providers, buyers, researchers, and development organisations) in joint problem-solving, and in improving farmers' access to broader information relating to market and credit linkages (Kilelu *et al.*, 2011; Klerkx *et al.*, 2012). Further, extension has been associated with limitations in synthesising agronomists, extension agents and farmers' knowledge, and locality-specific information (socio-economic and bio-physical data), to embed appropriate technologies in farm management (Leeuwis, 2010; Lambrecht *et al.*, 2015; Karpouzoglou *et al.*, 2016). The above critique and need for new organisational arrangements in extension is amplified by the increasing complexity of the challenges that agriculture is facing due to climate change, and related new demands and standards arising in value chains (Klerkx and Leeuwis, 2009; McIntrye *et al.*, 2009).

Over the years funding for public extension in many developing sub-Saharan African countries has been limited (Bennett, 1996; Pretty, Toulmin and Williams, 2011). This has led to inefficiencies in extension service delivery and a response to this has been the emergence of private extension to supplement government efforts (Davis, 2008; Swanson and Rajalahti, 2010). However, despite the emergence of pluralistic extension systems challenges in agricultural systems have remained. For both public and private institutions, it remains difficult to facilitate the appropriate interaction among stakeholders to address technical and institutional challenges in farming, reach vast numbers of farmers, and contribute to capacity building at scale (McIntrye *et al.*, 2009; Swanson and Rajalahti, 2010).

Alongside the emergence of pluralistic extension systems in sub-Saharan Africa, the region is experiencing an ICT revolution driven by increasing access to mobile devices (World Bank, 2011). New ICTs as part of this revolution, precede analogue broadcasting and printed media, non-interactive and non-digital media (Lister *et al.*, 2003) include social media[15] (e.g., Facebook, WhatsApp), Short Message Service (SMS), Unstructured Supplementary Service Data (USSD), Interactive Voice Response (IVR), and data collection and storage technologies (e.g., Open data kit) that enable the exchange of textual, audio, video and pictorial information between two or more actors (Bell, 2015; Barber, Mangnus and Bitzer, 2016). The emergence of these technologies presents new opportunities for information sharing and alternative forms of connectivity (Bennett and Segerberg, 2012; Danes *et al.*, 2014; Van Vliet, Bron and Mulder, 2014; Karpouzoglou *et al.*, 2016; Lammeren *et al.*, 2017; Witteveen *et al.*, 2017). In development practice this era, coined Information and Communication Technology for Development (ICT4D) 2.0, is characterised by new ICT with social transformational capacity that positions users as information co-producers rather than consumers and enables online networks (Unwin, 1974; Heeks, 2009; Lie and Servaes, 2015). In this context there are high expectations of new ICTs to enhance interaction and information exchange in extension service delivery and other forms of innovation intermediation. Possibilities include enabling virtual communities for stakeholders to engage in learning and joint problem solving, facilitating virtual connectivity to improve farmers' linkages to services, and the collection of timely and locality-specific information to localise generic scientific knowledge and improve the response to emergent issues (Davis, 2008; Swanson and

[15] "Social media refer to technology artefacts that support various actors in a multiplicity of communication activities for producing user-generated content, developing and maintaining connections and social relationships, or enabling other computer- mediated interactions and collaborations,"(Van Osch and Coursaris, 2013: 700).

Rajalahti, 2010; Aker, 2011; Amadu and McNamara, 2014; Mccole *et al.*, 2014; Wright *et al.*, 2016). However, little is known about how new ICTs are used in practice by extension organisation to support innovation intermediation and address challenges in the agricultural systems.

This paper studies two new ICT platforms[16] in Ghana embedded in a public and private extension organisation respectively. The paper analyses the innovation intermediation roles both platforms aim to support, reports on user experiences and actual platform usage, and documents the interplay between ICT use and the broader agricultural systems landscape. In doing so the paper aims to identify constraints and opportunities related to these platforms facilitating innovation intermediation and draws lessons for further research and ICT platform development.

2. Conceptual Framework

Our research on new ICT platforms is founded on literature that connects to the functioning of agricultural innovation systems, i.e. the network of organisations and enterprises that are relevant to developing, exchanging, and utilising knowledge, technology and innovation in the sector, including the institutions and policies that affect the interactions among these actors and the eventual outcomes (Howells, 2006; Klerkx, Hall and Leeuwis, 2009; Klerkx and Gildemacher, 2012; Schut *et al.*, 2015). Though the study zooms into the extension system, a segment of the AIS. More specifically, it focuses on actors in the immediate network of public extension organisations comprising value chain actors, Non-Governmental Organisations (NGOs), private extension organisations and researchers.

Innovation intermediation

Over the last decade climate change and soil degradation effects, in interaction with human factors and societal development, have dis-oriented traditional farming systems and made farming more complicated (McIntrye *et al.*, 2009; Schut *et al.*, 2015). This has

[16] Platform refers to the base upon which multiple applications are developed and integrated.

placed a higher demand on agricultural stakeholders to adapt and respond to simultaneous challenges and multiple goals for the sector to remain viable and sustainable (Klerkx and Leeuwis, 2009; Leeuwis, 2010; Swanson and Rajalahti, 2010). This situation has placed added pressure on extension organisations to engage in systemic approaches that link them effectively to broader dynamics and innovation support services (Daane, 2010; Leeuwis and Aarts, 2011; Klerkx *et al.*, 2012).

Klerkx *et al.* (2012) have argued that extension organisations may usefully engage in a broader set of innovation intermediation roles to enhance the extension systems performance. Innovation intermediation relates to three roles - refer to the table below.

Table 1. Roles of innovation intermediaries

Role	Components |Activities
Demand articulation	Locality-specific stakeholders needs identification Systemic problem diagnosis Collaborative problem assessment
Matching demand and supply	Tailored knowledge provision Weather services linkage Transport and tractor services linkage Credit options and linkage Input prices and linkage Market prices and linkage
Innovation process management	Coordination and joint problem solving Maintaining and strengthening relationships Facilitating learning, knowledge integration and co-creation

Source: authors with insights from Klerkx *et al.*, 2009

The roles are 1) demand articulation: engaging sector stakeholders to identify their (tacit and expressed) needs (technical, funding or policy), and facilitating the participatory assessment of constraints in meeting their needs and surfacing of interdependencies (Klerkx and Gildemacher, 2012); 2) matching demand and supply: establishing sector contacts (scanning, scoping and filtering actors), identifying potential partnerships that match demand and supply or harness resource complementarity, and developing mutually beneficial relationships (Howells, 2006); and 3) innovation process management: creating a discussion and negotiation space for actors to jointly mitigate constraints. This includes maintaining relationships (fostering continuous information flows, trust building and conflict resolution) among stakeholders to cushion mutual benefits (e.g., in credit and markets), and on-going facilitation of knowledge sharing for continuous innovation (Leeuwis, 2010; Hakanson, Caessens and MacAulay, 2011).

New ICTs' potential for innovation intermediation

While many public and private organisations in Africa are working towards operationalising AIS-based extension approaches, their capacity to perform and enhance the intermediation functions mentioned above remains a challenge (McIntrye *et al.*, 2009; Swanson and Rajalahti, 2010; Bell, 2015).

As mentioned in the introduction, it has been argued that new ICT can act as a bridging mechanism (Proulx and Heaton, 2011; Stone, 2011) and enhance innovation intermediation roles. In the sphere of demand articulation they may facilitate interaction between demand and supply side actors in various locations on virtual platforms to engage them in sharing viewpoints, experiences and knowledge relevant to clarifying needs and constraints.

Additionally, new ICTs offer opportunities for the creation of timely monitoring systems that support the detection of emerging issues in the field, enabling extension organisations or value chain actors to respond to issues promptly (Mccole *et al.*, 2014). The development of such systems involves engaging local agents (e.g., farmers) in collecting data on their on-going activities and challenges, through mobile applications. These data are linked to databases with interfaces that present data in an accessible manner (Buytaert *et al.*, 2014; Mccole *et al.*, 2014).

This decentralised monitoring of farming activities and data crowdsourcing resonates with forms of citizen science (Cieslik *et al.*, 2018) where information of societal stakeholders may be used to set agendas for innovation and problem solving. Citizen science is the involvement of ordinary people in scientific knowledge production through engagement in data collection and (or), data analysis (Stevens *et al.*, 2014), therefore facilitating the collection of more observations over a wider geography and expanding possibilities for scientific investigation (Van Vliet, Bron and Mulder, 2014; Cieslik *et al.*, 2018).

Such decentralised collection of locality-specific information (e.g., soil fertility data) may also support tailoring of advice and other forms of service delivery (Leeuwis, 2004) and; therefore, support matching demand and supply functions. Also, in this area new ICTs are expected to enhance farmers' and agents' access to various information. IVR technologies may for example support immediate access to market information, weather data, production advice, and information related to financial services (Qiang *et al.*, 2012; Barber, Mangnus and Bitzer, 2016).

In relation to innovation process management, the expectations are that new ICT (e.g., virtual platforms) may help facilitate continuous interaction, learning and coordination in support of joint problem solving and co-creation of innovation (Materia, Giarè and Klerkx, 2015; Karpouzoglou *et al.*, 2016). Moreover, new networking possibilities may support alternative modes of coordination and performance in extension (Amadu and McNamara, 2014) or farming communities. More specifically, Cieslik *et al.* (this issue) (Cieslik *et al.*, 2018) have argued that new ICT may enable the emergence of new forms of organisation in response to environmental challenges or other problems that require collective action. Bennett and Segerberg (Bennett and Segerberg, 2012) have introduced the term 'connective action' to refer to this new form of organisation that is informal and inclusive, and driven by personal motivations to engage with others in the pursuit of change (for instance, the Arab Spring). It involves the articulation of views, sharing of memes, information, images and agendas for action enabled especially by social media such as Twitter and Facebook. Bennet and Segerberg describe 'connective action' as a more loose or self-organised form of organisation that contrasts with traditional forms or collective action in which formal organisational management and coordination play an important role (Bennett and Segerberg, 2012; Cieslik *et al.*, 2018). It is interesting to explore whether and how such new forms of organisation affect coordination in extension systems.

<u>Mutual shaping of technology and society</u>

It must be noted that the high expectations associated with new ICTs reflect a (media) technology centred perspective in that it is assumed that technology and media capabilities determine the way new ICTs are used in society (Leeuwis, 1993). Such perspectives ignore the role of the social context in shaping technology use, including the significance of human abilities, preferences and motivations (Marchewka and Kostiwa, 2007; Toyama, 2011), socio-political influences (e.g., actors with interests in maintaining the status quo) and the wider institutional environment (e.g., policies, incentive systems, funding arrangements, prevailing communication cultures, etc.) (Ipe, 2003; Leeuwis, 2013; Cieslik *et al.*, 2018). While such factors can indeed influence whether or not and how new ICT are used the use of new technologies is also likely to influence society in intended and unintended ways. In relation to this anticipated 'mutual shaping' it is naive to expect that new ICTs use will yield only positive and expected outcomes (Stilgoe, Owen and Macnaghten, 2013; Cieslik *et al.*, 2018). New forms of extension service delivery may also foster new forms of exclusion or amplify existing inequalities, for example those related to illiteracy (Perez-Perdomo, Klerkx and Leeuwis, 2010; Toyama, 2011; Materia, Giarè and Klerkx, 2015). Similarly, technology use may take forms that deviate from the intentions of designers or implementing organisations (Stilgoe, Owen and Macnaghten, 2013). In all, it is simplistic to assume that new ICTs will resolve challenges in agricultural and innovation systems (Lie and Servaes, 2015) on their own. Therefore, we look at the (new) ICT revolution as a development that may potentially transform extension service delivery, but at the same time recognise that there may be social and institutional dynamics that deviate from this. Paying attention to the ways in which the use of ICT technology may shape and co-evolve with societal developments and vice versa (Scarbrough, 1992; Williams and Edge, 1996) is likely to provide a more realistic perspective on the contribution of new ICT to support innovation intermediation.

Against this conceptual background, this article investigates experiences with two new ICT platforms in Ghana. In relation to these cases, we seek to answer the following research questions:

1) What intermediary roles do public and private new ICT platforms (aim to) support?

2) What are the experiences of direct users with new ICT supported innovation intermediation? Are there indications that innovation intermediation is enhanced?

3) What is the role of decentralised information collection and new forms of connective action in the two cases?

4) What is the interplay between ICT supported innovation intermediation and the broader extension and agricultural systems landscape, including institutional set-ups?

3. Methods

The limitations associated with classical extension have also been reported in relation to Ghana's pluralistic extension system (DAES, 2011; Sigman, 2015). Therefore, public and private providers are working towards operationalising more AIS-based extension mechanisms, including experimentation with innovation platforms and value chain approaches (DAES, 2011; Van Paassen *et al.*, 2013). The pluralistic extension system in Ghana in combination with the country's growth as West Africa's ICT hub (McNamara *et al.*, 2012) presented opportunities for research on ICT-based innovation intermediation.

We conducted a comparative case study analysis of two new ICT platforms, E-extension and SmartEx, embedded in public and private extension organisations respectively. The approach served to achieve "rich, contextualized understanding of," the prospects and limitations of new ICTs in facilitating broader innovation intermediation roles, "through the intensive study of particular cases," (Polit and Tatano, 2010: 1451). Hence, the platforms were selected as cases based on being embedded in organisations operationalising towards broader extension approaches. The organisations involved were the Wenchi District Food and Agricultural Department (DFAD) under the Ministry of Food and Agriculture (MOFA) and emerging maize out-grower businesses in Techiman District affiliated to the Achieving Impact at Scale through ICT-enabled Extension Services (AIS) Project led by Grameen Foundation (GF).

The research site was in the Brong-Ahafo Region as it represented an area in which both E-extension and SmartEx were implemented. After consideration of five districts, Wenchi was chosen as the field research site based on the criterion of having a large farming community and that several Grameen agents were working near (i.e. within a 15km radius) the DFAD office, the base of Agricultural Extension Agents (AEAs). Additional criteria were that the mobile devices that accommodated platform use were still functional and had been in use for over a year, and that two operational agents per case were willing to participate. However, the research later extended into neighbouring Techiman District, as the two Grameen agents selected in Wenchi District exited Grameen's project. Whilst this presented a logistical challenge, this change did not compromise the basic research design which focused on the new ICT platforms as the units of analysis' and two organisations engaged in intermediation roles as the research context.

In order to understand new ICTs' (potential) role in supporting innovation intermediation roles, we first reviewed and characterised the content and functionality of both platforms. Additionally, we conducted in-depth interviews with key informants from both organisations to determine: 1) innovation intermediation roles they engaged in; and 2) mechanisms of facilitating these roles, including how the platforms were applied and intertwined with other methods and strategies of service delivery. In doing so, we simultaneously gained insight into the role division between the ICT platforms, and classical and conventional communication mechanisms (e.g., radio and field visits), and also with other new ICTs. Data from these interviews and that of in-depth interviews and observations of agents during fieldwork, from both organisations, were triangulated to determine the roles fulfilled. These sets of data also served to obtain user experiences, including challenges and opportunities for the platforms' improvement. Farmers associated with these agents, were also interviewed to gain insight into how they accessed and appreciated extension services. Data from farmers were collected to provide broader observations on intermediation and ICT use in extension service delivery. Data were collected from the sample presented in the table below.

Table 2. Method and Sample

Method	Sample
Key informant interviews: targets purposively sampled from GF, MOFA – DEAS and DFAD	Deputy Director DAES MOFA National Coordinator E-agriculture Programme MOFA Former District Director DFAD Acting District Director DFAD Programmes Manager GF Lead Content Developer GF 5 of 11 (45%) traders GF
In-depth interviews: randomly sampled agents	3 of 7 (43%) AEAs DFAD 4 of 10 (40%) agents GF
Observation and informal interviews: purposively sampled agents based (non) active use of platform	2 of 7 AEAs DFAD 2 of 10 agents GF
In-depth interviews: randomly sampled farmers from each observed agent's active maize farmer groups closest to the DFAD	15 of 41 (37%) Amponsankrom farmers, Wenchi 19 of 46 (41%) Buaso farmers, Wenchi 10 of 24 (42%) Tano Boase farmers, Techiman 7 of 19 (37%) Mesidan farmers, Techiman

Data analysis initially involved interview transcripts and field notes being uploaded onto Atlas.ti (qualitative analysis software) in which they were read and relevant text were coded. Thematic labels (major codes) that were applied to data collected from extension organisation staff included: 'service provided' and 'service delivery method', 'platform use' and 'platform value', and 'challenges in service delivery'. Labels that were applied to data from all research subjects were: 'advantages' and 'limitations' of ICT use in extension service delivery. Labels that were applied to farmer data specifically were: 'sources' and 'value' of agricultural services. After coding, for each organisation, text with similar themes were exported into 'primary document tables' in excel and then text with similar sub-codes under different themes were grouped manually. In order to describe the extent to which a sub-code was repeated, the number of times it occurred (enumerator) was divided by the number of respondents within a particular 'category' such as 'agents' ('denominator') and expressed as a factor of 10 to facilitate these descriptions: 7 of 10 and above – 'most'; 4 to 6 of 10 – 'almost half'; 1 to 3 of 10 – 'few'; below 1 of 10 - 'very few'. Further interrelations between themes were noted and explanatory factors related to certain findings (as presented by respondents) were identified. These were linked to exemplary quotes that were pulled up from the transcripts and the primary researcher's observations.

4. Findings

Case 1: Service delivery experiences with E-extension platform

The MOFA – Directorate of Agricultural and Extension Services (DAES) works within a policy framework that supports service delivery transcending technology provision to respond to challenges in the agricultural system (McNamara *et al.*, 2012). As part of improving extension service delivery in these lines, MOFA launched the E-agriculture Programme in 2014. Under the programme AEAs across Ghana were trained to use the E-extension platform on smartphones.

According to the official job description of AEAs their primary objective is to advise farmers (and other agricultural value chain actors) and demonstrate appropriate technologies. Furthermore, their responsibilities include socio-economic and bio-physical profiling of operational areas, diagnosing and advising on solutions to farming problems – including problems related to farm management, inputs, credit and market access (MOFA, 2001). In addition, they are required to conduct on-farmer-adaptive technology field trials and collect relevant data for researchers' analysis. The next section describes E-extension's functions in relation to the areas of service delivery outlined above.

Description of functions E-extension

The E-extension platform had three major functions (summarised in Figure 1 below). Firstly, the collection of Global Navigation Satellite System (GNSS) location data, alongside crop-specific production data of farmers under a tab labelled 'farmer'. Data collected through this tab was assumed to be useful for planning and intervention prioritisation. It also enabled the provision of unique randomly generated identification codes (ID) for farmers to facilitate the efficient management of the national input subsidy programme. The concept was that selected private input suppliers could run this ID through an online database to check if farmers had already received subsidised inputs for which they were eligible, therefore, preventing the double provision of subsidies to one farmer. Under the 'farmer' tab was another function of the platform, 'field visit report', which made provision for the digitisation of AEAs' field reports.

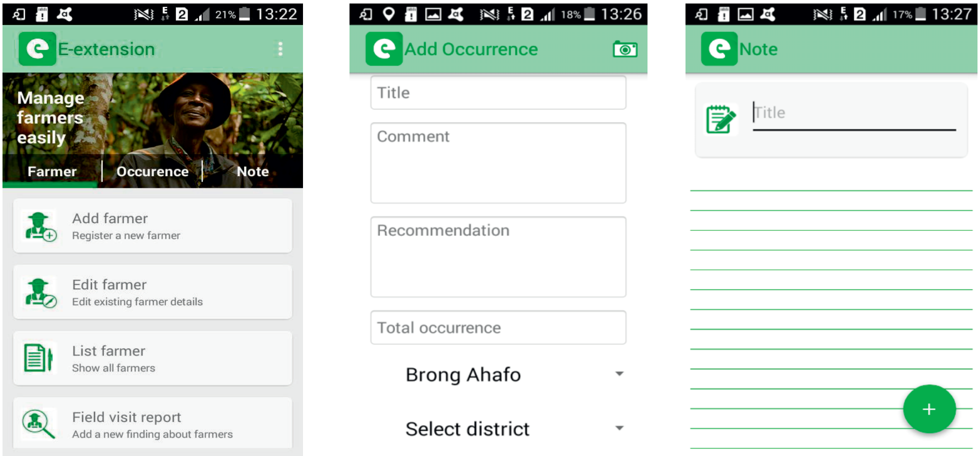

Figure 1. (Left to right) E-extension farmer tab; E-extension occurrence capture; E-extension note capture

Farmer tab: to facilitate 1) the registration of farmers involving: uploading farmers pictures; documentation of sex; mobile number; crops produced; GNSS location and district name; family size; 2) list farmer, a functionality to retrieve farmer records, and 3) field visit reports to digitise farmer monitoring activities

Occurrence tab: to add pest or disease occurrence: 1) label occurrence; upload a picture; document preliminary diagnosis; and recommended prescription; report the acreage affected; and GNSS location and district name, and 2) occurrence finding to retrieve records of occurrences

Note tab: to enable the AEA report any matter of interest or concern

The third function, 'occurrence', enabled MOFA head-quarters (HQ) to source timely information on the extent and location of events such as (new) pest infestations and drought occurrences. This was deemed useful for developing an "early warning system" to enable prompt and coordinated responses to emerging issues in the field. This and the other information collected through the platform was stored in a database with a dashboard, meant for HQ and DFAD management to track agents' activities and farmers' situations.

In addition to the functions above, the smartphones served to connect AEAs to a website (http://www.e-agriculture.gov.gh), vis-a-vis a service providers repository with links to research and finance institutions, input suppliers and commodity buyers, farmer-based organisations and transporters. The website aimed to reduce the time and mobility required by AEAs to vet and establish relationships with sector actors for the purposes of connecting relevant actors to each other.

User experiences

The platform's general value was associated with the development of a farmer database and; therefore, its main use was considered farmer registration. Of all the staff affiliated to MOFA interviewed most associated the platform's value with this function through statements such as *"We need to register farmers, because we lack farmer data in-country."* The DFAD staff (management and AEAs) not only recognised this value, but most also considered that HQ's main motivation for developing the platform was to assign farmers unique IDs to prevent fraud in input subsidies provision.

However, despite the anticipation that E-extension would improve the process of subsidy provision, there were challenges in achieving this. Firstly, all AEAs interviewed stated that limited funds to conduct field visits hampered data collection to populate the database. Secondly, almost half mentioned that they lacked internet bundles to send data to HQ, whilst a few DFAD staff stated AEAs lacked the capacity to use the platform to collect or send data. Additionally, the District Director pointed at technical hick-ups in the communication between local devices and the central database as a factor that hindered E-extension in improving input distribution. The overall success of using the farmer registration data to coordinate input subsidy provision in 2016 was limited, so that DFAD staff continued to use existing (desktop-based) farmer data available at the district office.

In relation to another use of the farmer data, almost half of the district staff interviewed expressed an interest in accessing the data analytics to improve intervention planning. According to HQ this information was not availed, because the Wenchi District Local Government (financially responsible for the DFAD operations based on decentralisation policy) was unable to provide a laptop and internet facilities for DFAD staff to access the database.

Regarding the 'occurrence' function, it was established through interviews with AEAs that few occurrences and also monitoring reports were being sent to HQ. Few AEAs expressed that they occasionally sent data on occurrences through E-extension. One said, "*Sometimes I use E-extension to send reports on peculiar things, for instance when fall armyworm broke out, but not to submit monitoring reports.*" Another AEA suggested that receiving feedback or prescriptions on problems reported on would motivate AEAs to use the function. Apart from the lack of feedback from HQ, the other factors contributing to the functions' low usage included funding limitations, which also hampered crop monitoring and follow-ups on occurrence reports received by AEAs via mobile phones. The other contributing factor related to the district management's concern that occurrences were reported directly to HQ before the extent of the infestation and actual pest was verified. The Director said this on reporting procedures: *"[...] with E-extension we [DFAD] only register farmers,''* and *"[...] before we report a pest outbreak the threshold should have been passed, and if it has not, there is no need to raise alarm."*

In relation to the MOFA website, no AEA stated that they frequented it to access contact information of value chain actors and other stakeholders to match demand and supply for services and other opportunities. However, almost half stated that they accessed the internet over their mobile phones to retrieve agricultural information, suggesting that they were able to visit the MOFA site to retrieve information. In relation to not visiting the website one agent said, *"I do not visit the website, the contacts on that site are not local. We make contacts on the ground, assess them and when we are satisfied we link them to farmers".* This statement reflected that AEAs preferred to link farmers to contacts they had vetted and built relationships with at a local level. That is if they engaged in these activities, given that no AEA expressed that their major duties included credit or market linkage and only a few said that they engaged in input provision. Therefore, another factor that could have contributed to the limited reference to and content on the website, such as the 'agro-marketing' tab being empty, was the service delivery focus of AEAs was knowledge provision.

Broader observations regarding intermediation and ICT use

Alongside E-extension, alternative service delivery facilitating mechanisms were identified. These mechanisms related to stakeholder engagement, needs identification and information brokerage, and systemic problem diagnosis and joint problem solving as well as knowledge provision; activities most DFAD staff stated they engaged in. These three blocks of activities were facilitated face-to-face: through engagement meetings with specific value chain actors (e.g., farmers or input suppliers) as the need arose, monthly review and technical meetings for (extension) district staff, and group training or demonstrations respectively. Furthermore, in interviews with the DFAD Director it was established that the Wenchi DFAD had been the first and only office to pilot a cassava value chain innovation platform in Ghana from 2011 to 2017, and MOFA was recommending its wider adoption. The reasons put forward for expanding the platforms to other areas and value chains were explained by the Director: *"Before we started the platform each actor would come with their own problem and we would try and solve it individually. [...] we know the problems producers face relate to other actors, so now we put all the actors on one platform [...] to solve problems with each other directly."*

Apart from the face-to-face methods of facilitating service delivery, informal WhatsApp groups emerged from DFAD staff as another new ICT being used in the office. According to some respondents under the DFAD it was easy for non-tech-savvy staff to engage through the social media messaging platform and attach pictures. The platform was used to share general and work-related information. The Director said, *"The group was created to share ideas, alert others of diseases or pests noticed and to send information about pending meetings."* Whilst an agent commented that "*the office group is informal, and people share what they want, even jokes".* Additionally, individual staff were members of informal value chain-based WhatsApp groups. Such groups served to maintain contact, facilitate easy connectivity and discussion between value chain actors and support organisations after relationships were established through meetings.

Plantwise was observed as another new ICT platform that AEAs used. Two of the nine AEAs under the DFAD used it as part of a nationwide project led by CABI (a research institution). The projects aim was to reduce crop losses by establishing plant clinics for farmers to access plant health advice. The clinics involved farmers bringing plant samples for "plant doctors" (AEAs) in their locality to diagnose. To support the clinics, the AEAs used three Plantwise functions on a tablet. The 'Plantwise Factsheet' containing pest and disease management advice and a Telegram (instant messaging) group of 192 AEAs across Ghana, agronomists and researchers. Furthermore, AEAs also recorded, through a digitised "prescription form" ('Plantwise Data Collector'), farmer's biodata and plant health problem diagnosis' and prescriptions. AEAs were motivated to use the 'Plantwise Factsheet' as it connected them to current technical information, one AEA said, *"Plantwise is current, this morning they sent us information on the armyworms life cycle, the information we need now to advise farmers on when [the stage] treatments are effective."* According to AEAs, the factsheet was also useful as it facilitated learning: *"Sometimes you hear of a disease you have no idea of and through fact sheet you see and learn about it, and then you can educate farmers on it."* The Telegram group was also valued for facilitating learning, an AEA said, *"At the beginning of the season many of us were mistaking armyworm for stemborer. The specialists were following our discussions on Telegram and then posted something on differentiating between the two."* Additionally, Telegram was found useful by AEAs for providing current sectoral news, for examples: *"The latest chemicals [...] banned chemicals [...] current happenings [...] like the other crops armyworm is attacking."* The factors mentioned above that motivated AEAs to use Plantwise platforms, directly related to areas of improvement they suggested for E-extension.

In relation to knowledge and production advice provision, a major focus of service delivery mentioned by all DFAD staff, all DFAD staff and farmers cited group training and demonstrations as the main teaching methods applied. Additionally, most AEAs expressed that they both received farmers' reports on challenges (e.g., pest infestations) and responded to these challenges over the phone. AEAs probably used mobile phones in this manner due to a lack of operational funds, in relation to this an AEA said, *"Those* *farmers that call me I give them advice over the phone, for some farmers I sacrifice and go and see them."*

Alongside mobile phones, most AEAs also mentioned radio as a method of knowledge and production advice provision. AEAs were required to participate in radio programmes on local radio stations as part of their official duties under the DFAD office. Aside from using radio in service delivery, few AEAs reported that they used a separate GNSS mobile application from that on E-extension, for measuring field sizes. Such geo-data were used to prevent or resolve conflicts over field measurements between farmers and ploughing service providers. These conflicts often arose from farmers using imprecise measures for field size and providing these measurements to plough operators to quote a price pre-works. At times this resulted in disputes over field size and price when operators came on site. The use of the GNSS technology typically involved AEAs walking around the perimeter of a field and pinning its coordinates with the application, and giving a precise and acceptable field size estimate to both parties.

Lastly, it was also observed that farmers use of available weather SMS push services was limited due to literacy and the timeliness of these services. One farmer said, *"Most farmers are illiterate, so if you want to go about such things [providing SMS weather data] it becomes difficult for them."* Additionally, another farmer commented that although the weather information sent via SMS was more accurate, the conventional radio forecasts were timelier. This was because at times the SMS data only reached farmers in the afternoon, which was too late for them to decide whether to go into the field or not considering they preferred to go into the field in the morning.

Case 2: Service delivery experiences with SmartEX platform

Grameen Foundation is an international development organisation rooted in business-oriented approaches to poverty reduction. Between 2014 and 2017 Grameen in Ghana partnered with Agricultural Cooperative Development International/ Volunteers in Overseas Cooperative Assistance (ACDI/VOCA), another development organisation, to build the capacity of maize traders to evolve into out-grower business owners and engage in broader extension service delivery. The project Achieving Impact at Scale (AIS) aimed to apply new ICTs in improving traders' management of farmers (suppliers), and their control over crop supply and quality through better monitoring, and technical and credit support coordination.

For the project, traders identify tech-savvy individuals for Grameen and ACDI/VOCA to train as agents. These individuals are trained on basic agronomic principles and SmartEX. Once trained the individuals (agents), using SmartEx via tablets, are required to identify farmers' needs, conduct demonstrations and train farmers on improved technologies, and develop seasonal farm management plans with farmers to facilitate crop monitoring. They are also required to liaise and negotiate with service providers to meet farmer's needs, the emphasis being on improving farmers' access to inputs. During the marketing period, they are required to purchase produce for traders and simultaneously receive payments (as produce) for input loans and other services (such as ploughing) they organise for farmers, and coordinate produce sales to end-market buyers. SmartEx was designed to support the agents in coordinating service delivery as described above.

Description of functions SmartEx

One of the AIS project assumptions was that agents required less agronomic training and networking skills than classical extension agents to engage in service delivery, based on having easier access to information through SmartEx. SmartEx's homepage consisted of six tabs labelled 'farmers', 'meetings', 'suppliers', 'markets', 'technical assistance' and 'farmer search' (summarised in Figure 2 below). The first two tabs facilitated data collection. The 'farmers' tab enabled the collection of farmer biodata and other data to automatically profile farmers, including the collection of baseline data on farmers' production practices and credit activities. Under this tab, agents could also create farm management plans and digitised weekly reports, including the reporting of emerging field issues (e.g., pest infestations). Similarly, the 'meetings' tab allowed for the creation of digital reports of group training and farm(er) monitoring visits. Thus, the first two tabs aimed to facilitate farmer enrolment and needs assessment to support farm monitoring and agents' timely response to emerging field issues. An important rationale underlying the collection of this information was also that it would be used by traders and/or other input providers to assess which farmers could be provided credit (in the form of inputs) with minimal risk and help convince their designated financial organisations to provide them with sufficient working capital to operate.

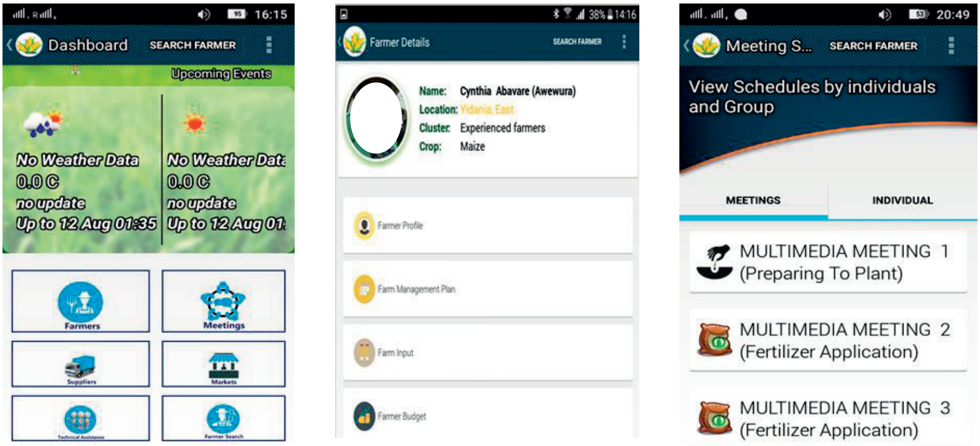

Figure 2. (Left to right) SmartEx homepage; SmartEx farmer records summary; SmartEx meetings data capture

Farmers tab: function to 1) facilitate the collection of farmer registration data and farmer profiling (as experienced; moderately experienced; farmers on the rise; and moving from subsistence); 2) collect baseline data on farmers production practices by crop and farming enterprise credit activities, and update it seasonally; 3) to document and update seasonal farm management and credit plans; and 4) to digitise agents weekly plans and weekly reports

Meetings tab: function to record out comes of 1) farmer group meetings by crop at pre-planting, first and second fertiliser application, and harvest or post- harvest; and 2) individual farmer visits planned according to the production activities to facilitate registration, farm planning, field measurement, crop assessments and fertiliser application

Suppliers tab: contact details of a range of agricultural input suppliers, financial institutions, tractor service providers and transporters arranged by region

Markets tab: contacts details of agro-processors, aggregators and traders by region

Technical Assistance tab: repository of various crop management guides, and videos on production, pest and disease control, processing and marketing

Farmer Search tab: search function to enable agents retrieve farmer records by crop, community (location), profile or name

The second two tabs 'suppliers' and 'markets' were meant to facilitate easy access to service providers contacts (with whom Grameen had established collaborative relationships), enabling agents to link farmers to services and facilitate value chain linkages. The SmartEx database, under the 'technical assistance' tab, stored a variety of crop management guides on good agricultural practices (GAPs) and teaching videos for agents to easily access information relevant for advising farmers. The 'farmer search' tab was designed to give agents access to analysed monitoring data to quickly understand a farmer's background, establish their needs and track their performance.

Alongside the above functions the tablets were internet-enabled to support wider access to agricultural information and weather services for agents - subsequently farmers, and SmartEx also had a dashboard meant for traders and Grameen staff that could track agents' field activities in real-time. The next section provides insight on Grameen agents' actual use of the SmartEx platform.

User experiences

In relation to farmer registration and profiling through the 'farmer' tab, most agents stated they engaged in this activity and considered this SmartEx's main function. All traders saw this as the major role of agents in their businesses, as one trader stated, *"The work of agents is to use the tablets to monitor farmers' activities, keep records on farmers and profile them."* Despite all the traders interviewed recognising the value of the data collected under the 'meeting' tab in tracking and monitoring farmers' progress, few agents collected these data or engaged in monitoring consistently. Similarly, few agents sent weekly reports through SmartEx, hence emerging issues on the ground were not actively reported to Grameen or traders. Additionally, few agents used the platform to develop farmer management plans. Most respondents associated with Grameen stated limited transportation (funds) as a constraint to visiting the field for data collection. Furthermore, agents indicated they had no contractual obligations to traders and were not remunerated by them, which contributed to their de-motivation to collect data. It was observed during the research period (5 months) that 3 agents (out of 15) dropped out of the project citing remuneration as a contributing factor. Meanwhile, despite these challenges, from the perspective of Grameen staff the project could be seen as working towards testing new business models for agricultural services provided by traders, where it was expected that SmartEx and agents' use would eventually lead to risk reduction for traders and other input providers, and thus improve their financial position enabling them to remunerate agents for their services.

While the 'suppliers' and 'markets' tabs meant to facilitate easy access to service providers contacts for agents to engage in value chain linkages, few agents used the platform to identify input dealers and financial institutions to improve farmers' access to inputs, and it was observed that market actors' repository was empty. A probable explanation for the empty repository was that traders had already established linkages with farmers and end-buyers prior to the project. Whilst the general limited use of the function could be related to the role defined for agents in traders' businesses. As already mentioned most agents and traders identified agents' role as a data collector and record keeper. In this situation traders, who had limited access to SmartEx and mainly engaged agents on the criterion of tech-savviness, continued to rely on their personal networks to provide loans to farmers. These networks included both organisations from which traders had accessed loans over the years, and those they had engaged with through ACDI/VOCA more recently. Developing these personal networks with financiers involved a series of meetings in which traders vouched for farmers or convinced them of their capacity to be guarantors for farmer loans. However, one trader said he sometimes used farmer records from SmartEx to negotiate farmer credit arrangements with financial institutions, but in general the use of farmer records and plans for these purposes was not widespread.

With regard to production advice provision, despite almost half of the agents expressing involvement in this, only a few stated that they referred to the SmartEx crop management guides. Interviews suggest that traders and not agents as assumed by the project had closer contact with farmers on issues of production and other advice. In relation to this almost half of the agents alluded to farmers with challenges often calling traders for advice, and this seemingly limited agents' incentives from referring to the training material.

Broader observations regarding intermediation and ICT use

It was observed that traders as part of service delivery and in collaboration with ACDI/VOCA, Grameen also linked farmers to other new ICT platforms providing production advice, specifically ESOKO a direct-to-farmer SMS agricultural information service. Of the few farmers interviewed using ESOKO, few alluded to actively accessing production advice from ESOKO. Those that did said that they received valuable timely weather-based guidance on when to engage in farming activities (e.g., fertiliser application), but stated that interaction with an expert was still required for them to grasp the advice. In relation to this, most farmers considered AEAs their main production advice provider. The following statement reflected farmers' views on the comparative advantages of sourcing production advice from ESOKO and experts (AEAs): "*ESOKO only sends us information, whilst the "agric-people" [AEAs] come directly to the field to assist us when we are not clear. Then again, the goodness of the ESOKO information is that it is readily accessible when agents are not always able to come into the field."*

Further, very few farmers accessed SMS market information through ESOKO or radio. Farmers appreciated having access to commodity prices in wider markets. However, access to this information did not necessarily translate into improving their negotiation position with traders, whom they were often tied to by supply and credit agreements. It rather enabled them to ascertain whether their designated trader was offering a fair price. However, interviews with traders suggested that ESOKO's market information service was more valuable to them in scanning markets, price setting and negotiations, as they had higher mobility than farmers and access to larger volumes of produce. Most traders interviewed valued the SMS service in this manner. Furthermore, they were wary of farmers being privy to price information, an agent said, *"It [ESOKO] helps me to know commodity prices at different markets. So, I know the best prices to sell my produce at a profit,"* and he continued, *"It is even spoiling our [agents'] negotiations with farmers. Now farmers know the prices and want to sell their produce at the ESOKO price."*

Additionally, very few farmers interviewed accessed ESOKO weather data, the majority accessed forecasts via radio. One of the few farmers accessing the SMS based weather data valued the service in this manner: *"Getting the information from the phone is good, as it is always with me and the information they give is correct more times than the one on the radio."* He further alluded to illiteracy being the major factor deterring other farmers from engaging with the SMS service.

Grameen also established a WhatsApp group for agents to report technical challenges of operating SmartEx to Grameen staff. One agent revealed that the group was also being used to report on other field challenges, including pest infestations, and explained why through this statement: *"All the Grameen managers, facilitators and agents are on the group [...], and they help find solutions. [...]I found when I reported problems through WhatsApp I got a more immediate response than when I reported through SmartEx [weekly reporting].''* The WhatsApp group also enabled the sharing of ideas and experiences with more immediacy than the quarterly review and sharing meetings that ACDI/VOCA organised for agents and traders to discuss progress and field experiences.

5. Analysis and Discussion

This section analyses the findings in relation to the research questions posed about the role of new ICTs in supporting innovation intermediation. Subsequently, we discuss the implications of these findings for the further development of new ICT platforms and future research.

<u>Intermediary roles supported by new ICT platforms and user experiences</u>

In terms of the intermediary role supported by E-extension and SmartEx, we see some similarities and differences (see Table 3 for an overview).

Both platforms were embedded in organisations with the intention of transitioning to broader (extension) service delivery and thus attention for the platforms to support a variety of innovation intermediation roles was observed. A common feature of both platforms is that there was emphasis on database development and the collection of farmer registration data (names, locations, farm size, crops grown, and in the case of SmartEx also farm development plans etc.) as a basis for enhancing service delivery and innovation intermediation.

Furthermore, both platforms included a service providers repository to facilitate value chain linkages, and enabled the digitising of agents' monitoring activities to track agents and identify emerging issues on the ground with immediacy. Below, we analyse in more detail how these features link to other platform characteristics and the three types of innovation intermediation distinguished in Tables 1 and 3: demand articulation, matching demand and supply and innovation process management.

Table 3. Comparative summary of intermediation roles that E-extension and SmartEx aim to support

Role	Components | Activities	E-extension	SmartEx
Demand articulation	Locality-specific stakeholders needs identification Systemic problem diagnosis Collaborative problem assessment	Basic locality-specific data collection to enable needs identification for groups of farmers with similar features	Detailed locality-specific data collection to enable detailed needs identification at the individual farmer level
Matching demand and supply	Tailored knowledge provision Weather services linkage Transport and tractor services linkage Credit options and linkage Input prices and linkage Market prices and linkage	Matching basic farmer data to tailor advice to groups and locations *Networking shortcut to identify and vet service providers to facilitate value chain linkages	Networking shortcut to reach technical experts – easy access to GAPs repository Matching detailed farmer data to foster access to tailor-made and in-kind credit provision Networking shortcut to identify and vet service providers to facilitate value chain linkages
Innovation process management	Coordination and joint problem solving Maintaining and strengthening relationships Facilitating learning, knowledge integration and co-creation	Decentralised monitoring data to enhance coordination and organisational feedback Enhancing coordination in the delivery of subsidised inputs	Decentralised monitoring data to enhance coordination and organisational feedback Creating farmer credit and production history to support trust building in credit and commodity markets

*This function was facilitated through the MOFA website linked to E-extension.

Demand articulation - For both platforms, farmer registration and database development were meant to support demand articulation, but for different purposes and with different levels of interaction and detail. In the case of E-extension, registration and database development involved the collection of basic farmer information (location, crops grown, farm size) and reporting on emerging issues (e.g., pests and diseases). This information served in part to rationalise and control the delivery of input-subsidies, but also inform extension organisations of farmers' knowledge demands. However, the degree of interaction between 'supply and demand' in E-extension was limited and thus the registration data was not oriented towards the in-depth articulation of specific demands, but rather to general categories that were helpful for planning and prioritising extension activities and targeting production advice provision to groups (e.g., maize growers). In practice, however, potential advantages of this modality for demand articulation were not realised, as implementation was complicated by a range of technical, resource and capacity constraints, resulting in few farmers being registered through this system. Therefore, AEAs continued to rely on pre-existing farmer registration data for planning and on conventional demand articulation modes during field visits, group meetings and –more recently- face-to-face innovation platforms and mobile phone conversations.

For SmartEx the interaction was designed to be more intensive and detailed, and mostly oriented towards the articulation of individual demands for services (input provision, ploughing, processing, transport, etc.) tied to credit provision (in kind) by traders. To this end farmers registration through SmartEx automatically facilitated farmer profiling, placing them into categories (experienced, moderately experienced, farmers on the rise, and moving from subsistence) that described their farming level, capacity and priorities for service delivery. SmartEx further supported the collection of baseline data on farmers' production practices and credit activities, alongside seasonal farm management plans to aid agents in the identification of farmers' financial, equipment and input requirements based on their intended farming practices and area of cultivation. In all, demand articulation in SmartEx was meant to be more intensive, continuous and individual than in E-extension and less oriented to articulating knowledge demands. However, in the case of SmartEx we also see that this potential was not realised. Insufficient incentives existed for agents to actively engage in the articulation of individual demands for services, still pointing to resource constraints and additionally unconducive remuneration relations between traders and the newly established agents. In the situation, traders mainly relied on pre-existing information and relationships rather than on information collected through SmartEx.

While both platforms paid attention to articulation of farmer demands, it is interesting that the needs and demands of service providers themselves played a prominent role in how the platforms operationalised demand articulation. The effective and efficient working of MOFA and its extension services was the centre of attention for E-extension, while the needs of traders and other credit providers played an important role on SmartEx. At a more abstract level SmartEx served to test a new business model for commercial service delivery, as envisaged by Grameen, based on the notion that the collection of information about farmers could reduce risks in lending for credit providers, as they would be in a better position to judge farmers' trustworthiness. At the same time, provision of credit (in kind) would allow farmers to access a range of services. It was assumed that addressing demands of extension organisations, traders and credit providers would indirectly serve the interests and needs of farmers. Considering that from an innovation systems perspective demands and interests of different stakeholders play a role in service delivery, this assumption is a reminder that it is important to contemplate about how a good balance between different demands driving the design of (new) ICT platforms may be negotiated (Alexiou and Zamenopoulos, 2008).

Matching demand and supply – Both platforms included modalities to facilitate the matching of demand with appropriate services. To support matching both platforms provided contact details of types of service providers. However, in both cases this information appeared to be of limited use. On E-extension local contacts were largely absent in the system and AEAs preferred to connect farmers to their own local and personally vetted contacts. In the case of SmartEx more local contacts were provided, but the results also indicate that existing ties and personal networks dominated matchmaking. Additionally, the SmartEx platform included the introduction of a new professional – the tech-savvy agent - whose tasks included facilitating commercial matchmaking. Although potentially useful from the Grameen perspective, the remuneration of this new professional remained problematic.

SmartEx also included general reference materials on Good Agricultural Practices (GAPs- in text and pictures) for agents to use in response to farmer profiles and queries. This information had a generic nature and would have to be tailored to farmers' needs by agents. For SmartEx the potential for tailored production advice provision was greater than in E-extension due to the more refined demand articulation process, but agents did not intensively use these opportunities as production advice provision received relatively little attention in practice. As observed the agents selected had limited agricultural know-how and their role was mainly defined as data collectors and record keepers as opposed to knowledge providers. In addition, there were problems with internet connectivity in the field, the pace at which the repository was updated was slow and traders fostered linkages to DFAD or NGOs who offered similar information through conventional media. Overall, there was no indication that agents used the repository frequently.

Innovation process management – Both platforms aimed to foster new forms of coordination among stakeholders. E-extension aimed to enhance coordination especially with providers of subsidised inputs through the farm registration system and SmartEx was geared towards introducing new coordination arrangements among a range of service providers with agents and traders as linking pins. We already indicated that both coordination mechanisms faced problems in implementation.

Both platforms also offered learning opportunities in broader networks in the form of monitoring systems. However, in both cases these monitoring systems were not intensively used as the platforms facilitated one-way (bottom-up) data flows, so that AEAs and agents experienced that responses were slow or not forthcoming. Perhaps more importantly, we observe that they found more suitable new ICT for networking, learning and problem solving in the form of informal WhatsApp groups and the Plantwise Telegram group. These discussion platforms were easier to use, did connect expertise and experience from a diverse membership (e.g., AEAs, researchers, subject matter specialists, managers, service providers) and frequently yielded immediate responses.

Neither E-extension nor Smart-Ex had functions geared towards conflict resolution. However, we observe that some AEAs effectively used geo-data and GNSS technologies to assist in settling and preventing disputes between ploughing service providers and farmers over field measurements.

Finally, it must be noted that – even though both platforms paid attention to enhancing coordination and organisational feedback - it cannot be said that the two new ICT platforms were geared deliberately towards facilitation of multi-stakeholder interactions towards socio-technical innovation to replace e.g., face-to-face innovation platforms or complement virtual knowledge sharing platforms as was the case in the study of Materia *et al.* (Materia, Giarè and Klerkx, 2015) in the Italian agricultural knowledge and innovation system. Thus, in this case, innovation process management remains much more piecemeal and ad-hoc than might be feasible based on the organisational goals for the platforms.

<u>The role of decentralised information collection and connective action</u>

Both platforms intended to make extensive use of decentralised information collection about farmers and their farms, and to a lesser extent about (extension) agent performance. However, the purposes and features of this data collection diverged from the idea of using environmental monitoring and citizen science in support of collective problem solving and innovation (see Cieslik *et al.*, this issue). In contrast to this data collection was not connected to any scientific ambition, did not involve farmers (or others) sending in their own contextual information (as in many citizen science projects), and was neither accompanied by a facilitated process of exchange and social learning to address collective problems (e.g., combating emerging plant diseases). Instead, it involved data collection by professionals and modes of one-way communication that were intended mainly for fostering new forms of coordination (as described above) and the enhancement of organisational efficiency and effectiveness in delivering services. In relation to this, decentralised information collection focused mainly on characteristics and practices of humans (farmers and agents), with only limited attention to monitoring the kinds of agro-ecological processes implied by the notion of 'environmental monitoring' (Cieslik *et al.*, this issue).

As explained, the enhanced forms of organisation and coordination strived for had yet to materialise. Nevertheless, it is interesting to note in the context of this special issue (see Cieslik et al, this issue) that both projects did seek to capitalise on improved new ICT connectivity and use decentralised information collection and monitoring in an effort to change (inter)organisational patterns. This was also true for the Plantwise Telegram group and the various informal WhatsApp groups that emerged around both the Government extension service and Grameen project. In these groups enhanced connectivity did involve the sharing of personalised information (experiences, ideas, viewpoints, images, etc.) through enhancing interaction of multiple actors virtually in an effort to achieve collective organisational purposes, more specifically related to managing issues of uncertainty such as the new threat of the fall armyworm pest. Thus, there are indications of new forms of organisation emerging that resemble what Bennet and Segerberg (2012) have labelled as 'organisationally enabled connective action' (see also Cieslik *et al.*, this issue), as the WhatsApp and Telegram platforms were organisationally embedded and supported, but still facilitated sharing of personal action frames, information and knowledge with limited organisational moderation. Our interviews and observations suggest that these relatively simple technologies (running on standard smartphones and software packages such as WhatsApp) where among the new ICTs that (extension) agents were more inclined to use.

The interplay of ICT use with the Agricultural Innovation System

We observed that new ICT supported innovation intermediation was affected by various processes and conditions in the broader social and institutional context.

Clearly, poor literacy and smartphone penetration among farmers (as associated with poverty) shaped the way in which E-extension and SmartEx were designed, namely with AEAs and agents (rather than farmers) targeted as direct users. As we observe, the uptake of direct-to-farmer SMS services too was widely affected by poor literacy.

Moreover, a number of institutional conditions constrained the use of both platforms. We observe that resource constraints in both the public and private setting affected

AEAs' and Grameen agents' use of the platforms. We also find – especially in the case of E-extension that supportive organisational arrangements and capacities for technical problem solving, responding to monitoring reports and ensuring regular renewal and updating of information were lacking. Thus, the available new technology and envisioned use were not complemented with appropriate organisational innovations (e.g., novel organisational arrangements and incentive systems) (Leeuwis, 2013).

Additionally, we observe in SmartEx's case that pre-existing networks and institutional arrangements around trade and credit provision were strong. Existing dependencies between traders and farmers made it difficult for the latter to capitalise on improved market information, except to ascertain that their designated trader offered fair prices. Moreover, it was not easy for the newly introduced agents to establish and position themselves and be valued (also financially) by traders, which raises concern for the sustainability of Grameen's intended business model for service delivery.

In relation to sustainability, it is also relevant to note that ICT projects in Ghana tend to be donor-funded, with more support garnered to platforms with commercialisation plans. Both E-extension and SmartEx were donor-funded, as was Plantwise. Coordination between the projects was not self-evident, which is reflected in the fact that there was duplication in the three platforms' functions (e.g., farmer registration systems, databases of service providers and technical repositories). The prevailing innovation system landscape enabled these parallel initiatives. It is common knowledge that the often temporary nature of donor funding may influence the attitude with which stakeholders engage with initiatives, whereby a certain degree of opportunism may undermine the possibility of interventions becoming sustainable (Moyo, 2009; Lambrecht and Ragasa, 2016). To be clear, there was no compelling evidence that this is the case for E-extension or SmartEx. However, the fact that sustainability is a relevant concern for such platforms is evidenced by a World Bank review of 92 ICT4Ag applications in developing countries, which demonstrated that only 20 percent of commercial and 11 percent of non-commercial applications reach the sustainability stage of business development (Qiang *et al.*, 2012).

Discussion: Implications for further design, development and research

In this discussion section we first present a comparative summary of platform functions and user experiences in the form of a table (see Table 4). In this table we summarise and associate the main findings for both platforms to the appropriate innovation intermediation roles. This table then serves as a basis for discussing three themes that merit further reflection, action and research in connection with the future design of new ICT platforms for agricultural extension. We have grouped these themes in three categories: 1) the need to embed new ICT in prevailing media landscapes, 2) fostering coordination and arrangements for sustainability, and 3) enhancing user orientation and understanding of user initiatives.

Embedding new ICT platforms in prevailing media landscapes – The summary presented in Table 4 suggests that both E-extension and SmartEx face numerous problems in facilitating innovation intermediation roles. Thus, there is a big gap between the expectation that ICT-supported interaction, exchange, networking and monitoring would enhance the extension systems performance, and the reality on the ground in the Brong-Ahafo Region. Arguably, we see an opposite influence whereby dominant features of the existing innovation system make it difficult to capitalise upon the potential of new ICT platforms. Nevertheless, there are indications that standard social media platforms such as WhatsApp and Telegram are utilised to enhance particularly innovation process management. These platforms that are more geared towards multi-actor engagement are used in, for example, organising effective responses to pests and diseases. However, further research is needed to analyse such dynamics and assess whether this indeed involves (organisationally enabled) connective action (see Cieslik *et al.*, this issue).

Table 4. Comparative summary of platform functions and user experiences

Role	E-extension	SmartEx
Demand articulation	**Farmer registration** Limited financial resources to collect basic locality-specific data Function underutilised due to technical hick-ups and agents' level of ICT usage competence	**Farmer enrollment and profiling** Limited financial resources to collect detailed locality-specific data Insufficient incentives for agents to engage in articulation of individual demands for services
Matching demand and supply	**Value chain actors' website** Personally, vetted local contacts preferred in value chain linkages Limited reference to repository based on AEAs focusing on production advice provision versus value chain linkages	**Suppliers' and markets repository** Existing ties and personal networks dominated matchmaking Limited reference to repository based on agents focusing on data collection versus value chain linkages **Technical assistance repository** Limited reference to repository based on agents focusing on data collection versus production advice provision **Farmer enrollment and profiling** Limited financial resources to develop production and credit records
Innovation process management	**Field visit and occurrence reports** Limited financial resources to collect monitoring data Monitoring systems not primed and underutilised due insufficient data population One-way flow of data to HQ demotivated agents to engage in data collection Conflicting reporting channels and guidance hampered data population	**Weekly, training and monitoring visit reports** Limited financial resources to collect monitoring data Monitoring systems not primed and underutilised due to insufficient data population Slow responses from HQ hampered agents' data collection **Production and credit records** Credit and production history underutilised to negotiate farmer credit with credit providers as existing trust building mechanisms prevailed

Our findings also imply that classical media and conventional communication mechanisms still play an important role in a variety of innovation intermediation processes and that they have qualities that continue to provide added value in the current context. This is in line with, for instance, Duncombe's (2016) assertion that face-to-face interaction remains critical for both demand articulation and the matching of such demands with an appropriate supply, in view of the importance of local ties and the dynamics of trust building. Further, similar conclusions about the continued importance of interpersonal methods and mass media in contexts of ICT-based service delivery are arrived at by other authors (Chapman and Slaymaker, 2002; Heeks, 2002; Livondo *et al.*, 2015). These conclusions include that classical extension agents remain relevant in knowledge tailoring based on their familiarity with farmers and farmers' areas of operation, and farmers' preference for face-to-face interaction in learning (CTA, 2016). All in all, we see that efforts to (re)design new ICT platforms for innovation intermediation should take into account that such platforms cannot be looked at in isolation. In relation to this Materia *et al.* (Materia, Giarè and Klerkx, 2015) and Sulaiman *et al.* (Sulaiman *et al.*, 2012) assert that (new) ICT interactions support, complement or spur real-life interactions to facilitate innovation processes. Therefore, designers should think carefully about whether or not (new) ICT options are likely to provide added value vis-a-vis existing communication patterns and explore what combination of media may – in a given context - be helpful in providing specific services.

Coordination and arrangements for sustainability – A point of contemplation is whether the existence of several new ICT platforms with areas of duplication, overlap and under-utilised complementarities is a problem or to be regarded as an inherent feature of pluralistic extension systems. From an evolutionary innovation perspective one could argue that it is beneficial to have multiple initiatives, because competition helps initiatives to improve quickly and ensure that 'the best' initiative survives (Geels, 2011). However, it is questionable whether this model of thinking applies fully to such a resource constrained environment. From an innovation systems perspective, one would also say that there is considerable scope for enhancing complementarity and coherence, and that there is promise in fostering relationships of resource sharing between public and private extension organisation and potentially research institutions. This could help to meet (content and technical) development and maintenance costs of the platforms, and take advantage of the strengths of public organisations (e.g., collective demand articulation, production advice provision, registration) and private parties (e.g., credit provision, value chain linkages). Such collaboration may also make it easier to develop a sustainable public-private model for service delivery in which conducive organisational arrangements for operations, technical support and substantive maintenance are connected to financial flows. Such considerations are already prominent in the Grameen project, but clearly the envisaged model is not yet working optimally. Therefore, action and research might be oriented towards increasing our understanding of the conditions under which traders, credit providers or farmers might be willing to remunerate agents for ICT enhanced data collection. Alternatively, it may explore and design altogether different models that stakeholders find promising.

Enhancing user-orientation and understanding of user initiatives – User experiences reported in this article suggest that many components of E-extension and SmartEx are not yet functioning as intended by the designers. To improve the usability of these systems there is certainly scope for soliciting additional feedback and incorporating this in the re-design of components of the platforms. Incorporating user feedback into design is suggested as broader experience with (new) ICT system development shows that structural involvement of users in the design process can help to discover and accommodate appropriate information and communication needs (Stewart and Hyysalo, 2008; Stilgoe, Owen and Macnaghten, 2013). At the same time, building on existing initiatives as opposed to 'starting from scratch' can also enhance the usability of (new) ICT systems (Chapman and Slaymaker, 2002; Heeks, 2009; Hansen *et al.*, 2014). Therefore, instead of studying how service providers use externally introduced new ICT platforms, it may be especially informative to analyse (new) ICT initiatives that service providers themselves take to support their work. In this case we have observed that there are self-organised WhatsApp groups transforming interaction patterns in extension systems and that mobile phones are used widely in the interaction between farmers and service providers. A content and/or network analysis of interactions taking place through WhatsApp groups or mobile phones may, for example, reveal in more detail what kinds of needs service providers and their clients have. At the same time, it can offer insight into new forms of organisation and collective action that are feasible and useful in extension (and more broadly) innovation systems. In relation to this, it is important to note that farmers are not yet widely connected to (or through) such virtual platforms, even though they are a source of relevant information. Thus, it is interesting to explore ways of enabling farmers to connect and share with other agricultural actors, considering that extension (agents) have limited mobility to provide services or collect information that serves farmers' interests.

6. Conclusion

There are high expectations regarding the role that new ICT platforms may play in enhancing the performance of agricultural extension in line with innovation intermediation in the face of complex challenges. In line with the idea of 'Environmental Virtual Observatories for Connective Action' (EVOCA, see Cieslik *et al.*, this issue), new ICT supported decentralised information collection and monitoring as well as connectivity-based modes of organising were expected to play a significant role in this. The study shows that both public and private sector parties use new ICT platforms to augment extension service delivery. While both platforms aim to support demand articulation, matching demand and supply and innovation process management the level of detail and underlying organisational purposes differ markedly. The public platform appears mainly oriented towards enhancing organisational efficiency in production advice provision and the private platform is geared towards testing a new business model for delivery of a range of commercial services. However, our exploration of user experiences suggests that both platforms face serious constraints and that new ICTs' potential to support innovation intermediation is far from realised. This is not because new ICTs have no capacity to link people in new ways and make information accessible, but due to the wider social, organisational and institutional factors that define the realisation of their potential. These include resource constraints and absence of supportive organisational arrangements that allow new ICT platforms to operate smoothly. Another important institutional constraint is that newly introduced business models have not successfully complemented or competed with pre-existing networks and arrangements around trade and credit provision. In light of all this, more conventional modes of interaction, production advice and credit provision and communication remain dominant and better adapted to the situation.

In the context of this special issue, it is interesting to note that several efforts to support innovation intermediation did make use of decentralised information collection, monitoring and enhanced connectivity to improve service delivery and change (inter)organisational patterns. However, the form in which this took place differed meaningfully from what was portrayed by Cieslik *et al.* (this issue): it involved data collection by professionals rather than by citizens, information collection about humans rather than about the ecological environment and it was oriented towards achieving managerial goals rather than towards supporting joint investigation, agenda setting, collaborative problem solving and/or collective action. While these efforts were not yet successful, the rationale behind these intended functionalities was regarded as valuable by many stakeholders. Moreover, we have seen that service providers made regular use of informal WhatsApp groups to share personalised content in an effort to achieve organisational objectives and/or respond to emerging pests and diseases. These platforms were easier to use than the monitoring systems embedded in E-extension and SmartEx, were effective in connecting expertise and experience from diverse groups, and frequently yielded immediate responses. Therefore, there are indications that forms of 'organisationally enabled connective action' (Bennett and Segerberg, 2012; Cieslik *et al.*, 2018) emerge and play a positive role in extension systems.

Enhancing the effectiveness and sustainability of new ICT supported innovation intermediation will require the resolution of the constraints mentioned, and thus the design and testing of alternative organisational and institutional arrangements surrounding these platforms. In addition, we suggest paying attention to user experiences in re-designing components of the two platforms. Similarly, we propose that the identification of possibilities for the further enhancement of innovation intermediation may benefit from a deeper analysis of more informal, inclusive and self-organised initiatives towards (new) ICT use, alongside forming a better understanding of the logic and strength of prevailing patterns of interaction and media-use around production advice and credit provision.

4

Chapter 4

Social media platforms, open communication and problem solving at the interface of research and extension in Ghana: a substantive, structural and relational analysis

Nyamwaya Munthali, Annemarie van Paassen, Cees Leeuwis, Rico Lie, Ron van Lammeren, Norman Aguilar-Gallegos and Birgitta Oppong-Mensah

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Abstract

Addressing new agricultural challenges may benefit from open communication among field extension agents and other actors who hold relevant expertise, including subject matter specialists and applied researchers. In this context, this article investigates the contribution of two social media messaging platforms, in Ghana, to facilitating open information sharing and interaction amid the emergence of a new pest, fall armyworm. Using a variety of qualitative and quantitative research methods, we analysed the types of content that were exchanged on the platforms, the characteristics of the networks in terms of the involvement of different actors in sending and receiving messages, and how such interaction patterns were influenced by social relations, self-representational interests and organisational set-ups and rules. The results indicate that both social media platforms are characterised by relatively centralised network and communication structures, suggesting that participation in especially sending messages is non-egalitarian. Such structural features are not very conducive to more complex knowledge processes such as knowledge integration and for joint problem solving. In line with this, the analysis of the actual knowledge processes taking place demonstrated that the platforms were used more for knowledge and information dissemination as well as for the distribution of notifications in support of organisational coordination. Moreover, our investigations suggest that social hierarchies, organisational rules and tactics related to identity management markedly influenced these patterns of interaction and posed constraints to open knowledge and information sharing. Nevertheless, the platforms play meaningful roles in supporting coordination of activities and information dissemination, and are likely to generate useful input for knowledge integration and collaborative problem solving in complementary face-to-face settings.

Keywords: social media; Agricultural Knowledge and Innovation System (AKIS); agricultural extension; fall armyworm; knowledge processes; network analysis; Ghana.

1. Introduction

In Ghana and elsewhere, linkages between local agricultural extension organisations and other organisation (research institutions) that hold relevant expertise are reportedly weak (Anderson, 2008; World Bank, 2012; Adolwa *et al.*, 2017). This organisational isolation is a major agricultural sector concern as it limits the quality of extension services delivered and hampers the kind of interaction and collaboration that is needed to access, integrate and distribute appropriate knowledge to address challenges that farmers face (Van Crowder and Anderson, 1997).

Currently, there is renewed emphasis on strengthening these organisational linkages as climate change modifies production conditions in farming systems (McIntrye *et al.*, 2009; Karmakar *et al.*, 2016; Schroth *et al.*, 2016). Climate change has led to the emergence of constraints and shocks that require updated knowledge and immediate action (Klerkx and Leeuwis, 2009; McIntrye *et al.*, 2009). The emergence of the fall armyworm pest in the Ghanaian maize farming system, in the 2016/2017 farming season, is an example of such a challenge putting pressure on Ghana's agricultural extension organisations to respond in new ways (Abrahams *et al.*, 2017; Day *et al.*, 2017; Godwin, Hevi and Day, 2017).

Like much of Africa, Ghana is currently experiencing an (new) Information and Communication Technology (ICT) revolution that has rapidly transcended the analogue and broadcasting-oriented media landscapes (World Bank, 2011). New ICTs include social media[17], such as Facebook and WhatsApp as well as Short Message Services (SMS), Interactive Voice Response (IVR) mobile applications, and mobile data collection and storage applications (Lister *et al.*, 2003). Such new ICTs have revolutionised how people communicate and connect (Ahmed *et al.*, 2019), for instance social media technologies are to able foster user-driven online networks for multi-actor engagement and interconnectivity (Bennett and Segerberg, 2012; Hansen *et al.*, 2014; Cieslik *et al.*, 2018;

[17]"Social media refer to technology artefacts that support various actors in a multiplicity of communication activities for producing user-generated content, developing and maintaining connections and social relationships, or enabling other computer- mediated interactions and collaborations,"(Van Osch and C. K. Coursaris, 2013:700)

Munthali *et al.*, 2018; Fielke, Taylor and Jakku, 2020). New ICTs present opportunities for local extension organisations to connect with relevant expertise through more informal networks[18]. Local extension organisations may for example utilise online networks alongside formal organisational communication structures to enhance interaction with subject matter specialists and applied researchers to respond to challenges such as fall armyworm. These networks may function as open communication spaces: multi-actor discursive spaces that side-step an organisation's official communication chain to support intra and inter-organisational linkages, and support equal access to information and free information sharing to integrate knowledge and jointly solve problems as well as widely and speedily disseminate farming-related solutions (Bennett, 1996; Sexton and Lu, 2009; Abouzeedan and Hedner, 2012).

Notwithstanding the opportunity for new ICTs to facilitate open knowledge and information exchange for the purposes of problem solving, there is limited scientific evidence of new ICTs' contribution to supporting such collaboration in African or agricultural settings (Van Osch and Coursaris, 2013; Ahmed *et al.*, 2019). Current literature on new ICTs' contribution mainly focuses on knowledge sharing via social media (specifically Facebook), but does not provide details on how this serves processes of knowledge integration and joint problem solving (Van Osch and Coursaris, 2013; Ahmed *et al.*, 2019). Ahmed et al. (2019) assess the current state of research regarding social medias' use in knowledge sharing and only identify two articles on Africa out of 103 that fit their inclusion criteria. Furthermore their study indicates that although the use of social media for knowledge sharing is a promising new research area, a better understanding of the processes involved is required (Phillips, Klerkx and Mcentee, 2018; Ahmed *et al.*, 2019; Fielke, Taylor and Jakku, 2020). Related to this call Osch and Coursaris (2013) in their review on 'organisation social media', a topic they state has received little attention, identify a number of research opportunities. These opportunities relate to understanding how social media platforms facilitate broader

[18] According to Klerkx and Proctor (2013) informal networks are more useful for open information and knowledge exchange in pluralistic extension systems - such as Ghana's (DAES, 2011) - that is also characterised by decentralised coordination which hampers these exchanges (Labarthe and Moumouni, 2008).

forms of collaboration and professional activities than knowledge sharing, alongside understanding how organisations use social media to meet their goals. These other forms of collaboration and professional organisational uses include knowledge co-production, learning, innovation, monitoring, relationship building, lobbying, advertising and marketing (Van Osch and Coursaris, 2013; Hansen *et al.*, 2014; Kane *et al.*, 2014b; Ahmed *et al.*, 2019).

Nonetheless, within the limited literature Materia *et al.* (2015) provide useful insight into new ICTs modest contribution to supporting knowledge sharing, in research on the role of virtual and non-virtual communication platforms in the Italian Agricultural Knowledge and Innovation System (AKIS)[19]. They establish that online virtual platforms play a complementary role of initiating or supporting real-life interaction in facilitating knowledge sharing and learning between researchers and extension service providers. Other authors, in Latin America and South Asia respectively report a similar complementarity between conventional communication methods and new ICTs in knowledge sharing (Perez-Perdomo, Klerkx and Leeuwis, 2010; Sulaiman *et al.*, 2012) and coordination (Colfer and Baldwin, 2016). Sulaiman *et al.* (2012) further suggest that the combination of communication mechanisms includes user-driven new ICT platforms such as Facebook that are emerging as powerful drivers of bottom-up collective action (e.g., the Arab Spring) (Bennett and Segerberg, 2012). Sulaiman *et al.* (2012) are critical with regard to expert (organisation) driven platforms for knowledge sharing based on their findings that most organisations in South Asian agricultural systems are still operating in a linear technology transfer manner and that their (new) ICT designs reinforce this approach rather than enable broader stakeholder interaction.

Overall, the literature suggests that user-driven new ICT platforms have the potential to facilitate improved ways of knowledge sharing when complemented with conventional communication methods. However, African studies on this topic are scarce, and there is a general lack of insight into the contribution of social media platforms to function as

[19] Organisations involved in agricultural extension, research and education (Adolwa *et al.*, 2017) as well as farmers, scientists and extension staff (Klerkx, van Mierlo and Leeuwis, 2012).

open communication spaces that support extension organisations and their immediate contacts in knowledge sharing, and broader forms of collaboration. This article aims to address this gap, and also contributes to the limited literature on the back-office activities of local extension organisations (Dhiab, Labarthe and Laurent, 2020), by studying the contribution of two linked social media messaging platforms in Ghana (one affiliated to an extension organisation and the other to a research institution) to enhancing information sharing, interaction and problem solving in the context of a newly emerging pest, fall armyworm that severely affected Ghana in the 2016/2017 farming season.

2. Analytical framework

Our study focuses on communication and interaction within extension organisations and among extension staff and applied researchers with expertise in pest management in the context of responding to an immediate threat. The literature on extension communication (Leeuwis, 2004) and social media networks (Carolan, 2014a, 2014b) suggests that it may be useful to analyse platforms actors' interactions along three dimensions. The first dimension relates to the type of content being exchanged in interaction (the substantive dimension). The second dimension relates to 'who communicates with whom', the structural dimension of interaction in the network that reflects on whether open communication is taking place over the platforms. Finally, it has been argued that communication has a relational dimension that is people are likely to manage their social status, identity, image and social relationships when interacting with others, which may in turn affect who communicates with whom about what (Goffman, 1959; Leeuwis, 2004). Below we elaborate on these interrelated dimensions and introduce the research questions following from this.

<u>The substantive dimension: knowledge processes and functions in pest and disease management.</u>

Literature on AKIS suggests that in order to support decision making and innovation in problem solving, relevant organisations in-country (including extension and applied research) should effectively work together in processes of knowledge and information "generation, transformation, transmission, storage, retrieval, integration, diffusion and utilisation" (Röling, 1990: 1). We assume that in order to deal with fall armyworm, extension and applied research organisations need to engage in several of the knowledge and information processes mentioned (e.g., generation, integration, diffusion, sharing, etc.), and also exchange problem solving content related to pest and disease management (e.g., pest alerts, pest identification, pest monitoring, control measures, etc.). In relation to such substantive exchanges, we recognise that the level of complexity involved in the various knowledge processes may differ. Processes such as diffusion or the sharing of a pest alert can typically be performed in a one-directional manner, while processes such as knowledge integration and the co-creation of solutions normally require open discussion and knowledge sharing among actors with diverse perspectives and experiences (Aarts and van Woerkum, 2005; Phillips, Klerkx and Mcentee, 2018). In this study, therefore, we explore the actual knowledge processes and substantive exchanges that are enacted on the social media messaging platforms.

The structural dimension: multi-actor engagement and decentralised communication in social networks

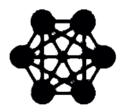
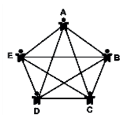
To understand the contribution of social media to multi-actor knowledge generation and problem solving processes, it not only important to consider the content exchanged on the platforms, but also the structure of content flows within the networks the social media platforms support. Such structures can be identified through social network analysis in which networks are defined as "a set of individuals or organisations [actors/nodes] and their relationships [edges/links],"(Kaushik *et al.*, 2018: 3). Social network theory seeks to explain the offline or online relationships amongst a set of actors (individuals, groups and organisations): why such relationships occur and how they influence actors' behaviour (Knoke and Yang, 2011), while social network analysis measures and represents the structure of actors' relationships (e.g., authority or power, association or affiliation, kinship and descent, transactional or communication relations (Wasserman and Faust, 1994; Knoke and Yang, 2011). As is detailed below, the structures through which actors communicate and interact may differ with regard to their level of (de)centralisation or openness. This resonates with the notion of open communication spaces that is based on the concept of open innovation. Chesbrough *et al.* (2006) define open innovation as a firm's process of (re)combining knowledge or co-creating it with a variety of stakeholders external to the firm to accelerate inter-organisational innovation and to expand the external use of innovation. The opportunities for online networking presented by social media (Haythornthwaite, 2002) may foster enhanced multi-actor engagement through the creation of new inter and intra organisational linkages as well as facilitate the emergence of open communication spaces that could support a variety of knowledge and information processes, including the opportunity to share and discuss information of various kinds amongst actors. In view of our interest in open communication spaces, the analytical focus of this study is on the implications of network structure for "communication relations - connections between actors that are channels through which messages may be transmitted" (Knoke and Yang, 2011: 8).

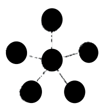
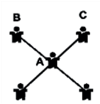
Network and communication structure

We identify to what extent the actors' connections (interactions) on the online social media platforms are (de)centralised, which simultaneously influences patterns of communication on the platforms. A network structure is centralised when there are many nodes (actors) with relatively few connections to others, and few or one node with an exceptionally high level of connectivity (Carolan, 2014b). In contrast, a network structure is decentralised when the number of connections per node is distributed more or less equally and when there are few nodes with an exceptionally high level of connectivity (Carolan, 2014b). The latter structure denotes a network has no dominant nodes and actors have equal influence in a network or equally contribute to the network (Carolan, 2014a). A decentralised network supports free information sharing and discussion - relevant to non-routine[20] problem solving, whilst a centralised network

[20] "According to Smedlund's typology, a centralised network has been found adequate for maintaining adequate knowledge in order to achieve operational effectiveness for what he calls 'routine problem solving' aimed at solving common problems which have a well-known solution space,"(Klerkx and Proctor, 2013: 16).

supports information dissemination and diffusion (Carolan, 2014a) - useful in routine problem solving. This shows that network structure is closely related to 'communication structure': that is, the pattern in which content or information flows in a social group (e.g., network or organisation) (Knoke and Yang, 2011). In the context of social media platforms the idea of network structure is by definition synonymous to communication structure since we study the exchange of messages; in other contexts there may also be other types of exchanges in the network (e.g., financial, goods, etc.). Figure 1 visualises and describes the type of decentralised (open) and centralised (wheel) communication structures associated with specific network structures that are relevant to this study. In the remainder of this contribution we will use the term network-communication structure to indicate the overlap in meaning of these two terms in the context of social media interaction discussed above.

<table>
<tr><th colspan="3">Network structure | Communication structure</th></tr>
<tr><td colspan="2">Decentralised</td><td rowspan="2">This structure facilitates a many-to-many communication flow. Therefore, each member has equal access to the information shared in the group and the freedom to communicate with any other group member.</td></tr>
<tr><td>
Fully connected</td><td>

Open</td></tr>
<tr><td colspan="2">Centralised</td><td rowspan="2">This structure facilitates a one-to-many and vice versa communication flow. Therefore, a single person or few individuals are pivotal and supply information to the other members, and the other members engage with these central actors.</td></tr>
<tr><td>
Star</td><td>

Wheel</td></tr>
</table>

Source: Bicsi, 2002; communicationtheory.org 2020

Figure 1. Centralised and decentralised network structures and associated communication structures

<u>The relational dimension: social factors influencing dynamics of interaction</u>

The content and structure of communication and interaction on social media platforms may be influenced by various types of social factors. This reflection is based on the notion that society and technology mutually shape each other (Scarbrough, 1992), whereby social interests and dynamics of power are likely to play a role. Therefore, beyond the technological potential of new ICTs to open opportunities for and incite new types of communication, we view technologies and organisations as intertwined based on two considerations.

Firstly, social roles and identities (e.g., supervisor, subordinate or expert, non-expert, etc.), and related authority or responsibility configurations, may influence dynamics of interaction on the platforms (Jones *et al.*, 2006) in ways that open up or close down open knowledge and information sharing. According to Halliday (1994), actors in interaction assume discourse identities (questioner, answer provider, giver, receiver) that are shaped by social roles and related ideologies (Kress, 1985; Halliday, 1994). Based on Halliday's functional-semantic view of dialogue, these discourse identities that position both the speaker and the potential respondent in interaction involve conversational moves - various initiating moves (statements, offers, questions, and commands) and various responding move (acts of acknowledgement, agreement, rejection, contradiction) (Jones *et al.*, 2006). Social relations and identities may enable or constrain the conversational moves (types of messages) that are available to particular actors, thus influencing whether free information sharing and discussion occurs.

Social roles and identities also influence interactional dynamics because actors may opt out of information sharing and discussion in view of self-representational interests. According to Goffman's theory on social interaction, actors in (face-to-face) interaction naturally engage in various defensive and impression management strategies to achieve specific and tacit interactional objectives (Goffman, 1959). Thus, actors on social media platforms may, for example, abstain from interaction to save face that is to "prevent feelings of failure, embarrassment, incompetence and inferiority," (Aarts and van Woerkum, 2002: 426).

Another set of factors relates to how organisational choices, strategies and set-ups may impact communication and interaction on social media platforms. In connection with this we need to consider that organisations involved in technology development or application make design choices (Williams and Edge, 1996), either intentionally or unintentionally. This implies that there is scope for organisations to shape new ICTs' design to a preferred purpose and outcome, modelling them to fit their existing organisational structure and associated chain of communication (MacCormack, Baldwin and Rusnak, 2012). Thus, the type of content shared over the social media platforms, the actors involved and how content flows between actors may be influenced by strategic choices, power configurations and organisational set-ups.

From this analytical backdrop the central question of the study emerges: what is the contribution of social media platforms (WhatsApp and Telegram) to facilitating open communication to support knowledge processes and collaborative problem solving among extension staff and applied researchers in the context of a newly emerging pest (fall armyworm). More specifically, this study aims to establish:

1) The type of content shared on the platforms: what kinds of knowledge and problem solving processes take place on these platforms, and what is the content of the information that is exchanged?

2) The network-communication structure of the platforms: how do platform actors connect with each other and what is the resulting degree of (de)centralisation?

3) The relational dynamics and social factors shaping interaction on the platforms: how do different roles, identities and interests manifest themselves on the social media platforms and how does this relate to the prevailing network-communication structure?

3. Methods

In this section we provide insight into the emergence of fall armyworm in Ghana. We then provide a brief description of the cases studied, and explain how data collection and analysis proceeded to align with the study objectives.

<u>Emergence of fall armyworm</u>

Research and extension in Ghana are under pressure to respond to new challenges emerging in the agriculture sector as a result of climate change (McIntrye *et al.*, 2009).

The emergence of the fall armyworm pest in the Ghanaian maize farming system is an example of one of these challenges. Fall armyworm is a pest with origins in the Americas that emerged in Ghana around 2016 due to favourable weather and temperatures caused by climate change (Abrahams *et al.*, 2017). Fall armyworm impacted severely on the Ghanaian agricultural sector during the farming season 2016/2017. From the perspective of Ghanaian farmers, the pest led to an average maize loss of 45% (range 22-67%) in 2017 (Day *et al.*, 2017; Kassie *et al.*, 2020). The emergence of this new pest not only introduced shocks and uncertainty into the Ghanaian maize farming system, but also put pressure on extension and research organisations to monitor real-time pest occurrences, establish appropriate pest control measures and roll out a mitigation strategy speedily (Abrahams *et al.*, 2017).

Case selection and description

During 2017, when efforts to respond to the fall armyworm infestation were in progress, the research team was simultaneously studying the application of new ICTs by public and private extension organisations in the Brong-Ahafo Region. During this period we identified two linked social media messaging platforms that were in use by the MOFA - Wenchi District Food and Agriculture Department (DFAD) (the public extension organisation) and the Plantwise Programme of the Centre for Agriculture and Bioscience International (CABI), Ghana. The platforms were linked as select extension agents of the MOFA-DFAD were members of both platforms.

MOFA-DFAD WhatsApp platform

The MOFA-DFAD is a public extension organisation that engages in frontline diagnosis of crop pest and diseases, and advises farmers (and other agricultural value chain actors) on appropriate control measures. Additionally, it conducts on-farm-adaptive technology field trials with researchers and collects data on farmer’s knowledge demands. This organisation established the WhatsApp platform in 2017. Initiated by a middle level manager (DAO – see description below), it was primarily developed for social purposes and later unofficially adapted to improve information flows between DFAD managers and extension agents.

The entire DFAD staff of 34 persons[21], comprising extension field staff and managers, were included on the platform (Figure 2). Extension field staff comprised Agricultural Extension Agents (AEAs), Youth Extension Agents (YEAs) and National Service Personnel interns (NSPs). The management team included the DFAD Director and the District Agricultural Officers (DAOs) who are specialised middle management officers that are directly supervise extension field staff. Participating middle management officers included: a crops officer, senior veterinary officer, and management information systems officer, women in agriculture officer, agriculture engineering officer and agricultural marketing officer. The other actors on the platform were finance and administrative staff.

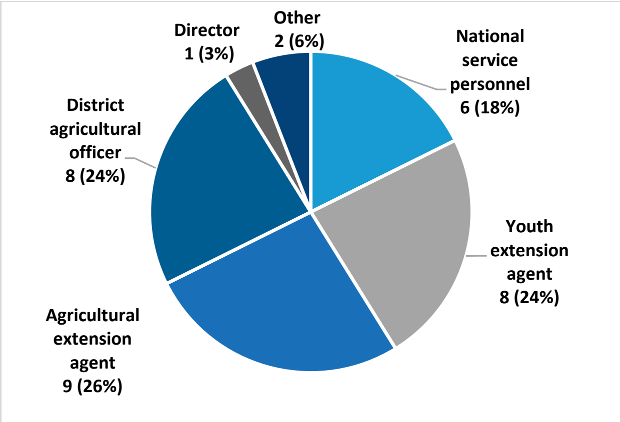


Figure 2. MOFA-DFAD WhatsApp platform actor composition

CABI-Plantwise Telegram platform

The other organisation identified that was coordinating a social media platform was CABI, an international research institution. Through the Plantwise global programme, CABI engages in research to identify (new and re-emerging) pests/diseases and their management strategies. Further their role is to detect pest/disease risks and spread

[21] At the initiation of the study in May 2018 the MOFA-DFAD office had 34 staff members. However, in terms of actors on the platform for the period of analysis the figure increased by 3 as more actors, new members of staff, were included on the platform.

awareness of these risks, and engage in training of frontline extension staff to support farmers in accessing appropriate plant health advice to minimise their crop losses to pests and diseases. CABI works with a national implementing partner, the MOFA-Plant Protection and Regulatory Services Department (PPRSD), to achieve the Plantwise Programme objectives. CABI established the Plantwise Telegram platform in 2016 to improve knowledge flows and diagnostic support between a nationwide network of public extension agents (trained as plant doctors) and various crop protection subject matter specialists. This moderated platform was preceded by an informal WhatsApp group initiated by a MOFA-PPRSD district level manager to share and source information. Similar to the DFAD WhatsApp platform, extension agents formed the bulk of the 230[22] actors on the CABI-Plantwise Telegram platform (Figure 3). In the rationale of CABI, AEAs and DAOs (extension staff) had relatively less scientific expertise about pests and diseases, whilst subject matter specialists had high-level scientific expertise: agronomists, pathologists, entomologists, taxonomists and extension advisors from various organisations and in various geographical locations. CABI and PPRSD staff (at HQ and district level), who were also the platform coordinators, made up two-thirds of the specialist population.

[22] At the initiation of the study in May 2018 the platform had 230 members. However, in terms of actors on the platform for the period of analysis the figure increased by 5 as more actors, new plant doctors or specialists, were included on the platform. For unknown actors, these could be attributed to already existing platforms actors re-joining the platform with new numbers.

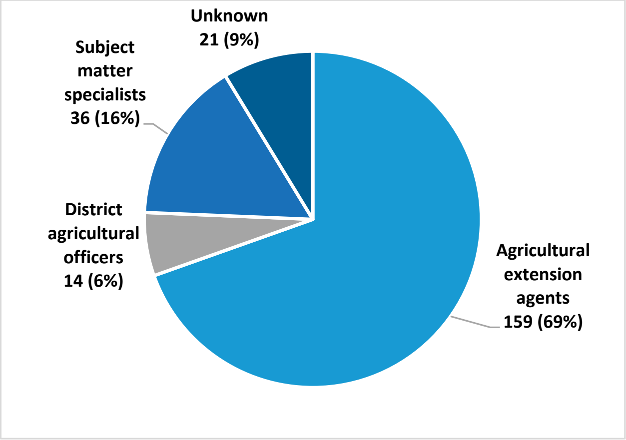


Figure 3. CABI-Plantwise Telegram platform actor composition

Data collection and analysis

Data collection for the study involved accessing records of interaction for both platforms and user surveys. These methods are described below alongside the technique used to analyse the data collected.

Accessing records of platform actors' interaction

Permission was requested from the organisations above to observe interaction on the platforms. Permission was granted by the organisations and the principle researcher was added to the WhatsApp and Telegram groups. We specifically accessed interaction data for the DFAD WhatsApp platform from July 2017 to June 2018 and for the Plantwise platform from April 2017 to June 2018. The data accessed was from the earliest date possible in 2017 until June 2018. This data was sufficient to cover analysis for part of the 2016/2017 farming season, the season fall armyworm appeared. Further, the data covered a full maize production cycle, in the minor season of 2017/2018, and enabled the analysis of how the pest was being managed the season following its' emergence. To analyse the interaction data, we exported data on platform interactions into text files using the export function available on both WhatsApp and Telegram applications. The text files on platform actors' interaction data were then uploaded into ATLAS.ti software for content analysis and for processing to apply social network analysis.

Content analysis, complemented by descriptive statistical analysis, was applied to the platform actors' interaction data to achieve two outcomes. Firstly, to establish the type of content (messages) posted on both platforms and the frequency of posting. For this study, a message was defined as a complete idea communicated to platform actor(s) in a single post or multiple posts if subsequent posts were a continuation of the initial post. Further, we applied an iterative coding method (Srivastava and Hopwood, 2017) and built the core coding scheme on Halliday's functional-semantic view of dialogue that highlights a broad set of initiating and responding moves that occur in interaction (e.g., commands and act acknowledgements) (Halliday, 1994; Jones *et al.*, 2006). We formulated the core coding scheme by identifying possible sets of initiating and responding moves (messages) that related to knowledge sharing and problem solving. However, we kept the scheme open to capture types of messages that emerged during the coding process – see Appendix 1: 158 for the detailed coding scheme.

Secondly, through content analysis and as part of determining the relational dynamics on the platforms, we identified the actors involved in posting specific types of initiating and responding messages and the extent to which they posted them. We applied this method of analysis to the message categories 'knowledge sharing for problem solving' and 'notifications', as these emerged as the main professional content shared over the platforms (see Figure 5 and 6).

In addition, we applied social network analysis to the interaction data to determine the network-communication structure of the platforms. To facilitate the analysis, we developed adjacency tables for nodes (labels of network actors) and for edges (connections between actors) for both platforms. The node tables specified the name and designation of platform actors, and the edge tables showed which actor directed a message at another actor (see the example in Figure 4). We uploaded the adjacency tables onto Gephi graph visualisation software.

Nodes **Edges**

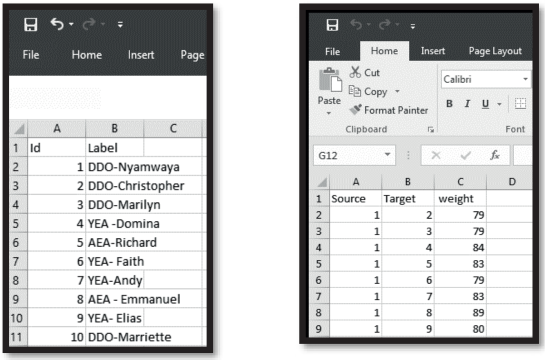


Figure 4. Example network nodes and edges adjacency table

Using Gephi software we calculated and visualised three measures, based on certain assumptions and conditions, to determine the network-communication structure of the platforms (Table 1). Firstly, at network level we calculated and visualised network density to establish the extent to which all the potential connections between platform actors were present in the network (Farr, Reed and Pejchar, 2018). This measure served as an indicator of platforms actors' general level of interconnectivity. Secondly, at node level, we calculated the clustering coefficients of all platform actors and visualised them as distributions to establish the actors' "tendency to group in pockets of dense connectivity" (Carolan, 2014b). This measure served as an indicator of the extent of interconnectivity around individual actors in the networks.

Table 1. Social network analysis indicators and interpretation in the research context

Definition of measure and interpretation	Assumptions/ conditions	Type of network-communication structure	
		Centralised	**Decentralised**
Network level of analysis			
Network density: the number of connections between nodes in a network expressed as a proportion of the total number of connections that are possible. Network density ranges from 0 (no connections in the network) to 1 (all possible connections in a network are present). High network density shows that networks actors are densely interconnected.	1 and 2	Low X < 0.6	High X ≥ 0.6
Node level of analysis			
Clustering coefficient for in-degree and out-degree: shows the extent to which all the actors linked to a specific node are connected to each other. Measuring this involves establishing for each network actor (the ego) the actors it is linked to (neighbours), and then representing through a ratio the extent to which the ego's neighbours are connected to each other. If the node's neighbours are fully connected the clustering coefficient is 1, whilst a value of 0 means there are no connections among neighbours. This coefficient can be measured in terms of in-degree (related to receiving messages) and out-degree (related to sending messages). A clustering coefficient distribution with most actors having a high clustering coefficient shows a network has numerous pockets in which actors (egos) have densely interconnected neighbours, and indicates that there are reciprocal connections in the egos local network that support content exchange and discussion.	1, 3, 4, 5, 6 and 7	≥ 60% of nodes = X < 0.6	≥ 60% nodes = X ≥ 0.6
Degree distribution: the degree is the number of connections for each node. These connections can be measured as in or out-degrees. An egalitarian degree distribution indicates there are no dominant networks actors, and there is equal contribution of actors in the network and free content sharing.	1,4,5,6 and 7	Long-tale distribution	Egalitarian distribution

Assumptions and conditions of analysis

1. A message was defined as a complete idea communicated to platform actor(s) in a single post or multiple posts if subsequent posts were a continuation of the initial post.
2. We calculated undirected as opposed to directed network density, with a weight of '1' attached to each connection, to show the connection between actors regardless of which actor-initiated contact or the number of times a connection was made between actors.
3. We calculated the measure considering the direction of the connection.
4. For in-degree we considered that initiating messages that were untargeted were sent to all platform actors.
5. For out-degree we considered only targeted messages sent by actors.
6. For in-degree we excluded messages received by unknown actor (unidentified actors).
7. For out-degree we excluded messages sent by unknown actors (unidentified actors).

Source: authors with insights from Carolan, 2014

Lastly, and also at node level, we visualised frequency distributions that showed the number of connections each actor had with other actors in the network (Wasserman and Faust, 1994). Through the visualisations, we determined the type of distribution for the in-degrees and out-degrees of the platforms.

User survey

Aside from the content analysis and social network analysis we conducted a complementary online survey to gain insight into how platform actors experienced interaction on each platform. The survey questionnaire was developed with insight from key informant interviews with senior managers from each organisation, the platforms' initiator and administrator, and two extension agents from the DFAD that were on both platforms. These interviews provided preliminary insight into two broad areas: 1) the general use and perceived value of the platforms when compared to prevailing communication mechanisms for specific organisational activities; and 2) factors seen as hampering or enabling interaction on the platforms. The insights from the key informant interviews were used to formulate questions and statements on which a broader selection of platform users could indicate their level of (dis)agreement using a five-point Likert scale. The questionnaire also included open ended questions to capture unprompted views from respondents on the above topics. It was expected that these user evaluations could support the interpretation and explanation of the observed dynamics of interaction over the platforms as well as highlight the value of the platforms for users.

The survey response rate was 77.1 % (27 of 35) for the DFAD staff and only 23.9% (55 of 230) for the actors on the Plantwise platform. We faced challenges in getting responses from Plantwise platform actors as they were widely distributed across Ghana, unlike the DFAD office staff. Their dispersion made it difficult to follow them up in person to provide them with a device with internet access and prompt them to fill out the survey. However, the responses received were sufficient for valuable insights into user perceptions of the Plantwise platform's function and interactional dynamics. Data from the online survey were analysed using the automated analytics of Google Forms, generating descriptive statistics.

4. Findings

In this section, research findings are presented under sub-sections that relate to the study objectives.

Content exchanged on the platforms

Types of messages shared on the platforms were identified and grouped into five categories (Table 2). The first category 'knowledge sharing for problem solving' encompassed messages that outlined or contributed to resolving problems, and the second category 'knowledge dissemination' encompassed messages related to knowledge sharing for the purposes of education and information. 'Pest/disease monitoring', the third category, incorporated notifications from field staff of pest/disease occurrences and official notifications of a pest/disease threats. The fourth category 'notifications' incorporated communication on tasks or activities scheduled, pending, in progress or completed, and the final category 'social' was associated with recreational and other non-work-related messages.

Table 2. Categories of messages shared on the MOFA-DFAD WhatsApp and CABI-Plantwise Telegram platform

Categories of messages	Type of messages	MOFA-DFAD WhatsApp platform	CABI-Plantwise Telegram platform
Knowledge sharing for problem solving	Knowledge gap stipulation	✔	✔
	Pest/disease identification	✔	✔
	Prescription provision	✔	✔
	Practical problem stipulation	✔	✔
	Practical problem solution	✔	✔
Knowledge dissemination	Lectures	✖	✔
	Working solution sharing	✖	✔
	Technical information sharing	✔	✖
	Innovation sharing	✔	✔
Pest/disease monitoring	Pest/disease occurrence	✔	✔
	Pest/disease alert	✔	✔
Notifications	Activity annoucement	✔	✔
	Practical annoucement	✔	✔
	Agricultural news/update	✔	✖
	Directive	✔	✔
	Field activity report	✔	✔
Social	Joke	✔	✔
	Inspirational message	✔	✖
	Crime alert	✔	✖
	Bible quotation	✔	✖
	Job advertisement	✔	✖
	Non-agricultural news	✔	✖

✔ shared over platform ✖ not shared over platform

There were distinct differences in the main categories of messages shared on the platforms (see Figures 5 and 6). The DFAD platform was dominated by 'social' messages. Moreover, in relation to extension service delivery, 'notifications' were the main category of messages shared on this platform (Figure 5). According to some DFAD staff socialising played an important role on this platform. In the survey, two DFAD staff stated that socialising relieved tension on the platform and motivated actors to engage.

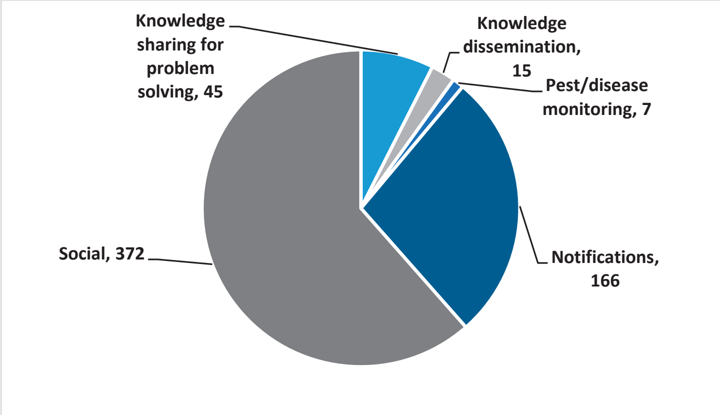


Figure 5. Proportions category of messages shared on the MOFA-DFAD WhatsApp platform

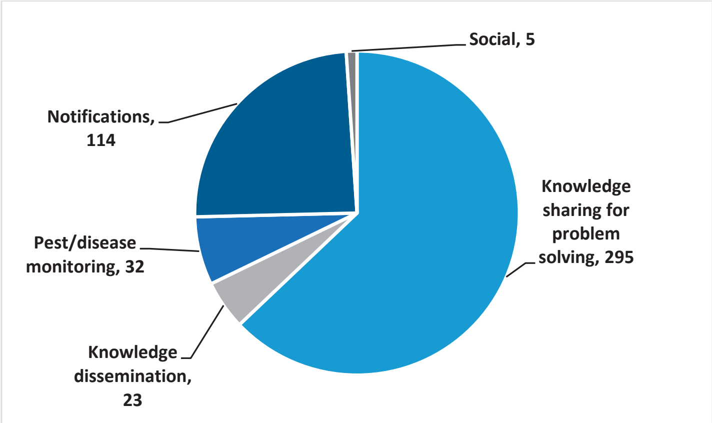


Figure 6. Proportions category of messages shared on the CABI-Plantwise Telegram platform

On the Plantwise platform, most of the messages fell under the category ‘knowledge sharing for problem solving’ (Figure 6), while ‘social’ messages were virtually absent. Here too, ‘notifications’ were quite prevalent. On both the DFAD platform and Plantwise platforms, there were few messages related to ‘pest/disease monitoring’ and ‘knowledge dissemination’.

<u>Platforms’ perceived usefulness in supporting knowledge processes in fall armyworm management</u>

In addition to the observed substantive exchanges, platform users also expressed their views on the value attached to each platform. In general, the survey data revealed that the professional value DFAD staff attached to the WhatsApp platform was broader than the earlier observed emphasis on exchanging 'notifications' (see Figure 5 and Table 3). Aside from improving coordination of extension field activities, a very high percentage of respondents (strongly) agreed the platform's value also lay in enabling personal learning (91.3%), improving pest identification skills of staff (82.6%) and disseminating pest and disease threats speedily (95.7%).

Table 3. Actors' perceptions of value of MOFA-DFAD WhatsApp platform

Value statements	Strongly agree	Agree	**(Strongly) Agree %**	Neutral	**Neutral %**	Disagree	Strongly disagree	**(Strongly) Disagree %**
Improves information flow in office	14	9	100.00	0	0.00	0	0	0.00
Enhances team coordination	14	9	100.00	0	0.00	0	0	0.00
Cheaper method of information exchange	10	10	86.96	3	13.04	0	0	0.00
Enables personal learning	10	11	91.30	1	4.35	1	0	4.35
Improves pest/disease identification of staff	10	9	82.61	2	8.70	0	2	8.70
Faster dissemination of pest/disease threats	14	8	95.65	1	4.35	0	0	0.00
Faster method of field monitoring	7	10	73.91	2	8.70	3	1	17.39
Faster method of receiving field (activity) reports	11	11	95.65	0	0.00	0	1	4.35

Similarly, the Plantwise platform survey data revealed that the perceived value of the platform was broader than the dominant usage observed. The most highly appreciated contribution related to improving the knowledge base of users, which arguably links well with the observed emphasis on knowledge sharing for problem solving (see Figure 6 and Table 4). Here too several other value statements were responded to in a highly positive manner (agree or strongly agree), including enabling personal learning (90.9%), facilitating timely identification of pest risks (80%), responding to these risks (83.6%) as well as facilitating a cheaper mechanism of responding to pest/disease threats (78.2%).

Table 4. Actors' perceptions of value of CABI-Plantwise Telegram platform

Value statements	Strongly agree	Agree	**(Strongly) Agree %**	Neutral	**Neutral %**	Disagree	Strongly disagree	**(Strongly) Disagree %**
Enables personal learning	22	28	90.91	3	5.45	2	0	3.64
Enhances knowledge base of plant protection staff/AEAs	31	22	96.36	2	3.64	0	0	0.00
Improves pest/disease diagnosis and controls provided by plant protection staff/AEAs	30	19	89.09	6	10.91	0	0	0.00
Cheaper method of providing refresher training	20	23	78.18	9	16.36	3	0	5.45
Faster identification of pest/disease risks	25	19	80.00	11	20.00	0	0	0.00
Faster responses to pest/disease risks	21	25	83.64	8	14.55	1	0	1.82
Cheaper method of responding to pest/disease threats	19	24	78.18	7	12.73	4	1	9.09

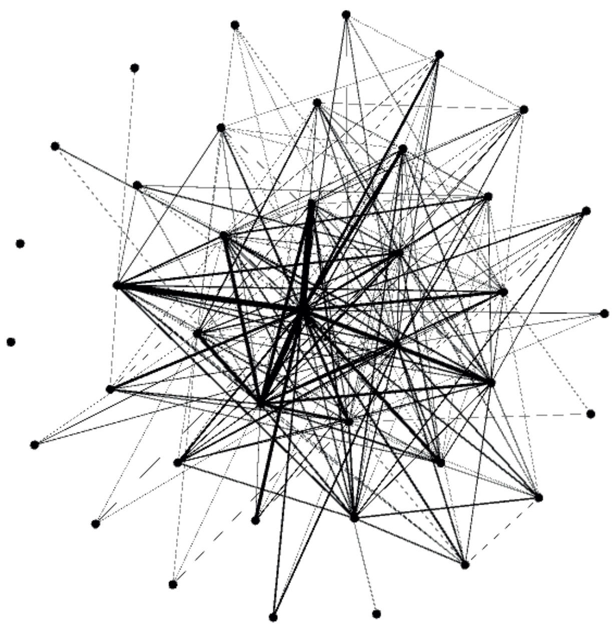
In relation to fall armyworm management, the perceived value of both platforms lay in early detection of the new pest, alerting and raising awareness of stakeholders, and disseminating controls. In relation to this, a key informant from CABI stated that in the initial stages of the infestation there were a number of platform posts showing pictures of infested maize plots. When the frequency of such posts increased, while no prescription was being provided, the problem was seen by CABI and PPRSD as escalating and prompted laboratory testing to identify the pest. The key informant further explained that once the pest was identified and reported to the authorities (MOFA headquarters) as a new threat, a stakeholder meeting was organised to establish how the fall armyworm infestation would be managed. Another key informant from PPRSD added that once appropriate control measures for the pest were established by the stakeholder meeting, awareness creation on the pest and dissemination of its controls followed through various channels. Through the platform content analysis, we observed that these channels included both the Plantwise platform in the form of lectures and as responses to subsequent posts on challenges in identifying or diagnosing fall armyworm and the DFAD platform in the form of technical information sharing messages and bulletins. Another key informant from PPRSD and the two extension agents interviewed

4

that were on both platforms added that social media platforms were a cheaper and faster channel of disseminating pest alerts than prevailing mechanisms (emails and phone calls), and sped up the response to controlling the infestation.

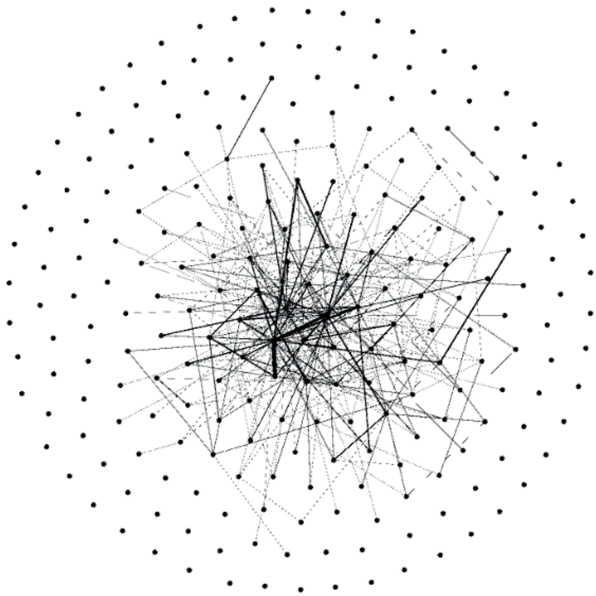
Platforms' network and communication structures

Based on network density and clustering coefficient distributions, we established that the DFAD platform had higher interconnectivity than the Plantwise platform. The network density of the DFAD platform was 0.3 with 94.7% (36 of 38) platforms actors being connected to another platform actor by either sending or receiving messages (Figure 7). In comparison, the Plantwise platform had a lower network density of 0.01 with 42.6% (97 of 235) of platform actors not having a single connection to another platform actor (Figure 8). However, despite the DFAD platform having higher interconnectivity than the Plantwise platform, both platforms scored a low network density that was less than 0.6.



Network density undirected: 0.3; Network size: 38

Figure 7. Network density MOFA-DFAD WhatsApp platform



Network density undirected: 0.01; Network size: 235

Figure 8. Network density CABI-Plantwise Telegram platform

In relation to the clustering coefficient distributions of the platforms, we observed for the in-degree distribution that all nodes (actors) in the DFAD platform had a high clustering coefficient greater than 0.6, while this was also true for most nodes (actors) in the Plantwise platform (Figure 9 and 10). Further, the platforms' average clustering coefficient was higher than 0.6 in both cases (the average coefficient of the DFAD platform was 0.78 and that of the Plantwise platform 0.76. Collectively these findings indicate that both networks had a decentralised and open structure when it comes to receiving messages from others in the network.

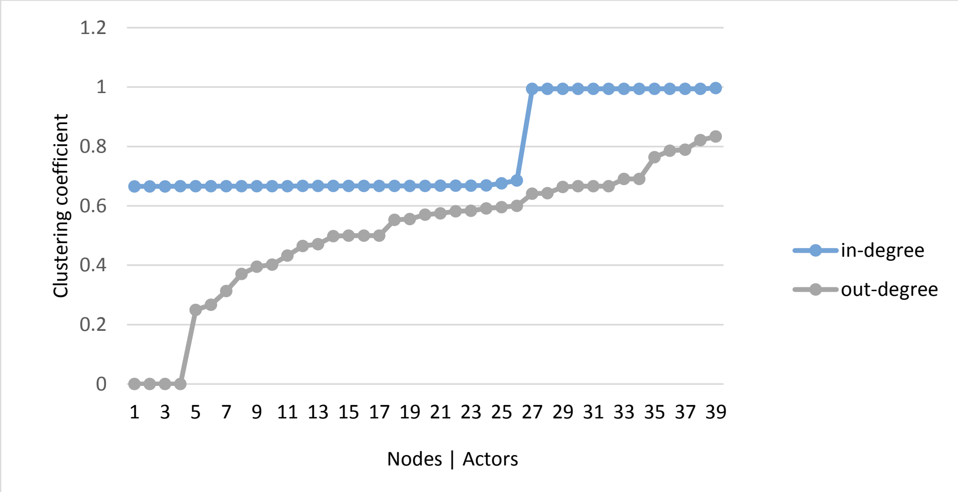


Figure 9. In-degree and out-degree clustering coefficient distribution MOFA-DFAD WhatsApp platform

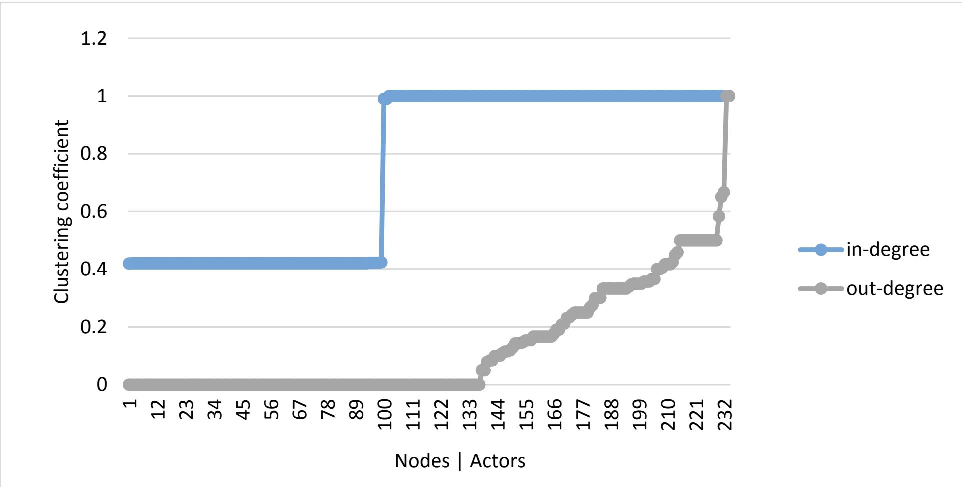
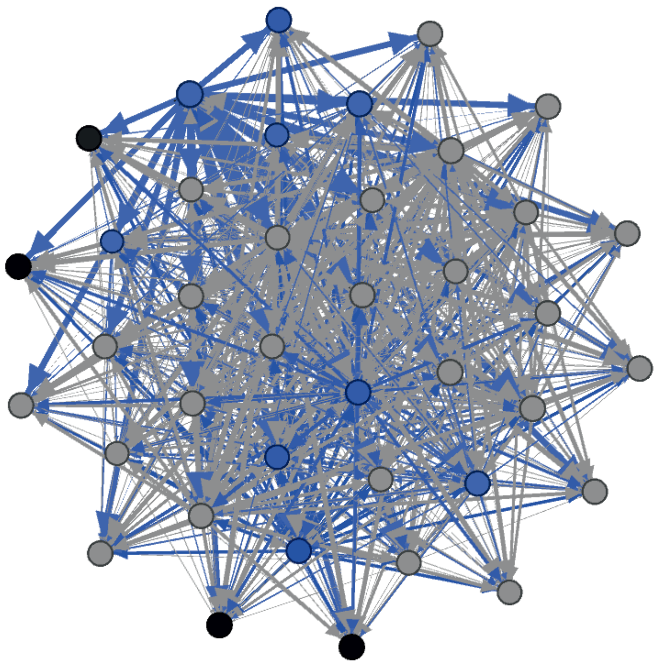


Figure 10. In-degree and out-degree clustering coefficient distribution CABI-Plantwise Telegram platform

However, in relation to the out-degree clustering coefficient distribution the data for both platforms revealed that most actors had a low clustering coefficient - lower than 0.6 (Figure 9 and 10). Additionally, the DFAD platform had an average clustering coefficient of 0.51 and the Plantwise platform 0.13. Therefore, both platforms scored a lower average clustering coefficient for out-degrees than for in-degrees. Moreover, the Plantwise platform scored a noticeably lower average clustering coefficient for out-degrees in comparison to the moderate score of the DFAD platform. This indicates that both networks had a relatively centralised structure when it comes to sending messages to others in the network, with the Plantwise platform being considerably more centralised than the DFAD platform.

Moving to the type of degree distribution of the platforms for different types of participants (as related to the platforms' level of egalitarian participation), we established that the degree distribution for both platforms was similar. For both platforms, the in-degree distribution values were evenly distributed over the different types of actors – as reflected in a limited variation in node sizes in each network (Figure 11 and 12). Therefore, for both platforms there were no particularly prominent nodes or actors in the network with regard to receiving messages.



Number of in-degrees: 1004; Average in-degree: 25.69

Figure 11. In-degree distribution visualisation MOFA-DFAD WhatsApp Platform

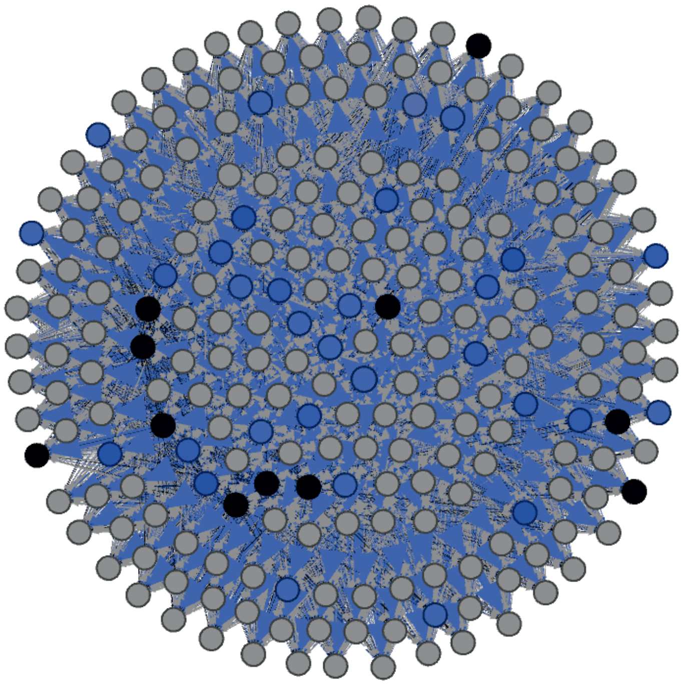
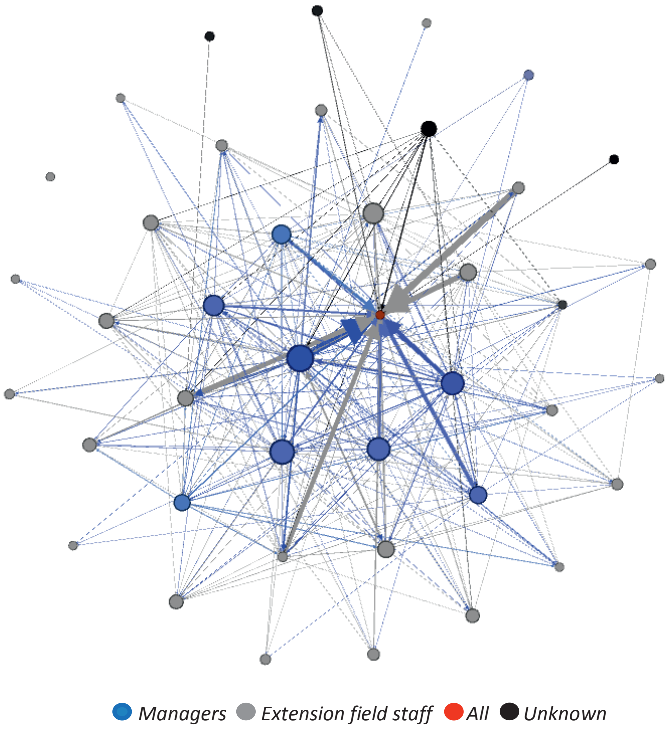


Figure 12. In-degree distribution visualisation CABI-Plantwise Telegram Platform

However, the out-degree distribution of both platforms showed that few platform actors accounted for the bulk of messages sent in the networks – as reflected in the noticeable variation in node sizes in the network (Figure 13 and 14). However, the average out-degree for the DFAD platform was much higher than that of the Plantwise platform, suggesting a relatively more egalitarian participation in sending messages for the former. In the case of the Plantwise platform, we found that some actors did not have any connections at all which indicates that they had not sent any messages (see Figure 14). These findings suggest that the platforms had some dominant actors with regard to sending messages. The dominant actors on the DFAD platform were mainly the managers, while on the Plantwise platform we see that dominant actors included a few actors with high scientific expertise as well as some extension staff.

A plausible explanation for the DFAD platform having an out-degree distribution that was much closer to an egalitarian distribution than the Plantwise platform, and a higher average out-degree clustering coefficient, relates to the social nature of the DFAD platform (see Figure 5). This arguably made it less restrictive in terms of the type of messages that actors could share than the Plantwise platform which had rules of interaction to ensure that it was only used for knowledge sharing and problem solving. Six survey respondents on the DFAD platform stated they posted messages on the platform anytime they felt like it and 10 stated that sharing social messages on the platform was beneficial to keeping actors motivated to engage and creating a relaxed atmosphere for sharing. Such motivations were not prominent for the Plantwise platform: here a substantial proportion of survey respondents (20 of the 55) stated they were motivated to post messages when they had a problem that was beyond their capabilities.



Number of out-degrees: 361; Average out-degree: 8.81

Figure 13. Out-degree distribution visualisation for the MOFA-DFAD WhatsApp platform

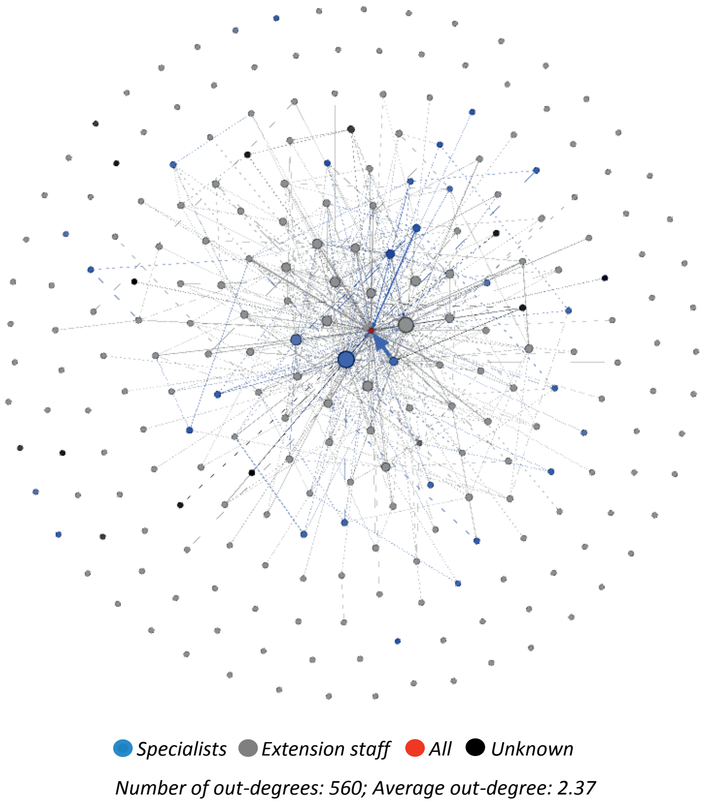


Figure 14. Out-degree distribution visualisation for the CABI-Plantwise Telegram platform

Finally, our network analysis suggests that for both platforms, the average in-degree was noticeable higher that the average out-degree. This indicates that the platform actors mostly received messages as opposed to sending them.

Overall from this section we established that the platforms possessed centralised network and communication structures - suggesting that platform users participation in especially sending messages over the platforms was non-egalitarian. Therefore, the platforms did not facilitate open communication spaces. However, the user survey indicated that platform actors did not only value and use the platforms for interaction. Instead, many actors used the platform by reading posts. On the DFAD platform, 73.9% of respondents stated they read posts daily, compared to 53.4% on the Plantwise platform.

Platform actors' key relationships shaping interactional dynamics

A number of relationships central to interaction on the platforms were identified through key informant interviews. Based on the set-up and observed dominant professional usage of the DFAD platform (notifications for purposes of management and coordination), a key relationship among platform actors was that between supervisors (managers – DAOs and Directors) and supervisees (extension field staff – NSPs, YEAs, AEAs). Similarly, on the CABI-Plantwise platform, the main relationship that emerged as relevant in the context of knowledge sharing for problem solving (the dominant usage) was that between subject matter specialists and extension staff.

Key relationships and knowledge sharing for problems solving

Although the DFAD platform was dominated by other forms of usage, it also had significant 'knowledge sharing for problem solving' activity (see Figure 5). In relation to this, we established that DFAD managers (the director and DAOs) as supervisors were more actively involved in responding to problems posted (mostly by extension field staff) on the DFAD platform (see Figure 15 – results bars 'knowledge gap stipulation response' and 'practical problem solution' combined). Hence, horizontal exchange among extension field staff was limited.

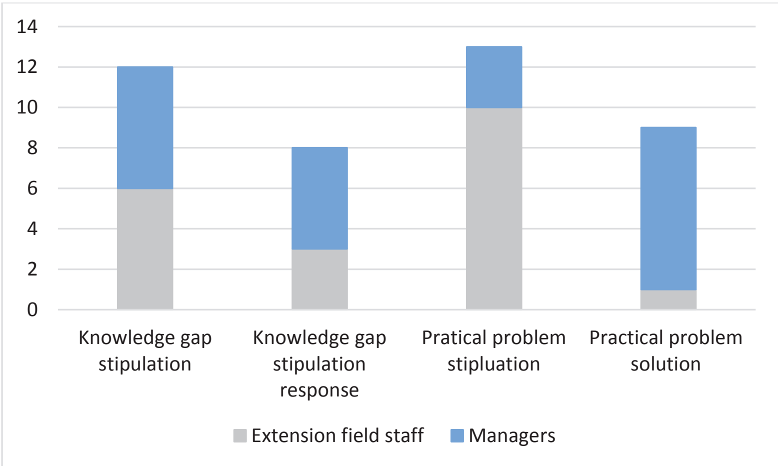


Figure 15. Extent actors posted initiating and responding message related to knowledge sharing for problem solving on the MOFA-DFAD WhatsApp platform

DFAD key informants expressed that active participation of DAOs in these activities could be attributed to the fact that DAOs were subject matter specialists that extension field staff were required to consult regularly. In line with this, most DFAD staff (>60%) expressed in the user survey that the main factors that hindered field staff from participating in knowledge sharing was that field staff were inclined to give actors with expertise (managers) the space to advise out of respect and also that field staff were concerned about providing wrong answers in the presence of superiors (managers) (see Table 5). Interestingly, one manager stated that he hesitated to participate on the platform when incorrect solutions were provided by others to avoid creating tensions. Instead, he opted to provide the correct solution in private conversations.

Table 5. Reasons for actors' inactivity on MOFA-DFAD WhatsApp platform

Reasons for actors' inactivity	Strongly agree	Agree	**(Strongly) Agree %**	Neutral	**Neutral %**	Disagree	Strongly disagree	**(Strongly) Disagree %**
Low confidence in knowledge level	2	8	43.48	8	34.78	4	1	21.74
Respectfully give space to more knowledgeable actors to respond	4	11	65.22	5	21.74	3	0	13.04
Fear of suggesting wrong solution in superiors' presence	3	11	60.87	4	17.39	3	2	21.74
Fear solution provided will be refuted by specialists	3	8	47.83	5	21.74	5	2	30.43
Feel knowledgeable actors dominate discussion making it difficult to engage	3	10	56.52	3	13.04	6	1	30.43

Key informants from CABI reported that the Plantwise platform was set-up to position extension agents as knowledge recipients from staff with specialised crop protection knowledge. However, the analysis of interaction on the Plantwise platform around 'knowledge sharing for problem solving' revealed that the specialists were not providing solutions on the platforms. Instead, extension agents and DAOs (extension staff) also actively engaged in providing solutions to problems that their immediate colleagues (other AEAs and DAOs) posted on the platform (Figure 16).

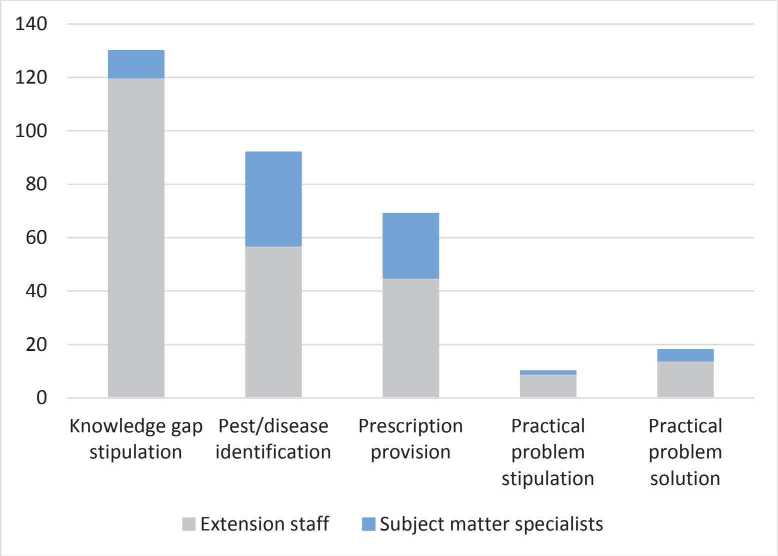


Figure 16. Extent actors posted initiating and responding messages related to knowledge sharing for problem solving on the CABI-Plantwise Telegram platform

The unanticipated high involvement of those who were supposed to be at the receiving end of solutions and prescriptions on the platform was attributed by three survey respondents to specialists being (a) too busy and (b) too few to respond to all knowledge gaps and other problems posted on the platform. Furthermore, despite extension agents playing a prominent role in solution provision on the platform, most survey respondents (>60%) on the Plantwise platform were of the view that such 'non-specialists' were not active in providing solutions as they were inclined to give space to actors with expertise to engage in this activity out of respect (Table 6). Additionally, a subject matter specialist stated that specialists were less inclined to post problems on the platform as this might jeopardize their reputation as a highly knowledgeable person.

Table 6. Reasons for actors' inactivity on CABI-Plantwise Telegram platform

Reasons for actors' inactivity	Strongly agree	Agree	**(Strongly) Agree %**	Neutral	**Neutral %**	Disagree	Strongly disagree	**(Strongly) Disagree %**
Low confidence in knowledge level	6	13	34.55	11	20.00	20	5	45.45
Respectfully give space to more knowledgeable actors to respond	4	29	60.00	16	29.09	6	0	10.91
Fear of suggesting wrong solution in superiors' presence	10	19	52.73	14	25.45	10	2	21.82
Fear solution provided will be refuted by specialists	5	20	45.45	12	21.82	15	3	32.73
Feel knowledgeable actors dominate discussion making it difficult to engage	5	19	43.64	15	27.27	15	1	29.09

Key relationships and professional notifications

Turning to the 'supervisor and supervisee' relationship on the platforms, we established that on the DFAD platform, managers (the director and DAOs) as supervisors not only played an active role in making announcements and posting directives, but also played a greater role in acknowledging and responding to posts than their subordinates (extension field staff) (Figure 17).

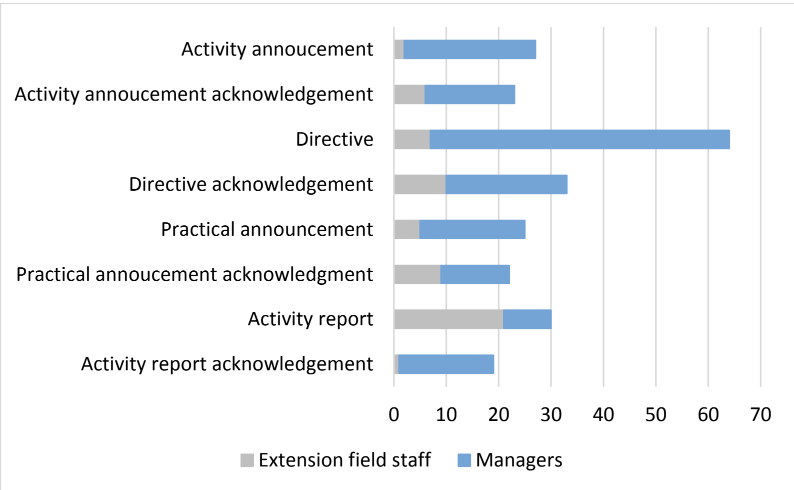


Figure 17. Extent actors posted initiating and responding messages related to notifications on the MOFA-DFAD WhatsApp platform

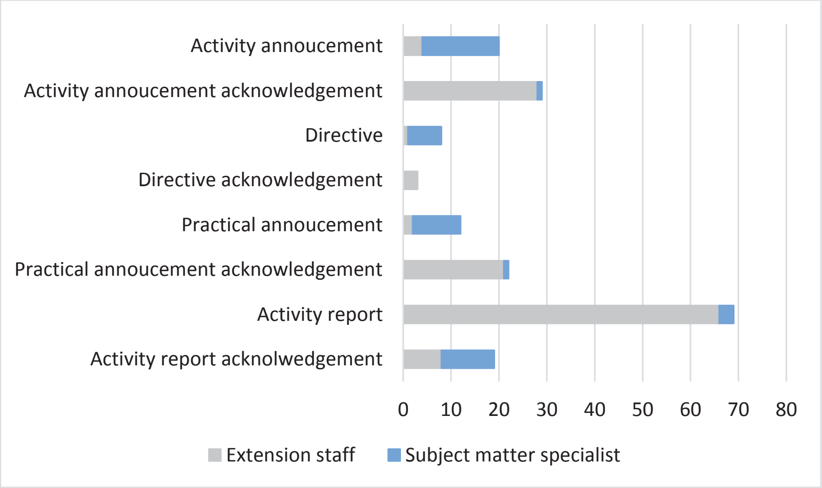


Figure 18. Extent actors posted initiating and responding messages related to notifications on the CABI-Plantwise Telegram platform

In the case of the Plantwise platform, the roles of the supervisor (specialists) being the initiators of announcements or directives and the supervisee (extension staff) being the receivers (acknowledging or making note of these type of messages) was explicit. This situation was explicit as specialists surpassed other actors in sending announcements and directives and were less likely to provide activity reports as they did not work in the field (Figure 18).

5. Discussion

Central to this study is that social media messaging platforms present opportunities for extension and research organisations to enhance their interaction and collaborative problem solving. We studied how two such organisations use social media messaging platforms: investigating the contribution of these platforms to facilitating open information sharing and interaction in the context of responding to a new pest (fall armyworm).

In the sections below, we elaborate on three key findings. The first is that the types of content shared over the two platforms varied, consistent with different organisational purposes and the corresponding set of actors involved in the networks. Secondly, we see that the network-communication structure of the platforms is relatively centralised and non-egalitarian, especially when it comes to actors sending messages to others on the platforms. Therefore, the platforms do not function as the kind of open communication spaces that are deemed conducive for knowledge integration and joint problem solving. Thirdly, we see that the centralised pattern of interaction that emerges on the platforms is influenced by organisational choices and rules, hierarchical social relations and self-representational interests. Below, we elaborate on these key observations and discuss their implications.

Organisation design choices and the role division between content shared over the platforms and other media

Despite the opportunity for both organisations to facilitate open communication spaces through the social media platforms, the organisations defined more specific platform purposes with regard to supporting substantive exchange, and in relation to this they select specific actors as participants. As a result, the two organisations have a different emphasis in terms of the knowledge and problem solving processes that are supported and take place on the platforms (Table 7). The DFAD platform serves mainly as an efficient mode of coordinating extension activities through its emphasis on disseminating announcements and directives from management to extension agents. In contrast, the Plantwise platform has a broader national actor composition and focuses on knowledge sharing among specialists and extension staff to bridge extension agents' knowledge gaps. Thus, we see that the platforms serve selected purposes and -at the substantive level- do not operate as an open communication spaces where varying content can be exchanged.

Table 7. Substantive knowledge and problem solving processes taking place on the MOFA-DFAD WhatsApp platform and CABI-Plantwise Telegram platform

Knowledge and problem solving process	MOFA-DFAD WhatsApp platform	CABI-Plantwise Telegram Platform
Knowledge demand identification	✓	✓✓
Knowledge co-creation	✗	✗
Knowledge integration	✗	✗
Joint problem solving and decision making	✗	✗
Knowledge diffusion	✓	✓✓
Individualised problem solving	✓	✓✓
Information dissemination and coordination	✓✓	✓
Knowledge storage	✓	✓
✓ occurs	✓✓ occurs with high intensity	✗ does not occur

These findings indicate that even though new ICTs present opportunities for new forms of interaction, organisations shape their application (design) to a preferred purpose among various technical possibilities (Scarbrough, 1992; Williams and Edge, 1996). Nonetheless, despite each platform supporting specific types of substantive exchange, collectively the platforms modify the interaction in the network in a meaningful way (Hamilton, Rosenberg and Akcaoglu, 2016). Collectively the platforms support a broad set of knowledge processes. Similar to Osch and Coursaris' findings (2013), the platforms support knowledge sharing for resolving problems of individual extension agents, and also enhance information dissemination to improve the coordination of last mile extension service delivery and enable more timely pest/disease monitoring. Moreover, it can be observed that the platforms are complimentary in supporting knowledge sharing within and between organisations or - phrased differently- can be seen to support the development of different forms of social capital (Cofré-bravo, Klerkx and Engler, 2019). The extension agents that are on both platforms can access new knowledge sources and fresh insights from the CABI-Plantwise platform that supports inter-organisational linkages (bridging social capital), and in turn they can channel this knowledge to their internal platforms and thus reinforce existing bonding social capital (Cofré-bravo, Klerkx and Engler, 2019).

The organisations' selective social media platform application responds to gaps within an existing landscape of communication and interaction mechanisms at the interface between research and extension, and at the same time, remains firmly embedded in a broader and complementary landscape of media-use and face-to-face interaction mechanisms. In relation to mitigating the fall armyworm infestation, for example, the value of the platforms lies in early detection of the new pest infestation, identifying the knowledge gaps associated with the pest, and dissemination of pest alerts and controls. At the same time, however, face-to-face fora remain important to facilitate in-depth discussions for knowledge integration and joint problem solving. At the national level (as CABI key informants inferred) stakeholder meetings constitute such complimentary fora used to discuss emerging problems that are identified over the platforms and to chart mitigation strategies. These findings highlight the continued relevance of face-to-face interaction for more complex knowledge processes and collaborative activities (Krone, Schumacher and Dannenberg, 2014; Aker, Ghosh and Burrell, 2016). Furthermore, the findings indicate that linking conventional communications methods with new ICTs can support inter-organisational innovation and improve collective performance (Materia, Giarè and Klerkx, 2015; Hage and Noseleit, 2018).

In terms of future research, mapping and visualising the configuration of conventional communication methods and new ICTs used within and between research and extension organisations (and at broader interfaces in the AKIS) can help to better understand their role and complementarity in supporting interaction related to knowledge processes and problem solving.

<u>Implications of the network-communication structure for knowledge integration and problem solving</u>

Although both platforms supported equal access to information, interaction on the platforms is limited because relatively few actors place content on the platforms. The limited interaction is reflected in the network-communication structures of both platforms, demonstrating an out-degree distribution that is not egalitarian, and a low clustering coefficient for most actors. Assuming that more complex knowledge and problem solving processes such as knowledge integration and joint problem solving require contributions from a variety of sources, we see that this network–communication structure alongside the selective actor composition on the platforms closes down opportunities for the platforms to support these processes (see also Table 7). In actual practice the bulk of platform messages are sent by few actors, while the low level of interconnectivity indicates that free information sharing and discussion are constrained. Hence, we see again that the platforms do not function as the kinds of open communication spaces that are described by authors such as Abouzeedan and Hedner (2012) or Chesbrough *et al.* (2006). Apparently, there exist constraints to free information sharing which lead to a low inclination of actors (especially those with a lower status) to contribute knowledge on the platforms, which is likely to negatively affect the diversity and richness of perspectives shared. This may be detrimental to the identification of integrative solutions to problems posted on the platforms (Aarts and van Woerkum, 2005). Similarly, the lack of discussion and interactive exchange among actors constrains actors in building on each other's perspectives in problem resolution. In the absence of open discussion and interaction actors who post problems on the platform need to make sense of multiple individual responses directed at them (Aarts and van Woerkum, 2002), and are faced with a form of competition among actors engaging in providing answers and solutions (Thomas and Kilmann, 2008).

However, we see the platforms' network-communication structure supports other and less complex substantive knowledge processes (see Table 7). The observed network–communication structures are better suited for supporting knowledge diffusion in response to extension field staffs' localised problems as well as for supporting platforms actors in individual-centred learning. Additionally, the prevailing communication patterns seem to adequately support information dissemination for coordination i.e. organising extension related activities and even pest/disease monitoring.

The findings above point to the inappropriateness of the social media platforms to directly support more complex knowledge processes and problem solving activities at the interface between extension and research. Further the findings also confirm earlier research indicating that centralised networks are suited for knowledge diffusion and information dissemination (Granovetter, 1973; Carolan, 2014b; Landström and Harirchi, 2018), and routine problem solving activities that do not require new knowledge or the recombination of different knowledge (Klerkx and Proctor, 2013). Further, the findings resonate with non-deterministic perspectives that are optimistic with regard to the partial adoption of technology in a particular context (Scarbrough, 1992; Colfer and Baldwin, 2016). This is in line with the observation that organisations shape and constrain (ICTs) technology design and application (MacCormack, Baldwin and Rusnak, 2012; Munthali *et al.*, 2018).

Finally, it is relevant to note that while the platforms have a similar network–communication structure, the Plantwise platform's is relatively more centralised. However, such quantitative findings should not be taken at face value. Important differences between the two platforms are that the Plantwise platform has a lower intensity of interaction than the DFAD platform and that the DFAD platform is dominated by social messages. It is therefore unclear how the levels of centralisation and openness would compare if we only based the network analysis on the professionally oriented messages. In more qualitative terms, one could regard the Plantwise platform as more 'open' in the sense that it facilitates inter-organisational linkages and accommodates actors with less defined hierarchical relationships, while the DFAD platform only includes intra-organisational linkages, and could be more susceptible to mirroring the existing formal communication structures and associated hierarchies that may constrain interaction (Colfer and Baldwin, 2016). Therefore, further research could analyse network-communication structures and levels of centralisation therein for different categories of messages.

<u>The influence of social roles, identities and interests on platforms' interactional dynamics</u>

Social roles were found to constrain the freedom of sharing information and discussion on both platforms. Besides affecting whether and how participants respond to messages of others, we also see that social identities and relations influence whether platforms actors engage in posting problems or solutions and take part in discussions at all.

On both platforms, we see that the dynamics of interaction are affected by social status in terms of who are considered to be more and less knowledgeable in view of their job designations and scientific qualifications. The survey questions on reasons for inactivity on the platforms indicate that those who are considered less knowledgeable (mainly extension field staff) are inclined to contribute less to problem solving, and more to posting problems, to give room to DAOs and specialists on the DFAD and Plantwise platforms to perform this task respectively. Despite this view of the platform actors, this dynamic is only clearly visible on the DFAD platform. Here we see a clear task division between extension agents actively posting problems and managers, subject matter specialists and superiors actively responding to them. These findings resonate with Halliday's notion that social roles and their associated authority define the conversational moves available to actors in interaction (Halliday, 1994; Jones *et al.*, 2006). On the Plantwise platform, these dynamics are not clearly exhibited as some specialists on the platform are deterred from posting problems as they are of the view that their designation confines them to providing solutions. Moreover, solution provision on the platform mostly involves peer–to-peer exchange among extension staff. One could argue that the fact that extension agents engage in conversational interaction moves (post messages) that are inconsistent with their social role and expected behaviour contradicts with Halliday's (1994) perspective. However, there are indications that the peer-to-peer exchange was enabled by the circumstance that there were only few specialists on the platform, which were moreover seen to be too busy to provide solutions to problems. Arguably therefore, relations of authority were not actively experienced through this de-facto absence, which is still congruent with the idea that conversational moves available are constrained or enabled by the prevailing relational configuration (Halliday, 1994; Jones *et al.*, 2006). In any case, the findings show that the Plantwise platform presents a more conducive environment for free knowledge sharing, possibly because it supports inter-organisational linkages so that hierarchal relationships may have been less obvious and immediate than on the DFAD platform.

While the issue of social status and authority offers considerable insight into the dynamics of interaction on the platforms, we can also analyse them in terms of self-representational interests and interactional strategies as proposed by Goffman (1959). Indeed, these issues appear to be closely intertwined. On the DFAD platform, a significant number of extension agents are deterred from providing solutions as they fear providing the wrong answer in the presence of a superiors. And – as already indicated - some specialists on the Plantwise platform are deterred from posting problems as they are of the view that their designation confines them to providing solutions. Similarly, we have seen examples were specialists did not respond in public to proposed solutions that they considered to be flawed. These examples clearly reflect Goffman's idea that actors in interaction engage in identity building, impression management and defensive strategies to achieve certain (tacit) objectives (Goffman, 1959; Aarts and van Woerkum, 2005). In this case such goals relate to face saving, image management and the prevention or avoidance of tension and conflict.

These findings regarding interaction patterns considerably nuance the quantitative assessment of network–communication structures which suggested that both platforms had a structure that was likely to limit information sharing - with the Plantwise platform's structure constraining these activities to a greater extent than the DFAD platform's structure. Thus, the network-communication structure of a platform only provides a partial and limited insight into the interaction dynamics among socially differentiated platform actors. Similarly, our findings suggest that it may be relevant to analyse network-communication structures for each category of messages identified on the platform and the associated actors involved in these substantive exchanges.

6. Conclusion

The starting point of this study was that social media platforms may present opportunities to enhance knowledge flows and problem solving processes at the interface of extension and research in the context of new agronomic challenges, potentially serving as open communication spaces where actors can freely share content and engage in decentralised and egalitarian forms of interaction. We explored how social media messaging platforms were applied in an agricultural extension organisation and by a research institution in the context of the emergence of fall army worm in Ghana and investigated the types of content exchanged (the substantive dimension), the patterns of interaction that emerged (the structural dimension) and how these are shaped by social relations and interests (the relational dimension). In this conclusion, we aim to draw some broader lessons that are likely to be relevant beyond Ghana and the fall armyworm crisis.

Our study suggests that the three dimensions of communication and interaction are indeed closely intertwined and mutually influence each other. The type of content exchanged on the social media platforms was clearly influenced by the different purposes ascribed to the platform by the two organisations and by the (in)formal rules that were imposed on platform actors, resulting in a much greater attention for socially oriented exchanges on the more informal, internal platform operated by DFAD staff. In contrast, the Plantwise platform operated by CABI was deliberately steered towards professional communication relating to pest and disease management across organisations. Despite the differential organisational purposes and degrees of formality, both platforms were highly valued by users for their contribution to disease detection and dissemination of relevant information on disease control. This indicates that social media platforms of various kinds may play useful roles in dealing with newly emerging challenges. Zooming in on the content of the professional exchanges that occurred on both platforms, we see that these are clearly linked with the emerging network–communication structures. Both platforms exhibited a network-communication structure that was relatively centralised and non-egalitarian especially regarding actors sending messages to others over the platforms. On both platforms, only few actors contributed to providing content which is not conducive to more complex knowledge processes such as knowledge integration and joint problem solving which typically require contributions from a variety of sources. Analysis of the knowledge processes taking place indeed suggests that the platforms were used more for knowledge and information dissemination as well as for the distribution of notifications in support of organisational management and coordination. Even so, it is clear that the platforms were intensively used and contribute to a number of important processes at the interface of extension and research. Moreover, it is clear the platforms do not operate in isolation of other modes of communication, and there are indications that exchanges on the platforms serve as an input in fora for face-to-face interaction where more in-depth discussion takes place. Thus, there is complementarity between social media messaging platforms and other media. This demonstrates that one cannot solely rely on social media platforms when complex challenges emerge and that additional efforts and media are needed to access and integrate diverse expertise.

The prevailing network-communication structures of the platforms appeared to be related to social hierarchies and micro-political interests and strategies at play during the interaction. Although there were differences between the platforms, it was clear that interactions were influenced by the prevailing idea that highly educated actors were supposed to provide answers and solutions, while less educated ones were supposed to pose questions and problems, and that actors were hesitant to challenge such task divisions. Simultaneously, such views influenced the content of the knowledge and problem solving processes taking place on the platforms. The more qualitative analyses of interaction patterns also suggest that there were meaningful differences between the two platforms, even though the platforms had similar network–communication structures in quantitative terms. Such quantitative similarities, therefore, cannot be taken at face value as they may conceal differences in content shared or differential interaction patterns per type of content messages posted on the platforms. Thus, it is important to understand the hierarchies and micro-political interests that may play a role in a specific context and anticipate these when developing social media platforms. When peer-to-peer exchange is deemed important, for example, one may need to create separate social media spaces where superiors are not present or devise specific rules of engagement that are to the advantage of people with lower social status.

Overall, the above findings suggest that social media messaging platforms may play useful roles in the context of newly emerging agronomic challenges, but do not function as open communication spaces since there are clear limitations in the types of professional content that can be meaningfully shared, and there exist constraints that prevent participants from equal participation in sending messages and sharing content. Moreover, the study indicates that the contribution of new ICTs to strengthening exchange within and among extension and research organisations can only be understood contextually, and with due attention to the interplay between the nature of the challenge at hand, the substantive processes required to address it, the relational and social factors that influence interaction patterns, and the broader landscape of media and communication mechanisms available. Thus, broad generalisations regarding their potential contribution need to be avoided.

Appendices

Appendix 1. Detailed coding scheme based on Halliday's functional-semantic view of dialogue

Categories of messages	Initiating moves	Responding moves
Knowledge sharing for problem solving	Knowledge gap stipulation	Pest/disease identification
		Prescription provision
		Knowledge gap stipulation response
	Practical problem stipulation	Practical problem solution
Knowledge dissemination	Lecture	Lecture acknowledgement
		Lecture clarification
		Lecture addition
	Working solution sharing	Working solution interest
		Working solution clarification
	Technical information sharing	Technical information sharing acknowledgement
	Innovation sharing	Innovation sharing interest
Pest/disease monitoring	Pest/disease occurrence	Pest/disease occurrence note
		Pest/disease occurrence clarification
	Pest/disease alert	Pest/disease alert note
		Pest/disease alert clarification
Notifications	Directive	Directive acknowlegdement
	Activity announcement	Activity annoucement acknowlegdement
	Practical announcement	Practical annoucement acknowlegdement
	Activity report	Field activity report acknowlegdement
	Agricultural news/update	Ag news comment
Social	Jokes	Social message response
	Inspirational quote	
	Crime alert	
	Job advertisement	
	Non-agricultural new	

5

Chapter 5

Ghanaian farmers' choice of information sources and use of mobile technology in managing a new pest - fall armyworm

Nyamwaya Munthali, Annemarie van Paassen, Rico Lie,
Cees Leeuwis and Ron van Lammeren

To be submitted

Abstract

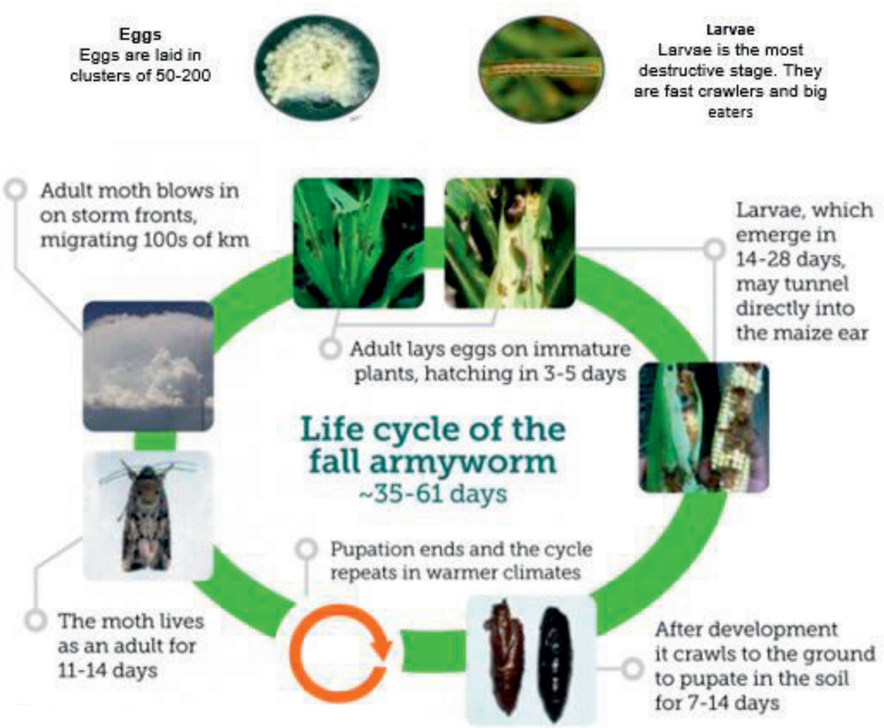
Fall armyworms' emergence in Ghana's maize farming system, in 2016, exemplifies the consternation and new challenges that climate change introduces to farming systems. In such situations where farmers lack experience with a pest and have the urgency to mitigate crop losses, they quickly need to mobilise new information and other resources to manage the pest. Farmers require different types of information (pest alerts, pest identification and pest control advice, and pests control access) and choose from multiple options the most appropriate source for each of these information dimensions. So far there are limited studies addressing farmers' source preference for the types of information required to manage new pests or fall armyworm in Africa or the role of mobile technology in these processes. While such studies are critical to deliver more responsive extension services in this era where climate change confronts farmers with new and unfamiliar problems and mobile technology opens possibilities for timelier, locality-specific information provision and networked communication to get new insights from broader sources to respond to these challenges. Semi-structured interviews reveal that farmers' information networks accommodate a range of sources, and farmers consult multiple sources in pest identification and pest control establishment to triangulate information and chart the best course of action when reliable solutions are not well known. Further, farmers rely on public extension agents for all but one dimension of fall armyworm management: for the pest alert dimension they listen to the radio. Farmers mainly engage with public extension agents in fall armyworm management based on their perceived credibility. Additionally, farmers sparingly use new ICTs in fall armyworm management. Nonetheless, the study points to novel ways farmers use conventional mobile phone functions, such as phone calls to extension agents and listen to radio over their phones, to access agricultural information. Additionally, the study points to opportunities for farmers to take advantage of IVR technologies as information sources, because they function similarly to their prevailing mobile phone usage.

Keywords: information seeking behaviour; mobile technology; fall armyworm; pest management.

5

1. Introduction

"Fall armyworms threaten Africa's crops"(BBC, 2017);*"Scientists search for sustainable solutions to stop fall armyworm,"* (VOA, 2018);*"Rampaging soldiers: fall armyworm causes destruction on farms*,"(MyJoyOnline, 2017): these were some of the news headlines on fall armyworm - an invasive pest with a voracious appetite for grass and forage crops that emerged in 20 African countries, in the 2016/2017 farming season (Godwin, Hevi and Day, 2017). The transboundary pest (moth larvae- Figure 1) that can destroy a field within a matter of days due to its insatiable appetite and ability to reproduce rapidly significantly affected maize yields. (Day *et al.*, 2017; Kassie *et al.*, 2020). The pest's negative effects on maize was a concern as the crop is a widely grown staple on the continent, including Ghana (Day *et al.*, 2017).



Source: International Maize and Wheat Improvement Centre and Grains Research and Development Corporation

Figure 1. Life cycle of fall armyworm

From the perspective of Ghanaian farmers, the pest led to an average maize loss of 45% (range 22-67%)(Day *et al.*, 2017; Kassie *et al.*, 2020). These losses were incurred as the novelty of the pest made it challenging for extension staff, researchers, crop health staff, input suppliers and Non-Governmental Organisations (NGOs) (among other agricultural stakeholder) to quickly raise farmers' awareness of the pest and alert them of infestations in their vicinities, and establish and disseminate farm appropriate pest controls and products (Abrahams *et al.*, 2017).

Fall armyworms' emergence in Ghana exemplifies the consternation and challenges that climate change introduces to farming systems (Karmakar *et al.*, 2016; Day *et al.*, 2017). Fall armyworm that is indigenous to the Americas emerged in Ghana due to favourable weather and temperatures caused by climate change (Abrahams *et al.*, 2017). Climate change fosters new location–specific (bio-physical and socio-economic) challenges at national and farming community level that require updated knowledge, context appropriate management strategies and immediate action to mitigate (McIntrye *et al.*, 2009; Day *et al.*, 2017; Godwin, Hevi and Day, 2017).

Amid the emergence of the new pest farmers still needed to produce maize to sustain their livelihoods and contribute to national food security. In such situations where farmers lack experience with a pest, and have the urgency to mitigate crop losses, they quickly need to mobilise new "knowledges", information and other resources to manage the pest. Farmers seek information as "[...] information is an important factor that interacts with other production factors [land, labour, capital, management skills],"(Vidanapathirana, 2012: 1). Relevant and timely information enables them to make informed and timely decisions in farm management (Bernard, Dulle and Ngalapa, 2014; Acheampong *et al.*, 2017). In order to mitigate the fall armyworm infestation and other new pests farmers require different types of information (Table 1). For familiar pests, farmers have experiential knowledge about the pest and its management; hence they merely need timely pest alerts (based on local reporting) and knowledge of the actual availability or access to pest management products. For a new pest, farmers need more information: a general awareness of the pest and capacity to identify it as well as information about how it spreads and the associated pest control practices most appropriate and effective for a specific farm (biophysical and socio-economic situation).

Table 1. Information dimensions of fall armyworm management

Dimension	Description
Pest alert	This relates to gaining awareness of the pest infestation
Pest identification	This involves identifying or confirming the pest species
Pest Control	This is about learning how the pest spreads and accessing advice on how to control it
Pest control access	This relates to establishing where to get inputs or products to control the pest

*The dimensions of fall armyworm management emerged from discussions with farmers during field engagement for a prior study

Historically a prominent information source for farmers has been the public extension agent - an information source being ,"an institution or individual that creates or brings about a message," (Acheampong *et al.*, 2017: 2). However, farmers currently have access to a broader range of information sources as over the years they have been introduced to new service providers by (non) governmental organisations and the research community (Davis, 2008; McNamara *et al.*, 2012; Qiang *et al.*, 2012; Cieslik *et al.*, 2018). Farmers' agricultural information sources include other farmers (farmer group leaders or neighbours), Farmer Based Organisations (FBOs), traders, researchers, extension agents of private and/or Non-Governmental Organisations (NGOs), and agents of input suppliers (Asante, Sefa and Sarpong, 2011; Kilelu *et al.*, 2011; Vidanapathirana, 2012; Bernard, Dulle and Ngalapa, 2014; Rahman, Lalon and Surya, 2016). Additionally, farmers have the opportunity to access agricultural information directly through Information and Communication Technologies (ICT) such as radio and television, and more recently through new ICTs that have become more accessible due to increasing mobile phone penetration (Davis, 2008; McNamara *et al.*, 2012; Qiang *et al.*, 2012; Mccole *et al.*, 2014). New ICTs have new capabilities that preceding analogue and broadcasting oriented media do not possess (Lister *et al.*, 2003). These technologies that offer new possibilities for connectivity and information exchange include social media (e.g., Facebook, WhatsApp), Short Message Service (SMS) and Interactive Voice

Response (IVR) technologies, and data collection and storage technologies (e.g., Open data kit).

Considering farmers currently have multiple and more options of information sources, we are interested in establishing farmers' choices of information sources for the dimensions of fall armyworm management. Further, we are interested in the reasons behind these choices, considering farmers determine the appropriateness of a source based on a number of factors. These factors include the sources' credibility, reliability, accessibility and cost-effectiveness (described in Table 2). Further, their choices are also influenced by other strategic considerations such as relationship management to access credit or inputs (Rahman, Lalon and Surya, 2016).

Table 2. Definition of factors influencing farmers' choices of information sources

Factor	Definition
Credible	Source is highly knowledgeable and/or a technical expert
Reliable	Source is experienced in diagnosing field problems and trusted for having a record of providing working solutions
Accessible	Source is consistently available and easy to access or use
Cost-effective	Source requires relatively limited funds or time to access
Strategic	Engagement with source serves a particular purpose that is valued more than the primary information service they provide

Source: authors with insights from Starasts, 2004; Dutta, 2009; Bernard, Dulle and Ngalapa, 2014; Rahman, Lalon and Surya, 2016; Acheampong *et al.*, 2017

<u>Current insight into farmers' information source preferences in pest management</u>

Various studies investigate farmers' information seeking behaviour in Africa (Lwoga *et al.*, 2013; Bernard, Dulle and Ngalapa, 2014; Krone, Schumacher and Dannenberg, 2014; Tafesse *et al.*, 2018). These studies mainly relate farmers' source preference to socio-economic factors (Tologbonse, Fashola and Obadiah, 2008; Daude, Chado and Igbashal, 2009; Lwoga *et al.*, 2010; Bernard, Dulle and Ngalapa, 2014; Acheampong *et al.*, 2017) and often do not connect farmers' source preference to specific information needs i.e., pest/disease management information (Tologbonse, Fashola and Obadiah, 2008; Lwoga *et al.*, 2010; Bernard, Dulle and Ngalapa, 2014; Acheampong *et al.*, 2017). If they do, the studies tend to focus on the pest/disease control advice dimension (Daude, Chado and Igbashal, 2009; Krone, Schumacher and Dannenberg, 2014). Some studies indicate that farmers rank 'other farmers' as the most preferred information sources, followed by extension agents and then radio (Dutta, 2009; Bernard, Dulle and Ngalapa, 2014). Other studies highlight extension agents as the 'preferred information source', before 'other farmers' (Tologbonse, Fashola and Obadiah, 2008; Daude, Chado and Igbashal, 2009). Many studies show a low preference for new ICTs as an information source (Tologbonse, Fashola and Obadiah, 2008; Bernard, Dulle and Ngalapa, 2014; Acheampong *et al.*, 2017), while recent studies simultaneously propose that new ICTs can support real-time disease monitoring, provide timely disease risk alerts, diagnosis, and control information (Damtew *et al.*, 2018; Munthali *et al.*, 2018; Tafesse *et al.*, 2018; Toepfer *et al.*, 2019).

So far there are limited studies addressing farmers' source preference for the different types of information required to manage new pests or fall armyworm in Africa and the role of mobile technology[23] in these processes. While such studies are critical to deliver more responsive extension services that better target specific information to farmers when new pests emerge (Bernard, Dulle and Ngalapa, 2014). Specifically, in this era where climate change confronts farmers with new and unfamiliar problems, and considering the increased accessibility of mobile technology opens possibilities for timelier, locality-specific information provision and networked communication to get new insights from broader sources to mitigate these challenges. In order to gain insight into this topic, the study targets farmers affiliated to a public and private extension organisation, in Ghana. More specifically, through this set-up we investigate these research questions:

1) What are farmers', affiliated to public and private extension organisation, main information sources for dimensions of fall armyworm management?
2) What are the factors influencing farmers' choices of information sources in fall armyworm management?

[23] Mobile technology is technology enabled by a mobile phone or device.

3) What is the role of mobile phones and new ICTs in managing fall armyworm?

2. Methods

In this section the research approach and associated sampling procedure, data collection and analysis methods are presented. The research was qualitative – descriptive in nature (Lambert and Lambert, 2012), as it was geared towards establishing farmers’ predispositions to sourcing information for fall armyworm management and gaining a better understanding of farmers’ choices in this respect. Therefore, the research described farmers’ information source networks and provided some explanation for this phenomenon through qualitative data collection methods.

Sample selection and data collection methods

The selection of interview respondents involved multi-stage sampling (Figure 2). Step one, purposive sampling, ensured that farmers in major maize producing groups were captured under the public and private extension organisation (step 1). Farmers operating in the Techiman/Wenchi area of the Brong-Ahafo Region were targeted, as this is a major maize producing area in Ghana (Angelucci, 2012) and the area is also susceptible to fall armyworm infestation. Further, the farmers were categorised by affiliation[24] to two types of extension organisations. This categorisation was because we assumed that farmers might have different information sources choices for fall armyworm management, given that the extension organisations had different service delivery approaches (see Figure 3 for extension approaches). We specifically targeted farmers under the Ministry of Food and Agriculture – Wenchi District Food and Agriculture Department (MOFA-DFAD) and farmers under the outgrower schemes of traders associated with Grameen Foundation, an NGO piloting and promoting ICT-mediated service delivery (for more details on extension approaches see Munthali *et al.*, 2018).

[24] Affiliation in this study refers to the organisation through which the research team gained access to the study subjects and did not denote that the farmer engaged exclusively with this organisation for extension services.

Step 1

- **Purposive sampling maize farmer groups**
- Sampling focused on maize farming groups with farmers affiliated to extension agents using new ICT platforms in service delivery in the Techiman/Wenchi area
- Maize farmer groups selected:
  - MOFA -DFAD: Amponsankrom 41 farmers; Buaso 46 farmers
  - Grameen Foundation: Tano-Boase 24; Mesidan 19 farmers

Step 2

- **Random sampling within maize farmer groups selected in step 1**
- Sampling criteria - approx. 40% of group members sampled:
  - Wenchi MOFA- DFAD: Amponsankrom 16 of 41 farmers (39%) and Buaso 19 of 46 farmers (41%)
  - Grameen Foundation: Tano-Boase 10 of 24 farmers (42%) and Mesidan 7 of 19 farmers (37%)

Step 3

- **Random stratified sampling within selected/profiled farmers in step 2**
- Sample size and selection criteria:
  - MOFA-DFAD 8 farmers:
    - Adult; female, male; smallscale; largescale; low education; owns mobile; non-owner mobile;
    - Excluding youth and highly educated farmer
- Grameen Foundation 8 farmers :
  - Adult; female; male; smallscale, largescale; low education; high education; owns mobile, non-ownership of mobile
  - Excluding youth and including 1 farmer representing a small scale farmer as well as a farmer that does no own a mobile phone

Figure 2. Sampling procedure

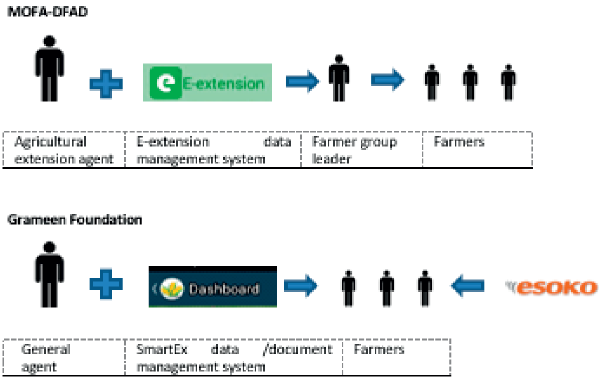


Figure 3. ICT and human mediated approach to extension service delivery MOFA-DFAD and Grameen Foundation traders

Step 2, random sampling, set the stage for sampling in step 3. This step ensured that a sufficient number (approximately 40%) of farmers in the farmer groups were unbiasedly selected for profiling based on general demographic variables. Step 3 involved random stratified sampling to unbiasedly select farmers with specific characteristics from those profiled. The sampling strata were the characteristics outlined in Table 3 - ICT adoption determinants derived from literature (Ali, 2012). Using these strata, we aimed to capture 20 farmers in total: 10 with each type of characteristic under each extension organisation. The farmers were selected according to these characteristics, alongside having experienced a fall armyworm infestation, as we were interested in farmers' mobile phone and new ICT usage in fall armyworm management and needed farmers with these characteristics represented in the sample to foster maximum variation and variance (i.e., capture subjects with high and low "values"), and ultimately capture diversity in the sample.

Table 3. ICT adoption determinants and distribution of ICT (non) adoption characteristics in sampling frames

Determinants	Characteristic Adoption ☐ Non-adoption ☐	MOFA-DFAD (of 35 farmers)	Grameen Foundation (of 17 farmers)
Age	Youth 15 years to 25 years	0	0
	Adult Above 36 years	35	17
Sex	Male	22	14
	Female	13	3
Education level	High (Short cycle) tertiary education	0	1
	Low No formal schooling	19	10
Maize enterprise size	Large-scale Above 10 acres	3	1
	Small-scale Below 5 acres	18	18
Mobile device ownership	Ownership	23	19
	Non -ownership	12	2

*Note the intermediate level farmers for the characteristics age, education level, maize enterprise size are not captured. Only the number of farmers with the specific characteristics highlighted above are captured.

However, given the distribution of the characteristics in the sampling population (Table 3), 16 farmers were selected and interviewed for the study (step 3). Eight farmers under each organisation were included in the sample (Figure 2 – see step 3 final sample composition). This situation was due to farmers with certain ICT (non) adoption characteristics being absent from the sampling frames (youth, highly educated) (Table 3). Further, some farmers in the sample were selected twice for two different characteristics, because there was low representation of certain characteristics within specific sampling frames (female, non-ownership of mobile - Table 3), and also due to the unavailability of farmers for the study. Therefore, under both organisations no youth were captured. While under the MOFA-DFAD no highly educated or large-scale farmer were in the sample, and under Grameen Foundation the farmer selected as a small-scale maize farmer doubled as the farmer that did not own a mobile device.

Data were collected from the 16 farmers through semi-structured interviews. The interviews were conducted in their localities. The choice of interviews and setting created a conversational face-to-face environment for farmers to freely respond to open-ended questions from an interview guide (Tong, Sainsbury and Craig, 2007).

Data analysis

The interview data for the research questions were analysed through content and descriptive statistical analysis. Below is a description of how this was achieved.

What are farmers’, affiliated to public and private extension organisation, main information sources for dimensions of fall armyworm management?

In relation to the first question above we marked and captured each farmers’ responses in a matrix. The matrix’ vertical axis fielded farmers’ potential information sources, while its horizontal axis reflected the dimensions of fall armyworm management. Through the matrices we identified the sources of information that each farmer cited for different aspects of fall armyworm management, and then collated the data into bar graphs to reflect the number of times a source was cited by a farmer in relation to a specific dimension (Figure 4, 5 and 6).

In order to identify farmers’ potential sources of information, we firstly referred to existing literature. We established that Rahman *et al.* (2016) and Bernard *et al.* (2014) respectively define 15 information sources for Bangladeshi and Tanzanian farmers that emerged from their data collection processes. We tailored these lists of sources to the Ghanaian context (Table 4). More specifically, we omitted what we considered extension service delivery settings and not information sources from our list (group discussion, demonstration meetings, farmers’ meeting, fair and exhibition). Additionally, based on consulting more contextual literature (Dutta, 2009; Ajani, 2014; Acheampong *et al.*, 2017) and field observations, we omitted obsolete sources (farm labourer, farm publications, fisheries officer) and included other sources (research institutions, trader, farmer based association agents, mobile applications, the internet).

Table 4. Farmers' potential sources of information

Category	Source
Extension agent	Public Private/NGO
Other farmer	Farmer group leader Neighbour
Traditional/classic media	Radio Television Newspaper
New ICTs /media	Mobile application Internet
Other service providers agent	Farmer based organisation Input suppliers Research institution

What are the factors influencing farmers' choices of information sources in fall armyworm management?

For the second research question the primary researcher analysed field notes of farmers' responses to why they engaged with particular sources in fall armyworm management. Applying a coding scheme to farmers' responses we identified factors that influenced their choices of information sources alongside the number of times a factor was cited. Additionally, quotations illustrating these factors (themes) were lifted from the data. The coding scheme themes were guided by Starasts (2004) characteristics of good information sources and other literature in which we identified factors that could influence farmers' information sources preferences (Dutta, 2009; Bernard, Dulle and Ngalapa, 2014; Rahman, Lalon and Surya, 2016; Acheampong *et al.*, 2017).

What is the role of mobile phones and new ICTs in managing fall armyworm?

Lastly, and in relation to the third question, we identified and collated how farmers used their mobile phones and new ICTs in fall armyworm management using a matrix. The matrix' vertical axis reflected possible mobile phones uses by farmers that we identified from literature (see list of mobile phone uses in Figure 9)(Martin and Hall, 2011; World Bank, 2018), and the horizontal axis of the matrix reflected the dimensions of fall armyworm management. Collated data from the matrix' was presented in a bar graph to show the number of citations of mobile phone and new ICT uses for each fall armyworm management dimension for all 16 interviews (Figure 10).

3. Findings

This section reports on the study findings. It reports findings in relation to farmers' information source preferences in fall armyworm, reasons behind these choices and the role of mobile technology in fall armyworm management.

Farmers' sources of information for fall armyworm management

We established that farmers engaged with a selection of their potential information sources (Figure 4). Based on the number of times the 16 farmers cited a source in the interviews, we found that farmers mainly engaged with public extension agents to manage fall armyworm (Figure 4). In this regard, radio was also a relevant source of information; however, few farmers mentioned using new ICTs.

Looking into farmers' information sources for specific fall armyworm management dimensions, the data reveals that farmers received pest alerts through the radio (Figure 4). While for the rest of the dimensions, farmers relied on public extension agents. Further, in most cases (13) farmers sourced information for pest identification and control from multiple sources. They sourced these types of information from two to four sources, mainly public extension agent (12 farmers), followed by the radio (11 farmers). When they sourced this information from private extension agents (5 times), they also consulted public extension agents for the same information, but this was not the case in the opposite scenario. Additionally, two Grameen farmers said they engaged with multiple sources to triangulate information and establish the best solution to farming problems. One of these farmers said, *"I have to combine different people's knowledge to get to a solution, and that is what helps me."*

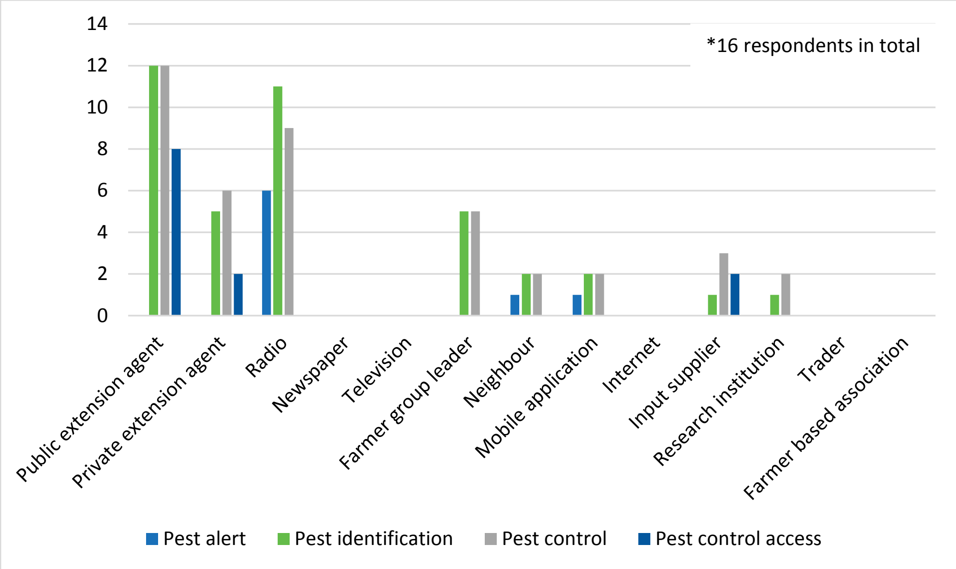


Figure 4. Number of citations farmers' source of information for fall armyworm management dimensions

When we compare the farmers affiliated to the public and private extension organisation, we notice similarities and differences in the use of information sources in fall armyworm management. Both categories of farmers accessed information from a range of information sources, but did not use television, newspapers, the internet, farmer associations or traders (Figure 5 and 6). Notwithstanding their affiliation, both categories primarily relied on public extension agents to acquire advice on pest identification, controls and accessing inputs. For pest alerts, both categories prioritised radio, but for information for pest identification and control radio was ranked second best. Additionally, farmers hardly sourced information from input suppliers, but in instances they did it was for pest control and access advice.

In terms of differences between the farmers affiliated to the public or private extension organisation, the data showed that farmers affiliated to Grameen Foundation generally consulted more sources than those affiliated to the MOFA-DFAD. Apart from the sources that they had in common with the farmers affiliated to MOFA, they also accessed information via mobile phone applications. A few of these farmers accessed pest alerts, pest identification and controls through their mobile phones.

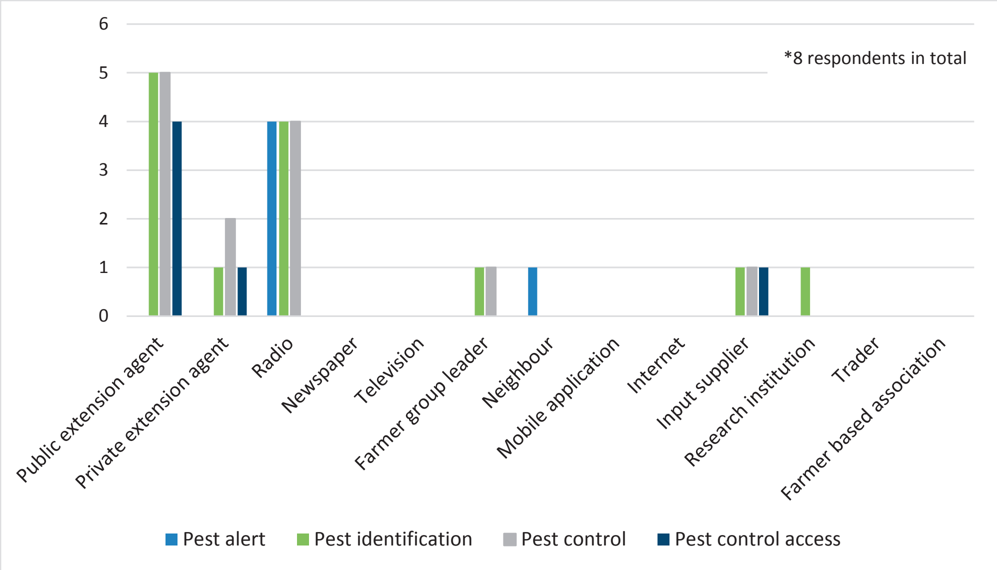


Figure 5. Farmers' affiliated to MOFA-DFAD – number of citations information source for fall armyworm management dimensions

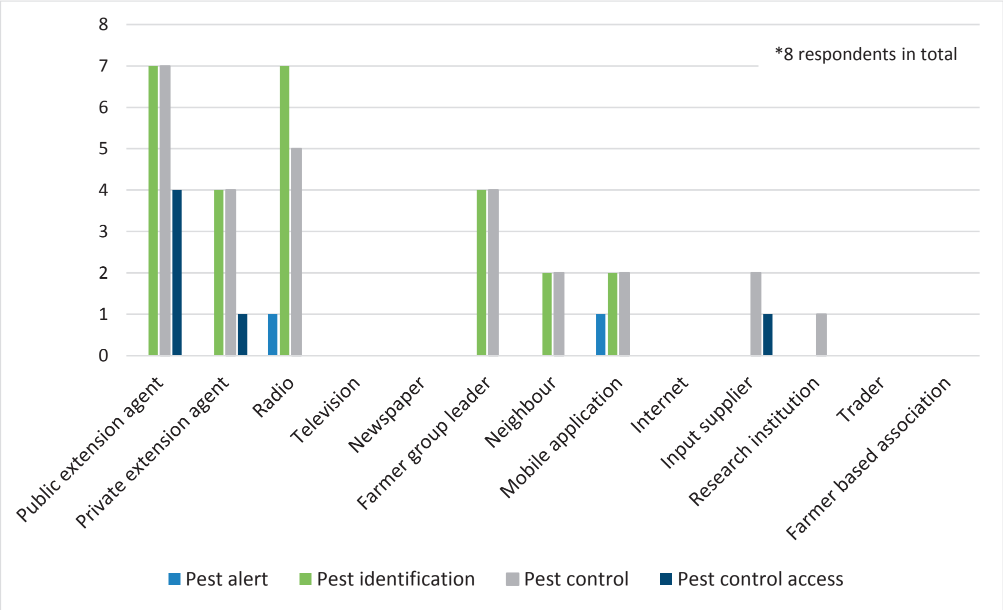


Figure 6. Farmers' affiliated to Grameen Foundation – number of citations information sources for fall armyworm management dimensions

<u>Factors influencing farmers' choice of information sources</u>

Farmers mainly relied on public extension agents in fall armyworm management due to a number of factors (Table 5). Farmers saw public extension agents as experts and they were perceived to provide workable solutions. Another reason that farmers largely relied on public extension agents as an information source was their availability. Related to these findings a farmer said, *"I met with the agric-person to identify the pest and get advice on how to treat it [fall armyworm] as he is knowledgeable and always provides solutions that work[...] I have no time to use my phone to get in contact with the agric-person who comes here and is available,"* and another stated, *"AEAs [agricultural extension agents] have a lot of knowledge and they are the nearest to us, so we can get to them anytime to report, get help with pest identification and control, and linkages to inputs."* Apart from credibility, reliability and accessibility these statements highlight the limited costs (finance and effort) for farmers to engage with public extension agents, who periodically visit their localities to provide agronomic advice or respond to agricultural crisis'.

Table. 5 Factors influencing farmers' choice of information sources

Source	Credible	Reliable	Accessible	Cost-effective	Strategic
Public extension agent	✔✔✔✔✔✔✔✔✔✔	✔✔	✔✔✔✔✔	✔✔	✔✔
Radio	✔✔	✔✔	✖	✖	✖
Private extension agent/NGO	✔✔	✔✔	✔	✖	✖
Farmer group leader	✔✔	✔	✔✔	✔	✖
Input supplier	✔✔	✔	✖	✖	✖
Neighbour	✔✔	✖	✖	✖	✖
Research institution	✖	✔	✖	✖	✖
Mobile application	✖	✖	✔	✖	✖
	✔ number of citations		✖ no citations		

Related to the accessibility of public extension agents, two farmers said they were preferred as a source of advice over radio and mobile applications. This was because farmers engaged with public extension agents through interpersonal communication that allowed them to seek clarification and access localised advice. In relation to this finding one farmer said, *"Radio and applications only give you information on pest identification and control, they cannot be called to come to your field to see what is going on. Therefore, you can get their advice, but you might need to call an AEA to establish measures for pesticides."* Additionally, these sentiments explain why this study found that farmers do not consider radio an accessible information source. In comparison to public extension agents, farmers do not find radio as accessible, because when dealing with new problems radio does not enable farmers to engage with an interactive and practical learning environment.

When public extension agents were considered unavailable, two farmers said they opted for alternative information sources: private extension agents and farmer group leaders. One farmer noted "*Grameen [private extension agent/NGO] is always with us, unlike MOFA AEAs [public extension agents] who only give us chemicals" and another farmer expressed:* "*I report to the farmer group leader as he is near and available to help me as I cannot get the MOFA agent."* Another farmer (one) relied on mobile applications alongside public extension agents for information in fall armyworm management due the limited reach of public extension agents. In addition, and in relation to public extension agents' unavailability, one farmer stated he only engaged with public extension agents to gain access to subsidised pest control inputs provided by the Ghanaian Government. In line with this last motivation for farmers to engage with these agents a farmer said: "*AEAs are not helping. I only went to their meeting to get inputs."*

In relation to the eight information sources that farmers engaged with, we also established that in practice there was overlap between some of these sources and public extension agents. Specifically, public extension agents may be involved in selling inputs as a side business, they are often involved in radio programming, and are a point of entry to the field for NGO projects and private extension workers or serve as their expert sources (Figure 7– see all sources linked to public extension agents). One farmer stated that input suppliers and public extension agents were the same, as a number of public extension agents entered into input trading as a side business or upon retirement. Farmers expressed they did not differentiate between public and private extension agents. One farmer considered both public and private extension agents as “agric-people” that were knowledgeable. Whilst two famers considered that these parties worked in close partnership and provided similar information. One of these farmers stated “*Grameen [NGO/private extension agent] and MOFA agents work in the same way,” and* another farmer said, “*NGOs are helpful, but they pass through AEAs”*. Five farmers noted that public extension agents and radio sources were synonymous; one particularly said: “*Both radio and AEAs are good as they are the same people and say the same things”.* Additionally, two farmers said they reported pest incidences to the farmer group leaders with the view that they would contact the public extension agent and/or channel down advice that they had been provided by these agents to farmers. One of these farmers said, “*We report issues to farmer group leaders as they have knowledge to share and transfer as experienced farmers.”*

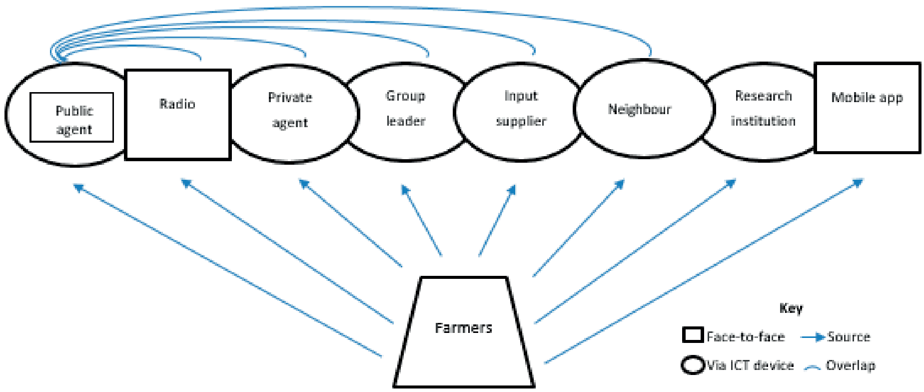


Figure 7. Farmers’ overlapping information sources

The fact that public extension agents served as or were the originators of information provided to other sources had implications on the perceived credibility and reliability of these sources. For radio two farmers expressed the source was credible and reliable because they assumed public extension agents provided advice through this medium. A farmer said, "*AEAs are also on radio providing pest identification and pest control advice, so we trust radio."* One farmer intimated they trusted input suppliers as providers of agronomic advice for a similar reason. The farmer explained: "*We also depend on input suppliers for pest control advice and inputs, they teach us how to use chemicals and they are the same as the agric- people, as they are former AEAs with shop*s,". Another (one) farmer also considered farmer group leaders as a credible and reliable source of information, because they served as a conduit of information from public extension agents to farmers. On this topic the farmer noted: "*I report to and get pest identification and control advice from the farmer group leader, as I see him as my "AEA" who is here to assist."* Other farmers, such as neighbours, were also considered a credible source when they were experienced farmers or being informed by public extension agents. The one farmer who expressed this said, "*Farmers also have experience or have links to AEAs and can give you advice they get from AEAs."*

<u>Mobile phones and new ICTs' role in fall armyworm management</u>

In order to gain insight in the farmers' use of mobiles and new ICTs for fall armyworm management, we first established the types of mobile phones[25] farmers owned (Figure 8). The data revealed that most farmers (14 of 16) owned the mobile phones they used. Furthermore, most farmers owned a feature phone that had a radio, multimedia and internet capabilities, as well as the capacity to take pictures and make video recordings. Only one farmer owned a smartphone, with an integrated computer, web browsing and the ability to run software applications.

[25] "The first type of mobile was a basic phone that could only be used for calls and text messages. Then came feature phones with added features like a calculator, light, camera, speaker, music player, voice recorder, and then also a basic and slow capability to access the Internet. Then came smartphones which were phones that incorporated PC-like features: their own operating system, their own software applications, and faster, better access to the Internet. And simultaneously emerged tablets which we could say are PCs with phone-like features: small size, touchscreens, intelligent voice interfaces, etc" (Heeks, 2018: 50).

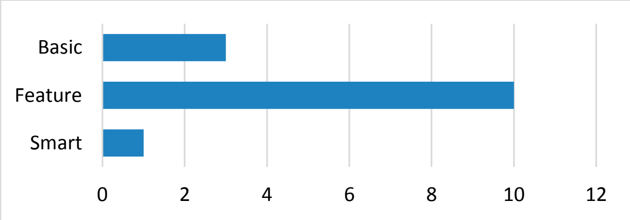


Figure 8. Mobile phone type ownership

Despite the capabilities of the feature phones that most farmers owned, farmers mainly used their mobile phones (or those they had access to) to make and receive phones calls (Figure 8). According to three farmers, the phone calls they received also included automated Interactive Voice Response[26] (IVR) calls. The farmers hardly used their mobile phones to search the internet or engage in social networking through, for instance Facebook or WhatsApp. Nonetheless, six farmers stated they checked applications. Of the six farmers, four farmers respectively engaged with the applications, ESOKO and Mobile Money on their phones.

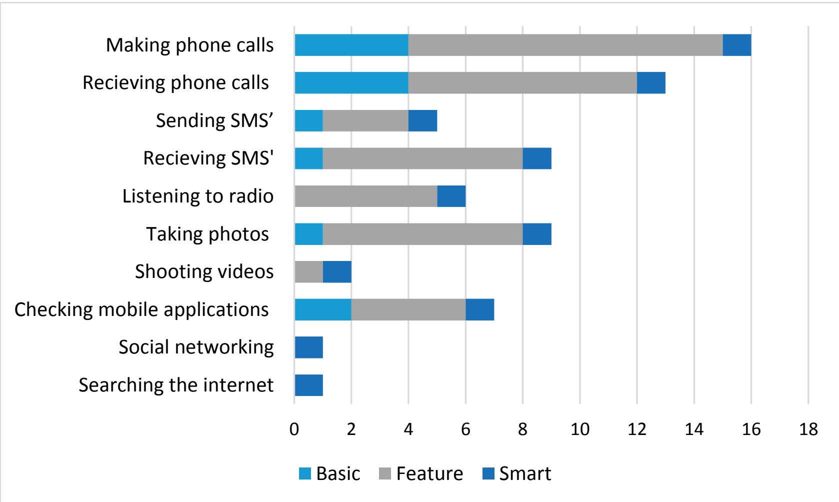


Figure 9. General mobile phone usage

Moving on to farmers' use of mobile phones and new ICTs to manage dimensions of fall armyworm, there was limited use of mobile phones and new ICTs in this regard (Figure

[26] "Interactive Voice Response (IVR) service – uses voice mail for delivery of important information by dialing into a premium number and accessing the information though simple menu steps,"(Qiang *et al.*, 2012: 80).

10). The data showed that farmers were made aware of the pest through phone calls from extension agents, other farmers or IVR applications. The data also showed that farmers primarily listened to the radio and when alerted they checked mobile applications and the internet to identify the specific pest and establish its controls.

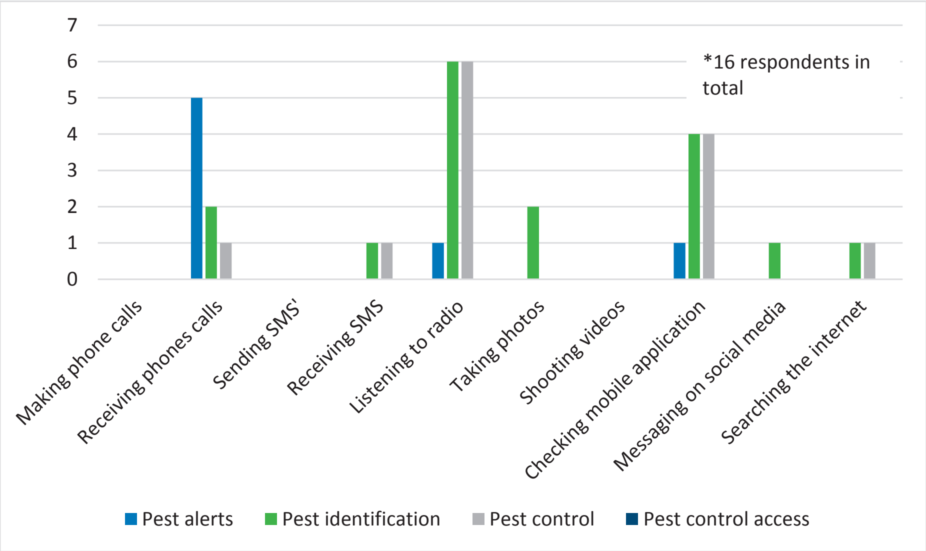


Figure 10. Number of citations mobile phone and new ICT usage in fall armyworm management

Farmers affiliated to Grameen used their mobile phones and new ICTs more broadly than those affiliated with the MOFA-DFAD (Figure 11). One of these farmers also received phone calls to identify pests, and SMS' that contained information on pest identification and controls. Additionally, two farmers affiliated to Grameen used their mobile phones to take pictures or shoot videos of their fields to share with extension agents to facilitate pest identification. Another Grameen affiliated farmer used his mobile phones to search the internet and engage with social media to access information for fall armyworm pest identification and control.

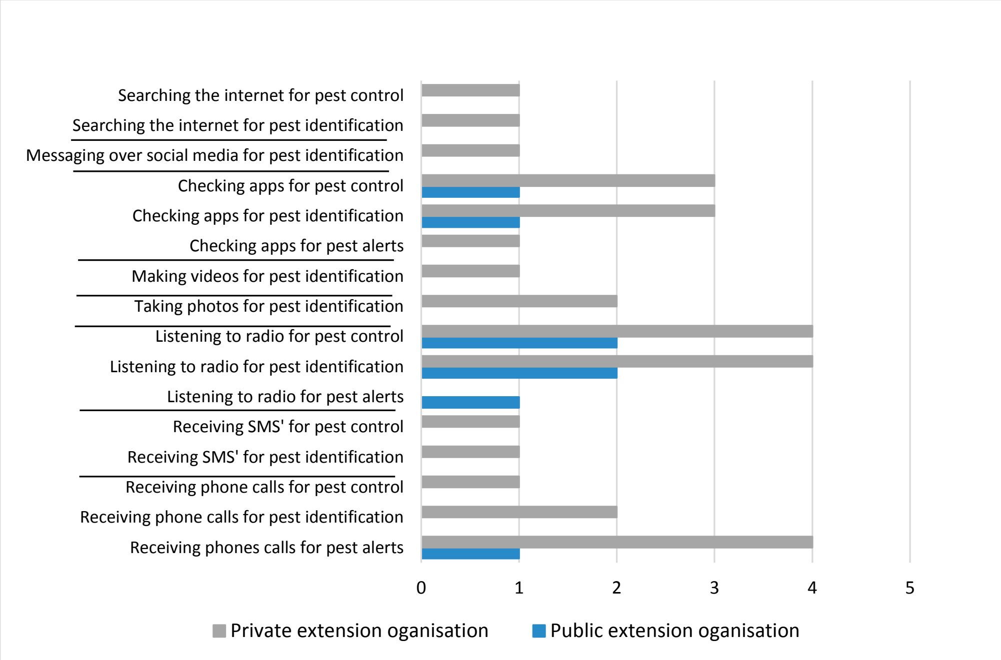


Figure 11. Mobile phone usage for fall armyworm management

All four farmers who used mobile applications to access information related to pest identification and controls were adult males that owned a mobile phone. Three of these farmers were affiliated to Grameen, large-scale maize farmers, but not highly educated. The farmer who used his mobile to search the internet and engage on WhatsApp was highly educated and met all the other criteria of a farmer more inclined to adopt ICTs (large scale maize farmer, male, owned a mobile device), except for being a youth - though he was in his early thirties. He was a teacher by profession that held a leadership position in a farmer group - secretary. He explained that he searched the internet for himself and also to assist other farmers on pest controls. He said he also did this by taking pictures of his fields and other farmers' fields and sent them to the extension agent as situation reports.

4. Discussion

The study aimed to identify farmers' information sources for different types of information needed to manage a new pest - fall armyworm, and foster understanding of farmers' information source preferences for managing the new pest. An additional research focus was to highlight the role of mobile technologies in fall armyworm management.

We find that farmers engage with a range of information sources to manage fall armyworm, but mainly rely on public extension agents based on their perceived credibility and accessibility. For all but one dimension of fall armyworm management farmers relies on public extension agents. For the pest alert dimension, they listen to the radio. The study indicates farmers perceive radio (alongside private extension agents, input suppliers, farmer group leaders) to be equally as credible and reliable as public extension agent as they are assumed to source knowledge from these agents. However, when public extension agents are not available to provide agronomic advice (pest identification and controls) they turn to other information sources such as private extension agent, farmer group leaders and mobile applications; and when farmers look to triangulate information and establish the best solutions they also turn to farmer group leaders and private extension agents. For the few farmers that used mobile phones in fall armyworm management they are used to access pest alerts via phone calls. Additionally, these farmers listen to radio and engage with IVR applications on their phones to identify pests and get pest control advice. We discuss these findings below.

Farmers' network of information sources in fall armyworm management

Farmers consult a range of information sources in fall armyworm management and consult multiple sources for certain fall armyworm management dimensions. Regardless of farmers' affiliation to public or private extension organisations their main sources of information for the dimensions of fall armyworm management are the same. Farmers favour radio as a means of accessing pest alerts, while they favour public extension agents for other fall armyworm management dimensions. These choices that are based on the combination of the perceived credibility and accessibility of sources for the specific information required counter other studies optimism of farmers using new ICTs in decentralised monitoring or to access pest alerts and advice (Damtew *et al.*, 2018; Munthali *et al.*, 2018; Tafesse *et al.*, 2018; Toepfer *et al.*, 2019). Farmers also have the tendency to consult multiple information sources (extension agents, radio, farmer group leaders), specifically in pest identification and to access possible pest controls. For a novel pest, and potentially other emerging problems, farmers value information and knowledge triangulation to validate pest diagnosis or determine the best course of action to take to control a pest from multiple sources. Other studies on African farmers' information seeking behaviour also highlight their inclination to engage with different information sources (Daude, Chado and Igbashal, 2009; Krone, Schumacher and Dannenberg, 2014). However, few do so in the light of a new pest Sub-Saharan African farmers are confronted with such as fall armyworm (Toepfer *et al.*, 2019) nor zoom into the use of information sources for specific types of information needed in pest management.

Farmers use multiple information sources to satisfy their specific information needs, but also perceive that public extension agents are behind or the same as other information sources. We find this is the case for information sources such as radio, private extension agents, farmer group leaders, neighbours, input suppliers. Beyond ranking farmers' information source preferences, these perceptions further highlight the continued relevance and central role of public extension agents in Ghanaian extension service delivery (Acheampong *et al.*, 2017; Munthali *et al.*, 2018). In other words in as much as this study reiterates that public extension agents are farmers' prominent information source (Tologbonse, Fashola and Obadiah, 2008; Daude, Chado and Igbashal, 2009), alongside radio (Toepfer *et al.*, 2019), we do not make this conclusion placing emphasis only on ranking all of farmer's potential information sources. We also draw attention to the perceived overlap between public extension agents and other information sources that indicates these agents are central in farmers' information source networks. Going forward we suggest research probing farmers' perceptions of who is behind specific information sources and ground truthing these perceptions to establish if overlaps between sources emerge in other contexts. The research would ultimately define an alternative and complementary method, to ranking, for establishing the prominence of specific sources in farmers' information networks. Social network analysis would be useful in this inquiry to visualise the relationships (overlap) of information sources and prominent source(s).

We also observe that farmers consult public extension agents notably more for information than new ICTs (Bernard, Dulle and Ngalapa, 2014; Munthali *et al.*, 2018; Toepfer *et al.*, 2019). Despite farmers' limited use of new ICTs in fall armyworm management we find they use their simple mobile phones to enhance extension service providers availability. Farmers engage with public extension agents through phone calls to access advice (Bernard, Dulle and Ngalapa, 2014; Munthali *et al.*, 2018; Tafesse *et al.*, 2018) and tune into radio on their mobile phones to access pest alerts and advice. However, even though this study reports these methods of farmers engaging with service providers, we also find farmers' prefer face-to-face engagement with public extension agents (Tologbonse, Fashola and Obadiah, 2008; Daude, Chado and Igbashal, 2009; Dutta, 2009). This preference is attributed to face-to-face communication enabling in-depth discussion that is useful in the exchange of complex knowledge such as pests/disease advice (Krone, Schumacher and Dannenberg, 2014; Aker, Ghosh and Burrell, 2016). Nonetheless, farmers' use of phones calls and use of mobile phones to listen to radio, reflect the slow and incremental advances in farmers' use of mobile technology to access information (Martin and Hall, 2011), even when confronted with new and highly challenging agricultural problems.

The findings on farmers' information networks also indicate that farmers associated with private extension organisation are more inclined to use new ICTs to access agricultural information. We observe that farmers affiliated to Grameen, unlike those affiliated to MOFA, were introduced to ESOKO - a mobile phone (SMS and IVR) application, and some of these farmers used it for agronomic information. This finding is important as it reflects on how NGOs' promotion of new ICTs can influence their uptake by farmers. However, it is important to point out that despite development organisations' efforts to promote ICT-based extension and simultaneously build private extension providers capacity to roll-out these approaches, public extension agents' exclusion from such interventions (as prominent information providers) could have a bearing on their success. In the same vein Fabregas *et al.* (2019) refer to the likelihood of a public-sector role in scaling mobile based extension and advisory services. Therefore, it is advisable that extension interventions that encompass new ICTs accommodate partnerships between private extension providers and public extension organisations to foster better new ICT uptake. The drivers of this success could be two-fold. Firstly, the interventions could engage more farmers, as public extension service delivery has broader reach. Secondly, considering trust is important for digital technology acceptance in Africa (Aker, Ghosh and Burrell, 2016), the new ICTs could be associated to public extension agents that farmers view as credible.

Lastly, in this section, we recommend more comparative studies on farmers' information source networks for managing new and familiar pests to improve the efficiency and fit of extension service delivery with farmer information needs. This research is prompted by our findings that farmers seemed less inclined to consult other farmers, than what is found in other research (Tologbonse, Fashola and Obadiah, 2008; Daude, Chado and Igbashal, 2009; Dutta, 2009; Bernard, Dulle and Ngalapa, 2014). In regard to our research, we cannot ascertain farmers need more expert-based information to deal with a new pest, when it seems logical that farmers would be inclined to consult more external information sources for advice and triangulate this information for new pests than for familiar ones. Therefore, we suggest the comparative study to provide insight into farmers' information source networks under these different circumstances.

<u>Factor influencing farmers' choice of information sources for fall armyworm management dimensions</u>

Similar to other studies, this research showed farmers' information source preference is primarily determined by the perceived credibility of the source, and to a certain extent on the reliability and accessibility of the source (Bernard, Dulle and Ngalapa, 2014; Rahman, Lalon and Surya, 2016; Acheampong *et al.*, 2017). The importance of credibility (expertise) when farmers choose to engage with a source especially arises when they are faced with new problems, for which reliable solutions are not well known (Tafesse *et al.*, 2018). In this study on fall armyworm, farmers underscored credibility as the major factor influencing which source they largely relied on for agricultural information, public extension agents. However, when the latter are unavailable, farmers opt to engage with alternative sources (private extension agents, farmer group leaders or mobile applications). This points to the relevance and value of these other information sources to supplement public extension service delivery that is challenged by a high agent to farmer ratio (1 agent to 1,300 farmers) and limited funding for fieldwork (Bennett, 1996; Pretty, Toulmin and Williams, 2011; McNamara *et al.*, 2012). Therefore, as long as public extension systems budgets remain limited, it is advisable that they invest in training private extension agents and farmer group leaders as well as promote new ICTs to complement face-to-face information and advice provision by public extension agents.

We also see that farmers perceived overlap between public extension agents and other information sources has implications on farmers' perceptions of the credibility of other sources (radio, private extension agents, other farmer inputs suppliers). More specifically, the implications are that the credibility farmers ascribe to public extension agents is also ascribed to these other information sources. Such that some farmers engage with these sources as they knew or expect public extension agents are behind these sources or provide them information and; hence, also consider them credible. In practice the transferability of credibility between sources could serve the purpose of fostering credibility for content provided over agricultural mobile applications, if the information source is associated to the public extension system.

<u>The role of mobile phones and new ICTs' opportunities for responding to emerging problems</u>

Despite the capacities of mobile technologies to provide farmers with immediate access to tailored information and gain new insights from broader, external sources of information for new pest management, farmers mainly use their basic or feature phones to call and exchange information with public extension agents (Krone, Schumacher and Dannenberg, 2014; Aker, Ghosh and Burrell, 2016; Damtew *et al.*, 2018; Toepfer *et al.*, 2019). Though the current role of mobile technologies for agriculture in Ghana is still limited, the few farmers using new ICTs in fall armyworm management hint at promising directions for their application.

There are opportunities related to farmers basic mobile phone usage. First of all, farmers could amplify their use of mobile phones to call extension service providers to access pest identification and control advice (Munthali *et al.*, 2018; Tafesse *et al.*, 2018). While a future option could involve farmers using their mobile phones to take pictures or shoot videos of their fields and emerging problems (Martin and Hall, 2011), and send them to extension service providers. These visualisations may enhance farmers' remote pest reporting, and contribute to speeding up extension agents turn-around time in pest identification. Further, acting on this opportunity could involve experimentation with the transmission of the visualisation through Multimedia Messaging Services (MMS) based on two considerations. Firstly, these services run on feature phones and there are indications that more farmers are using feature phones at present. Secondly, that the use of the combination of feature phones and MMS technology is relatively cheaper and more accessible that using smartphones and online messengers such as WhatsApp.

In relation to new ICTs, there are also future opportunities for IVR and social media messaging technologies (e.g., WhatsApp) in new pest management. The value of IVR applications lies in speedy dissemination of pest alerts (Toepfer *et al.*, 2019). These applications might easily be accepted by farmers as they match farmers' mobile technology competencies and preferences. More specifically, they are accessible to farmers as they function similar to phones calls as well as radio - a broadcasting medium. While for social media messaging technologies a promising area could be their application in coordination. For instance, we find in this study that an educated farmer group secretary takes pictures on behalf of farmers to send to extension agents as part of field reporting and attaining agronomic advice. In the same way a lead farmer can enable other farmers of limited literacy and technological means to leverage (hi-tech) mobile technology to access information. Therefore, similar to what is suggested by Damtew *et al.* (2018) and Leeuwis (2018) social media messaging technologies in combination with intermediaries and other forms of communication mediums (face-to-face,) can speed up and improve information sharing within farmer groups.

5. Conclusion

When confronted with a new pest such as fall armyworm, farmers tend to draw information from various information sources. In fall armyworm management, they consult a range of sources to choose the best fit(s) for each fall armyworm management dimension. Regardless of their affiliation to public or private extension organisation, farmers mainly engage with radio to become aware of pest risks and on public extension agents for the other dimensions of fall armyworm management. Additionally, farmers consult multiple sources in pest identification and pest control establishment to triangulate information and chart the best course to follow when reliable solutions are not well known.

Farmers mainly engage with public extension in fall armyworm management based on their perceived credibility of these sources. Where a sources' expertise becomes the most critical factor influencing farmers' information source choice when they seek new knowledge. Further, public extension agents' prominence in farmers information source networks is not only determined by ranking farmers' preference, but indications that farmers knew or assumed public extension agents are behind other information sources.

In terms of farmers' use of mobile technology the study highlights that similar to other studies farmers sparingly use new ICTs as information sources. This makes it difficult to define a future role for new ICTs in (novel) pest management. However, farmers' use of mobile technology, in fall armyworm management, fits their capacities and competencies. They engage via phone calls to access pest identification and control advice as well as listen to radio broadcasts (through the phone) to access pest alerts. Additionally, there are opportunities for farmers to engage with new ICTs that function similarly to their mobile phone uses i.e., IVR technology, and further opportunities for them to leverage social media technology such as WhatsApp, through farmer group leaders, to connect to agricultural information and service providers.

6

Chapter 6

General discussion

1. Introduction

This thesis investigates the role of new Information and Communication Technologies (ICTs) in broader extension service delivery, namely innovation intermediation, in Ghana. This research is prompted by the literature gap that compels research linking the topical areas of new ICTs' inherent capabilities and innovation intermediation, in Africa. This study is important because new ICTs have the potential to support extension organisations adapt to extension approaches that are broader than technology transfer, to include facilitation roles for extension staff to respond to wider agricultural system constraints. The research premise is that new ICTs present opportunities for innovation intermediation, but the use of these technologies for such purposes is not automatic as -in context- technology and society shape each other. Guided by this premise the thesis sought to answer the overarching question, what roles do new ICTs play in supporting innovation intermediation in the Ghanaian extension system?

Main findings

In order to answer this question four sub-questions were investigated. Below the main findings of each sub-question associated to an empirical chapter are reported, followed by the overall study findings that lead to the discussion and recommendations of this thesis.

1. What are experts' (scientists, researchers and practitioners) views on the intermediation capabilities of new ICTs in Ghana's agricultural system?

Using an experts' consensus building method, chapter 2 established the capabilities of nine new ICTs[27] to support communication and networking functions relevant to facilitating innovation intermediation. The results indicate that Interactive Voice Response (IVR) technologies have a high capability to support action-oriented, linear communication functions targeted at rural farmers. These functions are disseminating,

[27] Interactive Voice Response (IVR) inbound and outbound; Short Message Service (SMS) push and pull, Unstructured Supplementary Service Data (USSD), Data Management (DaM), Document Management (DoM), social media messaging and Spatial (Spa) technologies.

harvesting, retrieving and matching. However, there was no consensus among experts that the new ICTs identified in the study, including social media messaging technology that can enable multi-actor engagement, had a high capability to support transactional, interactive functions. The functions networking, coordinating and co-creating, which are relevant to facilitating collaborative innovation intermediation components (activities).

2. What are new ICTs' roles in supporting innovation intermediation in public and private extension organisations?

Based on interviews with extension staff, and by observing (extension) agents during fieldwork, chapter 3 shows Data Management (DaM) technologies are new ICTs used by both organisations. These technologies that are not oriented towards networked communication do not support connective action for innovation intermediation. Nevertheless, they can contribute to select innovation intermediation activities that benefit from decentralised data collection i.e., support monitoring of production practices or pest/disease occurrences to a certain extent and enable farmer database development to support tacit needs identification. These databases can further support intervention planning, advice tailoring as well as building credit providers trust to offer farmers loans, but to a lesser extent (Figure 1). However, the DaM technologies' potential to support these activities are far from realised. This is due to social, organisational and institutional factors, including organisation design choices, communication cultures, funding arrangements, and user technical abilities, preferences and information needs that limit the realisation of the technologies' potential. Therefore, conventional face-to-face communication mechanisms remain relevant to extension service delivery in the context and better suited for supporting more interactive and collaborative activities of innovation intermediation.

3. What is the contribution of social media messaging platforms to enhancing interaction for collaboration at the interface of research and extension?

Chapter 4 focuses on two social media platforms and investigates their contribution to facilitating open communication spaces to support knowledge sharing and other forms of collaboration involving researchers and extension staff. The platforms are a WhatsApp group of extension staff associated with a public extension organisation; and a Telegram group of researchers and extension staff associated with a research institution. Platform content and social network analysis revealed that both platforms possess centralised network and communication structures - suggesting that platform users' participation in especially sending messages over the platforms is non-egalitarian. This situation is influenced by social hierarchies, organisational rules and users' identity management tactics. The platforms' network-communication structures do not facilitate open communication spaces. Therefore, they are not suited for collaborative innovation process management activities, such as, knowledge integration and joint problem solving. Despite this, the platforms' structures play meaningful roles in supporting the coordination of extension activities on the ground, and information dissemination and harvesting for pest monitoring by organisation managers. The structures also enable knowledge sharing involving extension staff and subject matter specialists for individual-centred learning and problem solving by public extension agents. Therefore, the platforms are likely to generate useful input for knowledge integration and joint problem solving in complementary face-to-face settings.

4. What are farmers' information source choices in accessing information for managing new pests (fall armyworm), and the role of mobile technology in this process?

In chapter 5, semi-structured interviews reveal that farmers' information networks accommodate a range of sources. Farmers also consult multiple sources in pest identification and to establish pest controls to triangulate information and chart the best course of action when reliable solutions are not well known. Farmers rely on public extension agents for most dimensions of fall armyworm management, specifically pest identification, accessing control advice and identifying input providers. For pest alerts they listen to the radio. Farmers mainly engage with public extension agents because of their perceived credibility, while using new ICTs sparingly in fall armyworm management. Despite this, the study points to ways farmers use conventional mobile phone functions, such as phone calls or listen to radio, to access agricultural information.

Additionally, the study points to opportunities for farmers to actively engage with IVR technologies as information sources, because these technologies work in a similar way to their prevailing mobile phone usage.

Overall the study identifies opportunities for IVR outbound, DaM and social media messaging technology to support certain innovation intermediation components (Figure 1), while complementing the contributions of human intermediaries (public extension agents) and classical communication mechanisms (face-to-face communication settings and radio) to these activities. IVR outbound technologies can provide immediate access to information (advice, weather, market prices, and pest risks), while supplementing public extension agents in advice provision and supplementing radio in disseminating the other types of information. DaMs have the potential to facilitate the development of location-based farmer databases. These databases can further facilitate farmers' (tacit) needs identification, support extension intervention planning in district technical or national stakeholder meetings, and support advice tailoring by field extension staff in face-to-face interaction with farmers. Whereas social media technologies, WhatsApp and Telegram platforms', can support timely (field) monitoring in which problems are identified for discussion in national stakeholder meetings or district technical meetings. These platforms can also facilitate the coordination of extension activities (sending notifications and directives to field extension staff). Further, social media messaging technologies can support knowledge sharing among extension staff and subject matter specialists to enable individual-centred learning and problem solving. The knowledge shared over these platforms can also be input for knowledge integration or used in addressing knowledge gaps, in meetings at different levels of the extension system.

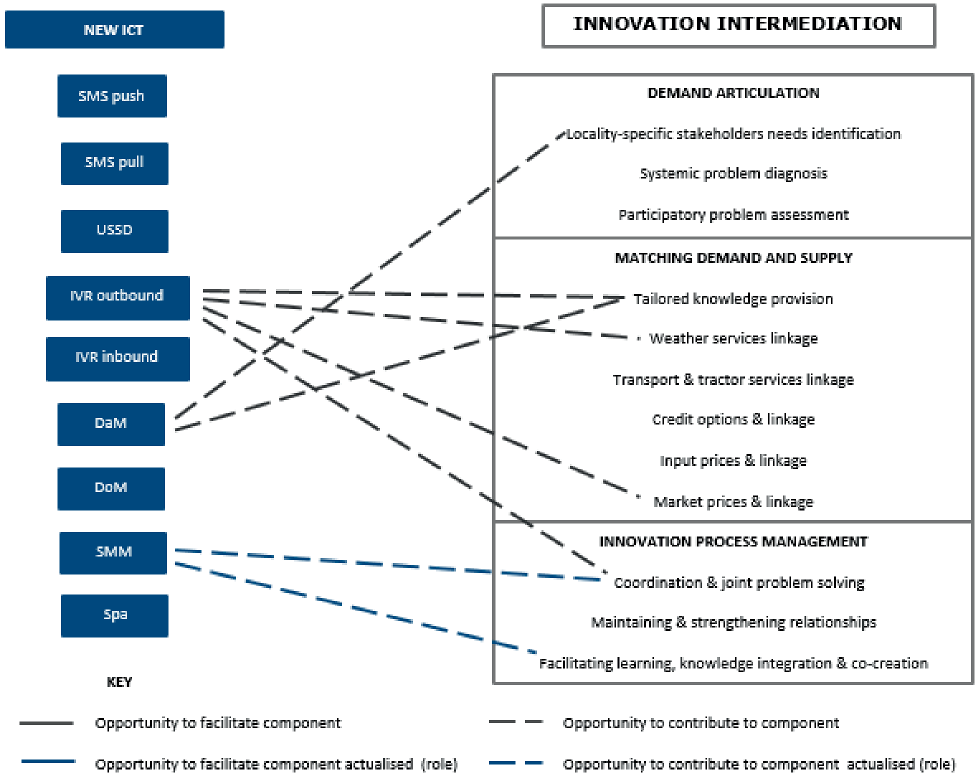


Figure 1. New ICTs' opportunities and role in innovation intermediation as observed in this dissertation

However, except for the social media technologies that are actively used due to certain enablers (familiarity, bottom-up initiation and availability of running costs), a role for the other technologies in innovation intermediation is not ascertained. This is because a number of social factors[28] limit the use of the IVR and DaM technologies by extension service providers, the research institution, and individual users in the Ghanaian context. Therefore, despite the opportunities afforded by IVR and DaM technologies, their potential is not realised.

[28]Social factors or influences: personal factors such as human abilities, preferences, motivations and identity management (Marchewka and Kostiwa, 2007; Toyama, 2011), socio-political influences (e.g., actors with interests in maintaining the status quo, power dynamics and social hierarchies in information exchange or sharing) and the wider institutional environment (policies, incentive systems, funding arrangements, organisation rules and values, and prevailing communication cultures, etc.)(Ipe, 2003; Leeuwis, 2013; Cieslik *et al.*, 2018).

2. Discussion and recommendations

The social factors that shape the technologies' use are discussed below. The factors are discussed as part of central themes that emerge from the general study findings. Each theme closes with recommendations for extension policy and practice. These themes relate to new ICTs' opportunities for innovation intermediation; the relevance of classical and conventional communication mechanisms for extension in the digital age; and farmers' exclusion from the networked society. Additional themes include new ICTs' untapped potential for responding to emerging challenges; social media messaging technologies as drivers of collective action and new ICT extension initiatives' financial sustainability. Following the discussion of these themes, are options for future research and the conclusion of this thesis.

<u>New ICTs' opportunities for innovation intermediation and limitations in actualising these potential roles</u>

A prominent theme emerging across the chapters is the disparity between the opportunities for specific new ICTs to support innovation intermediation and the extent to which these technologies are used to fulfil these potential roles. This situation applies to IVR and DaM, but not social media technologies for which a role is ascertained above.

IVR outbound technologies' potential to provide information speedily to farmers in Ghana (chapter 2) has been reported as far back as 2013 (McNamara *et al.*, 2012; Dittoh, Van Aart and De Boer, 2013). Despite the potential for these technologies to provide farmers with agronomic advice and market information (Aker, Ghosh and Burrell, 2016), farmers sparingly use IVR technologies. This is due to their preference and ability to receive support through face-to-face communication from human intermediaries – mainly public extension agents (chapter 3 and 5)(Aker, Ghosh and Burrell, 2016). These findings show that even though Klerkx and Gildemacher (2012) see the potential of new ICT intermediaries in information provision and linking demand and supply side actors in Europe, this is not the reality in Ghana. Further, though other African studies validate farmers' affinity to public extension agents as information sources, and explain their sparing use of new ICTs (Tologbonse, Fashola and Obadiah, 2008; Daude, Chado and Igbashal, 2009; Bernard, Dulle and Ngalapa, 2014; Acheampong *et al.*, 2017), additional factors can explain the latter. Farmers' low usage of IVR technologies can also be attributed to limited exposure (Misaki, Gaiani and Tedre, 2018). This explanation is prompted by two observations. Firstly, farmers associated with the private extension organisations that promote these technologies to pockets of farmers are more inclined to use new ICTs, although farmers generally refer to these sources when public extension agents are unavailable (chapter 3 and 5). Therefore, the promotion of IVR technologies by public extension organisations to the broader farmer population they serve could prompt more farmers to use them and supplement public extension agents' work. In the same vein Fabregas *et al*. (2019) refer to the likelihood of a public-sector role in scaling mobile based extension and advisory services. Secondly, farmers mainly use their phones to make and receive calls (chapter 5). Farmers mainly engage with the audio functions of their mobile phones (Aker, Ghosh and Burrell, 2016), which operate like IVR technology. Therefore, there are possibilities for more farmers to take advantage of IVR technologies.

DaM technologies are also underexploited despite their potential to contribute to a number of innovation intermediation activities (Figure 1). Chapter 3 shows that these technologies, as part of demand articulation and matching demand and supply, can potentially support location-based farmer database development for tacit needs identification, intervention and advice tailoring as well as building the trust of credit providers to a certain extent. In innovation process management, they can support field monitoring to improve problem solving to lesser extent. In relation to demand articulation, the opportunities for the DaM technology, on E-extension and SmartEx, are not actualised by both the public and private extension organisation. The factors that contribute to the underutilisation of the DaM technologies include limited funds for (extension) agents to visit the field (Fabregas, Kremer and Schilbach, 2019) for data collection and limited funds to access the internet to populate the farmer databases (chapter 3). Further, limited technical abilities (McNamara *et al.*, 2012) and financial incentives to collect data limit E-extension's use by some public extension agents and limit SmartEx's use by a number of Grameen agents, respectively (chapter 3). Further, DaM technologies are also underutilised in innovation process management. In particular, they are underexploited for monitoring by extension agents, because they support information extraction from the field to highest organisational level and extension field staff do not access the data analytics (chapter 3). In this respect, the DaMs design excludes field staffs' information needs, despite the technologies ability to accommodate these needs - demotivating field staff from using the technologies. Field (extension) agents respond to these limitations by using WhatsApp groups to support timely monitoring and feedback loops between organisational levels.

It is also important to note that an additional factor contributing to the low usage of, for instance the DoM technologies - only present on SmartEX – is the mismatch between the platform's design and the main activities and related information needs of the Grameen agents. This is exemplified by Grameen agents hardly using the elaborate DoM component on SmartEx, as they consider themselves more of data collectors (chapter 3). While public extension agents have an appreciation for the CABI-Plantwise Factsheet (DoM technology) that some used in their prominent knowledge advisory role (chapter 3). This is a further indication that the platforms are designed to meet the needs and assumptions of higher organisation levels. Therefore, there is limited added value for the agents to use the technologies that have seemingly been developed through a non-inclusive process.

All in all, it is evident that despite the capabilities of the new ICTs, social factors limit their use. These findings align with the concept of 'mutual shaping of technology and society'. The concept proposes that when technology is introduced into a context partial adoption or (use)fulness of a technology's capabilities is expected (Scarbrough, 1992). At the same time there is evidence that certain technologies are used in unanticipated, positive ways. The social-oriented, WhatsApp and Telegram groups, are used in professional activities, showing that the use of technology in context is difficult to predict (Stilgoe, Owen and Macnaghten, 2013).

The findings also point to practical implications of how new ICTs can be used effectively to support innovation intermediation in Africa. There is need for contextual considerations in technology design, which should also be an inclusive, anticipatory, reflexive and responsive process (Stilgoe, Owen and Macnaghten, 2013) to enhance technology as well as data access (Scarbrough, 1992; Zheng and Walsham, 2008; Cinnamon, 2020). Whilst, organisations' commissioning these designs should also look into data protection and privacy concerns of farmers resulting from the extractive nature of certain types of decentralised data collection processes (Mann, 2017). This is important, considering public and development organisation have justified using farmer data with little to no consent based on using it for development purposes (Mann, 2017). Lastly, the findings encourage extension organisations to build on existing technologies (De Bruijn, 2014), and integrate more user-driven technologies such as WhatsApp (Sulaiman *et al.*, 2012) in technology designs and strategies to broaden extension service delivery.

<u>Farmers' exclusion from networked society and leveraging new ICTs through human intermediaries</u>

Stilgoe *et al*. (2013) and Toyama (2011) reflect on the negative effects of technologies and their ability to amplify existing inequalities. For example, technology may foster data inequalities (haves and have nots) and may not democratise access to information. Related to these perspectives, social factors exclude farmers from the opportunity to engage with certain new ICTs and access their benefits (content, decentralised data provision or information and knowledge exchange). Farmers, comprising key agricultural stakeholders, are excluded from using social media messengers (chapter 2 and 5)(Fabregas, Kremer and Schilbach, 2019) that could enable them to engage directly or simultaneously with other agricultural stakeholders, and plug into collaborative activities related to demand articulation and innovation process management. This exclusion is due to the mismatch between the technologies design and farmers' interaction preferences. The other factors limiting Ghanaian farmers' access to these technologies relate to their capabilities i.e., limited literacy and limited smartphone access (chapter 2 and 5) (Dittoh, Van Aart and De Boer, 2013; Misaki, Gaiani and Tedre, 2018).

Despite the potential of social media, DaM and IVR technology to support innovation intermediation, a balanced perspective on farmers' use of new ICTs to benefit from such processes is required. A perspective that incorporates ICT-based and other intermediaries. Klerkx and Gildemacher (2012) imply there is a role for non-technological drivers in facilitating innovation. They put forward that types of intermediaries (organisations, consultants, projects or ICTs) often exist in combination, and at the same they suggest limited roles for ICT intermediaries (information provision and passive matching of demand and supply actors) leaving roles for other intermediaries to fill. Consistent with these findings, this study finds that farmers benefit from certain innovation intermediation activities through public extension agents and farmer group leaders that use new ICTs in their work (chapter 3) (Mccole *et al.*, 2014; Fabregas, Kremer and Schilbach, 2019). Therefore, even though IVR technology can potentially provide farmers with agronomic advice, farmers mainly rely on public extension agents in this regard (chapter 2 and 5). Extension agents access generic knowledge via DoM technology, such as the Plantwise Factsheet and other sources such as the internet, and then based on familiarity with farmers' situations localise the knowledge (chapter 3). Further, public extension agents where possible engage with farmers face-to-face to facilitate interactive learning, providing farmers the opportunity to provide input and seek clarification on the agents' advice (chapter 5)(Asiedu-darko, 2013). Additionally, chapter 3 shows that extension agents engage in decentralised data collection on farmers' situations as their proxies, while lead farmers use WhatsApp to link the broader set of farmers they represent with service providers (chapter 5).

From the findings it follows that policy related to farmers' involvement in new ICT extension initiatives should not fixate on a technological solution to farmers engaging in and benefiting from innovation intermediation activities. This is given the current situation that human intermediaries remain relevant in Ghanaian extension, even in the digital age. Therefore, extension policy and practice should focus on innovation intermediation models involving new ICTs and human intermediaries, alongside developing new technology skills for these intermediaries (OECD, 2018). This is because integrated models are more likely to be successful in broader extension service delivery from a knowledge provision focus (Damtew *et al.*, 2018; Leeuwis *et al.*, 2018).

<u>Conventional communication mechanisms' relevance to extension in a networked digital age</u>

Social media platforms, WhatsApp and Telegram, that enable multi-actor engagement and networked communication are new ICTs identified in this study (chapter 3). Despite the capabilities of these technologies the findings indicate that face-to-face settings are more appropriate for facilitating collaborative innovation intermediation activities (chapter 3 and 4).

The WhatsApp and Telegram platforms in chapter 4 provide equal access to information for platforms actors, but foster limited information sharing and discussion among them. Apart from conflict avoidance: platform actors' reluctance to challenge the contributions of others to prevent tension rising, actors' interaction is limited by the hierarchal relationships in which actors are perceived as knowledgeable and less knowledgeable. These relationships hamper extension agents, often perceived as less knowledgeable, from contributing to the platforms because they are worried about sharing wrong solutions in the presence of subject matter specialist or make them inclined to leave solution provision to these specialists. This situation does not foster the type of open communication required to facilitate collaborative activities, such as knowledge integration and joint problem solving. The study finds these activities occur in face-to-face settings, including national stakeholder meetings, district innovation platform or district extension departments technical meetings or other such meetings that include district staff from other government departments (chapter 3 and 4). Unlike a previous study that shows that social media capabilities can support networking to drive agricultural innovation in Europe (Hansen *et al.,* 2014), this study indicates that in Africa face-to-face settings are still the central mechanism for not only networking (Molony, 2006), but also for supporting collaboration (chapter 4). Even though face-to-face settings are susceptible to the same interaction constraints as the platforms, they probably remain prominent in supporting collaboration as they cultivate more trust between discussants; hence, face-to-face settings create a better environment for active learning and dialogue than online messaging media (Leeuwis, 2004).

Nonetheless the social media messaging technologies do contribute to supporting collaborative activities of innovation intermediation when combined with face-to-face settings (chapter 4). Similar to previous studies (Sulaiman *et al.*, 2012; Materia, Giarè and Klerkx, 2015), this study reiterates the value of the interplay between virtual communication platforms and face-to-face settings for knowledge sharing and learning. However, in this case, knowledge sharing is not mainly between researchers and extension staff (as in Materia *et al.*, 2015) or among researchers (as in Ahmed, Ahmad, Ahmad, & Zakaria, 2019), but more between extension staff who make up the majority of actors on the platforms (chapter 4). Additionally, this study highlights the platforms support individual-centred as opposed to joint learning (chapter 4).

Returning to the complementarity of the communication mechanisms mentioned – similar to the review on organisational social media (Van Osch and Coursaris, 2013), with limited studies on Africa or agriculture, in this study social media supports knowledge sharing, monitoring, and coordination (chapter 4). Specifically, the WhatsApp and Telegram groups studied support timelier monitoring through which topical issues for discussion and action (e.g., pest risks) in face-to-face meetings emerge. The technologies also support information dissemination and harvesting in coordinating extension activities, and they support the sharing of (new) production and pest/disease control techniques (Chapter 3 and 4). Additionally, it was observed (chapter 4) that the social media messaging technologies provide decentralised information such as experiential knowledge shared by different actors that potentially feed into knowledge integration efforts in the extension system. Aside for this the technologies enable the identification of tacit knowledge gaps (chapter 3), in this way passively contributing to collaborative demand articulation and joint problem solving processes. These findings align with Duncombe's (2016) assertion that face-to-face interaction remains critical for demand articulation considering the trust building dynamics in face-to-face settings already discussed.

Beyond face-to-face settings, the findings show that radio is a prominent medium of providing advice or raising farmers' awareness (Chapter 3 and 5). It follows that radio, which was the major mass communication mechanism in developing countries before the digital era (1950s to 90s) remains relevant to extension service delivery today (Heeks, 2018). Radio supports one-way information flows and is less interactive than social media, and also incurs additional costs for recording and redistribution (Heeks, 2018). Despite these limitations, radio should not be overlooked in disseminating information to farmers in relation to innovation intermediation. Radio's relevance is based on three considerations. Firstly, even though mobile penetration is increasing, radio has extensive reach in developing countries and attracts a large rural audience (ITU, 2010) - including farmers (chapter 3 and 5). Secondly, the combination of radio and mobile technologies has led to radio programmes that are more interactive (e.g., call-ins, beep to vote) (Asiedu-Darko and Bekoe, 2014; viamo, 2020). Lastly, analogue technologies, such as radio, are converging with mobile technology i.e., farmers listen to radio over their phones (chapter 5 - see also Heeks, 2018).

The value of classical communication mechanisms in extension (Krone, Schumacher and Dannenberg, 2014; Materia, Giarè and Klerkx, 2015) and their complementarity with new ICTs has implications for extension practice (Leeuwis *et al.*, 2018). The implications are that strategically embedding new ICTs in the existing media and general communication landscape of extension, based on their added value is essential to broadening extension service delivery.

<u>New ICTs' untapped potential for facilitating new learning and problem solving dynamics in response to emerging challenges</u>

There is untapped potential for the technologies identified (chapter 2) to contribute to broader extension service delivery, including the climate change response. There is optimism that new ICTs can support the climate change response in four areas: mitigation, monitoring, strategy and adaptation (United Nations, 2020).

Social media technologies that enable inter-connectivity, user generated content and fast information exchange among most agricultural stakeholders, excluding farmers (chapter 2 and 4), can enhance monitoring of the causes and impacts of climate change, such as new pest to support decision making and strategy formulation. They can also support adaptation by speedily raising awareness on climate change and its challenges as well as by identifying and disseminating coping strategies to respond to these challenges (chapter 4). Further, chapter 2 indicates that IVR outbound technologies can engage rural farmers directly to support climate change adaptation, if farmers' barriers to accessing and using these technologies are addressed.

IVR technologies can also contribute to climate change monitoring and other decentralised data capture processes that involve farmers providing information to extension staff or researchers directly. IVR inbound technologies may be used to harvest feedback or situation reports from farmers (chapter 2) (viamo, 2020) in systemic problem diagnosis or to further the citizen science agenda through participatory environmental monitoring (Leeuwis *et al.*, 2018). Alternatively, there is an opportunity for harvesting information from rural actors with moderate literacy through USSD enabled Facebook or those with limited literacy and access to smartphones by using the audio recording function of WhatsApp.

There are additional opportunities for rural actors to provide information directly through basic phone functions to speed up service providers' responses in (new) pest and disease identification (chapter 5)(Aker, Ghosh and Burrell, 2016; Fabregas, Kremer and Schilbach, 2019). Farmers can use their phone cameras, coupled with Multimedia Messaging Services[29] (MMS), to take pictures and send these images to report pests and diseases to extension service providers or researchers. These opportunities may

[29] The core capability of Multimedia Messaging (MMS) technology is that it enables the sending of messages than do not exceed 160 characters in length, 40 seconds of video and audio recordings and one image using feature or smartphones.

actualise considering most farmers have access to phone cameras and MMS (Heeks, 2018), and this combination is relatively cheaper than online messengers (e.g., WhatsApp) that function on smartphones.

DoM technology, on the other hand, has the potential to contribute to another area of extension service delivery, namely tailoring advice to farmers and possible other agricultural value chain actors. These technologies can provide extension agents with generic knowledge, which they can localise at the farm level (chapter 3). The association of DoMs to public extension is evident from the findings in chapter 3. The few public extension agents selected as CABI plant doctors who had access to the Plantwise Factsheet found this technology useful, unlike the Grameen agents that had access to a DoM component on SmartEx (chapter 3). It would thus appear that public extension agents, as central actors in advice provision, are more inclined to engage with such technologies to further their intermediary work, including disseminating location-specific coping strategies for climate change related challenges.

The untapped potential of new ICTs discussed above that points to areas for experimentation mainly relates to older generation mobile technologies, basic mobile functions and intermediated usage. This focus avoids the over-emphasis on new ICTs and smartphones as innovative solutions, because the majority of farmers, and other rural actors, have basic and feature phones (chapter 5; see Heeks, 2018) and they leverage new ICTs through human intermediaries (chapter 3).

<u>User-driven social media messaging technologies as drivers of collective action</u>

The study establishes that social media messaging technologies can play a role in achieving collective goals related to innovation intermediation (chapter 4). These technologies are used by extension staff and researchers in pest and disease management for joint monitoring of pest/disease emergence and coordinating information and knowledge dissemination to respond to these threats. These collective goals are achieved through a nuanced version of connective action - forms of collective action that occur without strong organisational coordination, and through the networking and self-organisation of multiple actors, enabled by social media to achieve collective goals (e.g., Arab Spring) (Bennett and Segerberg, 2012). Further, the type of connective action identified does not involve solving collective action problems, but achieving the collective goals aforementioned.

Three factors can explain the actualisation of the roles above. First, extension staff use social media messaging platforms more actively than organisationally-driven technologies (DaM technology - Chapter 3), because they are part of interaction in every-day life (Leeuwis *et al.*, 2018). They are easy to use (chapter 3) and are an accessible means of interactive and immediate communication (chapter 2). Second, is because they largely emerge as bottom-up initiatives - initiated by mid-level staff in both organisations (chapter 4). The third enabling factor is that internet costs for the work-related WhatsApp group are covered by platform users who primarily use WhatsApp for social interaction.

The enablers of social media use that support platform actors to meet collective goals back Sulaiman et. al.' (2012) and Bennett and Segerbergs' (2012) optimism of user-driven platforms, such as Facebook, in enhancing knowledge sharing and driving connective action respectively. Although this study specifically focuses on WhatsApp and Telegrams, which are more appropriate than Facebook, to achieve collective goals related to innovation intermediation in Ghana. Further, the study shows that these technologies that are promising for African extension in this regard support a nuanced version of connection action. In this study, social media technologies support what Bennet and Segerberg refer to as organisational enabled-connection action: actors still network to share personal experiences, views as well as information, but with a level of moderation by the organisation in which the technologies are embedded (Bennett and Segerberg, 2012; Cieslik *et al.*, 2018). Additionally, the study finds the problems the technologies address do not qualify as collective action problems. This is because the platform users cooperate to mitigate a problem (fall armyworm) based on their professional mandate (chapter 4). Therefore, unlike a group of farmers with adjacent fields responding to a transboundary pest problem (Damtew *et al.*, 2018), cooperation between the social media platform users (extension staff and researchers) is not marred by conflicts of interest, free-riders or the tragedy of commons problems - characteristics of collective action problems (Olson, 1965).

The findings on connective action and collective action problems raise two questions. Firstly, whether connective action as a concept is more appropriate for analysing political movements as opposed to interaction in professional (agricultural) organisations and networks. Secondly, whether collective action problems are more of an issue at the farm level and not the organisation level.

Financial sustainability of new ICT extension service delivery initiatives

The sustainability of ICT initiatives is a major concern in the ICT4D field (Heeks, 2018). For the public (E-extension) and NGO/private (SmartEx) led new ICT extension initiatives investigated in this study there are indications that financial sustainability is a key problem (chapter 3). The financial sustainability of these and other ICT4D initiatives raises concerns, because they are mainly donor-funded (Ali and Bailur, 2007) and donor-funding is tied to projects that are time-capped. This is a situation that often leads to project discontinuities as donors require new ICT initiatives that are largely rolled-out by government departments and development organisations to commercialise in a limited space of time (Qiang *et al.*, 2012; Robert, 2018), when these organisation often focus on social impact and often lack the business acumen to do this. Further, the initiatives mentioned (E-extension and SmartEx) duplicate each other in terms of content (chapter 3). This duplication reflects on the instability of the new ICT service delivery landscape, where new and similar initiatives are continuously piloted; thereby splitting the limited funds available in the ICT4D field (Robert, 2018).

Concerns over the sustainability of ICT initiatives have not been addressed even as far back as the height of ICT4D agenda in 2000 (Toyama, 2009; Marais, 2011). This and the issues raised above prompt questions on how the initiatives studied can achieve sustainability. The first question is, if commercialisation is currently prioritised as a route for financial sustainability (Robert, 2018), do government departments and development organisations have the capacities to drive these initiatives to financial sustainability, or do they need to develop or incorporate the skills required for this. The other question is whether the public and private initiatives that have similar data needs would benefit from partnering to share development, scaling and operations costs amid the (donor) funding limitations of public and private extension organisation (Bennett, 1996; Pretty, Toulmin and Williams, 2011).

Contrary to the initiatives mentioned, financial sustainability is seemingly less of an issue for the user-driven social media platforms identified in this study. This is because the platforms users, mostly extension staff, cover their internet costs and the organisations using them do not pay any development costs. It is debatable whether extension staff covering the costs for work-related communication is sustainable. One view is that platform users are willing to pay for primary benefits of these technologies, while simultaneously accessing secondary benefits such as work-related interactions. In any case, alternative funding sources to donor funding are needed to support new ICT initiatives for extension service delivery in Ghana.

<u>Reflection on ICT4D theory</u>

Prominent development informatics scholars call for ICT4D research with stronger theoretical grounding to understand ICTs role in development, even if the field is practical (Avgerou, 2017; Walsham, 2017; Heeks, 2018; Sein *et al.*, 2019). Theories are emerging to respond to this call. These theories are based on adaptations and combinations of theories from different fields, including development studies, informatics, organisational studies, communication studies (Sein *et al.*, 2019). The theories being advanced seek to understand ICTs' inherent technical features as well as to understand the context in which ICTs are introduced to establish the extent their inherent capabilities are made useful (e.g., socio-technical systems, design and reality gap framework, capabilities approach)(Toyama, 2011; Heeks, 2018; Sein *et al.*, 2019). Against this background, this study's underlying perspective of the mutual shaping of technology and society to explain the relationship between new ICTs and innovation intermediation can be seen as appropriate. Through this concept the study avoids a deterministic view of technologies' inherent capabilities, and instead takes a contingent (socio-technical) perspective on their influence in context by identifying social factors that limit or enable the technology's use. However, this general concept could have been linked better to new ICTs in particular. The study could have benefited from a more specific analytical framework. For instance the onion ring -model or design- reality gap framework (see page 32 and 34 in Heeks, 2018) might have enabled better anticipation of the social factors that shape new ICTs use based on information system levels and dimensions.

In a similar light this study adds to ICT4D theory. It connects the analytical framework of intermediation capabilities to the broader concept of bridging mechanisms (chapter 2) and contributes to theory. The framework describes the ways actors can connect (communication and networking function) through new ICTs to facilitate innovation intermediation, and is useful for establishing new ICTs' inherent technical features or actual capabilities in context. The framework builds on a similar framework of six social networking functions[30] developed by Hansen *et al*. (2014) in three ways - see chapter 2: 1) by creating a clear distinction between functions by merging and embedding overlapping functions (engagement, discussion, cooperation) into broader functions (coordinating and co-creation); 2) by including additional functions relevant to facilitating innovation intermediation, namely harvesting, matching, coordinating; and 3) by categorising all the functions according to three levels of interaction, from linear to more networked communication.

[30] Engagement, discussion, crowdsourcing, networking, co-production and cooperation (Hansen *et al.*, 2014).

3. Future research

The section outlines future research agendas that emerge from the study insights.

Social media platforms, the tension between their social orientation and professional uses

From this study WhatsApp and Telegram platforms are highlighted as promising for enhancing communication and interaction in extension service delivery, in Africa. However, despite the potential of these technologies and the growing use of social media in professional activities (Ahmed *et al.*, 2019) the tension between their social orientation and professional use requires investigation. This investigation could target platforms users in formal organisations to establish their views on the extent to which these social spaces can function professionally. The research could investigate issues such as the factors and conditions influencing the technologies use in professional activities, the challenges of using these platforms for these activities and also issues related to their financial sustainability. The research could also investigate the challenges of regulating these platforms for professional use, issues of individual and organisational data protection, the extent to which the establishment of formal WhatsApp group infringes on users' privacy or enables ethical compliance. These concerns are topical issues of the digital society that could inform ICT policy geared towards addressing the downside of these technologies (Heeks, 2018).

Comparing the interaction dynamics in face-to-face and virtual settings for collaborative activities

There is also need for research that compares the use and influence of face-to-face meetings and social media in collaborative extension (innovation intermediation) activities. This research direction is prompted by the lack of clarity on which technologies or communication mechanisms have high capabilities to support networking and co-creation (chapter 2), and the indication that face-to-face meetings are better suited for these functions that involve multi-actor engagement and intensive interaction (chapter 4). The research would interrogate if indeed face-to-face settings create a better environment (sense of trust or privacy) for active learning and dialogue than online messaging media (Leeuwis, 2004), and whether and to what extent interaction in these setting is also susceptible to social and political influences. Additionally, this research is important in the wake of Covid-19, where virtual interaction is taking precedence over face-to-face interaction to curb the spread of the novel corona virus.

Re-orientation of new ICT research to mixed communication medium designs

Another relevant research agenda relates to re-orientating new ICT research to focus on mixed media (classical and new) designs, and inclusive and responsive design processes (Leeuwis *et al.*, 2018). The study shows across the core chapters that human intermediaries and conventional communication mechanism, alongside new ICTs, can facilitate broader extension service delivery in Ghana. It follows that the combination of these mechanisms could potentially facilitate innovation intermediation in other African contexts. These possibilities stress that new ICTs cannot be studied in isolation. Therefore, experimenting with different configurations of these types of communication mechanisms with potential users and accompanying social enablers would be of value to identify future, functional innovation intermediation models. A starting point of inquiry would be the configuration of public extension agents, face-to-face meetings and more user-driven media, WhatsApp groups, that are highlighted as drivers of innovation in this study.

Expanding the knowledge base on new ICTs' role in innovation intermediation in Africa

Also, of importance is research comparing this study to similar studies. This study provides insight on the opportunities and the role of the new ICTs in broader extension service delivery, based on the specific organisation and user needs, and situations in the Ghana. The study cannot predict which new ICTs can successfully support specific innovation intermediation activities in other contexts, though it provides positive and negative indications for some possibilities in Africa. Therefore, considering context is key to outcomes of studies on this topic, and Osch and Coursaris (2013) call for more studies on new ICTs' capabilities, further research on new ICTs' opportunities and their contribution to supporting innovation intermediation in other contexts would be of value. The research would build a broader knowledge base on this topic to enable the comparison of study findings.

Building on a method to analyse interaction over social media messengers using network analysis

Additionally, this study prompts method focused research. In the ICT4D field, few studies have applied social network analysis (Renken and Heeks, 2018). This study contributes to this knowledge base, providing a method to analyse the communication and network structures of actors interacting over WhatsApp and Telegram group. Based on the platforms' data structure, certain assumptions were made on what could be considered dyadic connections between actors to facilitate social network analysis. Considering the novelty of social network analysis to the field and that social network analysis "is often used without considering how the novel capabilities of social media platforms might affect the underlying theories of social network analysis, which were developed primarily through studies of offline social networks,"(Labianca, Kane, & Borgatti, 2014: 274), research duplicating the method, to test it and build on it would be valuable.

New ICTs' contribution to building the capacity of extension staff for innovation intermediation roles

Lastly, beyond this study's scope, the use of Telegram in informal training (lectures) of extension staff (chapter 4) indicates that research into the education institution - new ICTs - extension interface of the extension system is required. Given that online education or training could support extension staff to develop (new facilitation and ICT) skills required to engage in innovation intermediation roles, research on new ICTs' contribution to this process of capacity building would be useful. This research is also consistent with the call by McCampbell *et al.* (forthcoming) for organisations to develop their identities in the digital age by acquiring new skills. Additionally, this research is timely because the online education and training environment has been prioritised over the prevailing face-to-face learning environment in order to support social distancing and limit the spread of the corona virus. During the COVID-19 pandemic, the Association of African Universities has called upon its member institutions to teach using technology and other distance learning techniques (Dell and Sawahel, 2020). Therefore, there are opportunities to investigate the possibilities of use and effectiveness of specific new ICTs (YouTube, WhatsApp, Zoom) for online extension education or informal training activities (discussions, lectures) during the pandemic, and as there may be long term benefits of such approaches.

4. Conclusion

Given that new ICTs have the potential to support new ways of connecting people and sharing information, this thesis investigated the role of new ICTs in supporting innovation intermediation. Responding to the call for more theoretically grounded ICT4D research, the underlying perspective used to investigate this relationship is the concept of mutual shaping of technology and society. Through this socio-technical perspective, it is established that indeed, technologies' inherent capabilities are not applied entirely, and that social factors define how technology is made useful based on user' needs, preferences, abilities and situations. At a broader level, the confirmation of the concept reiterates lessons on the progression of alternative technological revolutions (e.g., the Green Revolution). These lessons from the past have implications for how we think about technological revolutions at present and in the future. This is that once the hype surrounding specific technologies subsides, they appear to be less of magic bullets as their contribution to society is discovered, alongside the (new) problems they introduce.

Nevertheless, by linking the topical areas of new ICTs' inherent capabilities and innovation intermediation, opportunities are identified for these technologies. Out of the various types of technologies functioning in the Ghanaian agricultural system, IVR outbound, DaM and Social media messaging technology have the potential to contribute to select innovation intermediation activities, while complementing conventional communication mechanisms (face-to-face setting and radio) and human intermediaries (public extension agents) in these processes. A role is identified for social media messaging platforms to support timely field and pest or disease monitoring, the coordination of last mile extension activities, and information and knowledge dissemination to support individual-centred learning and problem solving in extension systems. However, despite these social media platforms fostering multi-actor engagement for these activities, none of the technologies studied were identified as having the potential to facilitate more collaborative and interactive innovation intermediation activities. For these types of activities related to demand articulation and innovation process management, there were indications that face-to face settings are more appropriate. Further, the study finds that IVR outbound technologies have the potential to support immediate information access for farmers, and DaM technologies the potential to support the development of farmer databases. These databases in turn supporting farmers' tacit needs identification for extension intervention planning and advice tailoring. However, the potential of IVR and DaM technologies is far from realised, and this is due to social, organisational and institutional factors.

Finally, from these overarching findings, three conclusions and associated implications for extension policy and practice are drawn. Firstly, new ICTs' inherent technical features do not determine their application, but social factors in a given context shape their use. Therefore, it is advised that contextual considerations and participatory technological design are engaged to foster technological access and realise new ICTs' potentials. Second, new ICTs cannot replace other communication mechanisms and should not be looked at as a specific solution to the limitations of extension systems. Therefore, they should be explored in combinations with classical media and face-to-face settings, and integrated into the communication landscape of extension processes where they are appropriate and add value, as this is where huge opportunities for facilitating innovation intermediation lie. Third, human intermediaries remain relevant for farmers to access agricultural services, even in a digital age, as farmers face certain barriers to leverage new ICTs directly for these purposes. Hence, innovation intermediation models should incorporate human intermediaries, alongside new ICTs, to have better chances of functioning effectively.

A

Appendices

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Completed training and supervision plan

Summary

Classical extension focuses on linear transfer of technology. Globally, and in Ghana particularly, we have seen attempts to address the linearity of classical extension with the shift to broader extension service delivery approaches - extension approaches that transcend technology transfer to include broader facilitation roles for extension staff. From an innovation systems perspective innovation intermediation is suggested for extension organisations to function more effectively and respond to wider agricultural system constraints. This involves three facilitation roles demand articulation, matching demand and supply, and innovation process management. Both public and private extension service providers in Ghana are expanding on the services they deliver. However, these efforts are hampered by human and financial resource constraints. At the same time, there is emphasis on exploring new Information and Communication Technologies' (ICTs') potential to improve and upscale extension service delivery. Despite this, there is limited knowledge of new ICTs' potential and contribution to facilitating innovation intermediation.

Considering that new ICTs can enable new ways of connecting people and sharing information this thesis sought to answer the research question: what roles do new ICTs play in supporting innovation intermediation in the Ghanaian extension system? To answer this research question four studies corresponding to the thesis' empirical chapters were conducted. The studies relate to (1) new ICTs' capabilities to support communication and networking functions that are relevant for innovation intermediation (chapter 2), (2) the role of new ICTs in supporting innovation intermediation in a public and private extension organisation (chapter 3), (3) the contribution of social media to facilitating open communication spaces to support knowledge sharing and other forms of collaboration involving extension staff and researchers; and (4) farmers' choices of information sources for managing new, emerging pests (chapter 5). Brief descriptions and summaries of the chapters' findings are provided below, and this is followed by the main conclusions and implications of the study as a whole.

The first empirical chapter, chapter 2, investigates the capabilities of new ICTs to support seven forms of intermediation: disseminating, retrieving, harvesting, matching, networking, coordinating and co-creating. Out of different types of technologies functioning in the Ghanaian agricultural system, the study finds experts (scientists, researchers, practitioners) see opportunities for Interactive Voice Response (IVR) technologies to support action-oriented, linear intermediation such as disseminating, retrieving, harvesting and matching. As for the other more interactive intermediation capabilities, experts agreed that social media messaging technologies can support coordination to a certain extent. However, there was no consensus among experts on which new ICTs can currently support networking or co-creating.

Chapter 3, investigates the use of new ICTs platforms E-extension and SmartEx in a public and private extension organisation to support innovation intermediation. Interviews with extension staff and observation of field agents show that both organisation use Data Management technologies (DaM). These technologies that support decentralised data collection can contribute to particular innovation intermediation activities related to demand articulation and innovation process management. They can enable farmer database development to: 1) support tacit needs identification for intervention and advice tailoring; and 2) build the trust of credit providers to serve smallholder markets to a certain extent as well as enable production practices or pest occurrences monitoring to lesser extent. Despite this, their potential to support these activities are far from realised and this is due to social, organisational and institutional factors. Therefore, face-to-face communication and settings remain relevant to extension service delivery in the given context and remain better suited to supporting more interactive and collaborative innovation intermediation activities.

Chapter 4 analyses the interaction of actors on two social media messaging platforms to investigate their [the platforms] contribution to facilitating open communication spaces to support collaboration involving researchers and extension staff. The platforms are associated to an extension organisation (comprising extension staff) and a research institution (comprising extension staff and researchers). The platform content analysis and social network analysis revealed that the platforms possess centralised network and communication structures - suggesting that platform users participation in especially sending messages over the platforms is non-egalitarian. This situation is influenced by social hierarchies, organisational rules and users' identity management tactics. This means that the platforms' network-communication structures do not facilitate open communication spaces, and as such are not suited for collaborative innovation process management activities (knowledge integration and joint problem solving). Nonetheless, the platforms support the coordination of extension activities on the ground, information dissemination and harvesting for pest/disease monitoring by the organisations, and knowledge sharing involving extension staff and subject matter specialists for individual-centred learning and problem solving by users (mainly public extension agents). The ability of the platforms to support these activities indicates that the technologies are likely to generate useful input for knowledge integration and joint problem solving in complementary face-to-face settings.

The last chapter engages with farmers through semi-structured interviews to establish and understand their information source choices for managing a new pest, fall armyworm. The findings show that from a range of sources farmers rely on public extension agents for most dimensions of fall armyworm management, specifically pest identification, accessing control advice and identifying input providers. While for pest alerts, they listen to the radio. Farmers mainly engage with public extension agents because of their perceived credibility. Additionally, the study reveals that farmers use new ICTs sparingly in fall armyworm management. Despite this, the study does points to ways farmers use mobile technology conventionally to access agricultural information. These include making phone calls and listening to radio over their mobile phones. The study further points to opportunities for farmers to engage with IVR technologies that work similarly to their prevailing mobile phone usage.

Overall, the study finds that there are opportunities for IVR outbound, DaM and social media messaging technology to contribute to innovation intermediation activities, and these technologies complement human intermediaries (public extension agents) and conventional communication mechanisms (face-to-face settings and radio) in these activities. These insights lead to three conclusions and associated implications for extension policy and practice. Firstly, new ICTs' inherent technical features do not determine their application, but social factors in a given context shape their use. Therefore, it is advised that contextual considerations and participatory technological design are engaged to foster technological access and realise new ICTs' potentials. Secondly, new ICTs cannot replace other communication mechanisms. Therefore, they should be explored in combination with classical media and face-to-face settings, and plugged into extension processes where they add value, as this is where huge opportunities for facilitating innovation intermediation lie. Thirdly, human intermediaries remain relevant for farmers to access agricultural services, even in a digital age, as farmers face certain barriers to leverage new ICTs directly for these purposes. Hence, innovation intermediation models should incorporate human intermediaries alongside new ICTs to have better chances of functioning effectively.

References

Aarts, N. and van Woerkum, C. (2002) ‘Dealing with uncertainty in solving complex problems’, in Leeuwis, C. and Pyburn, R. (eds) *Wheelbarrows Full of Frogs: Social learning in Rural Resource Management*. Assen: Koninklijke van Gorcum BV, pp. 421–437.

Aarts, N. and van Woerkum, C. (2005) ‘Frame construction in interaction’, in Gould, N. (ed.) *Multi-organisational Partnerships, Alliances and Networks: Engagement*, pp. 229–237.

Abouzeedan, A. and Hedner, T. (2012) ‘Organization structure theories and open innovation paradigm’, *World Journal of Science, Technology and Sustainable Development*, 9(1), pp. 6–27. doi: https://doi.org/10.1108/20425941211223598.

Abrahams, P. *et al.* (2017) *Fall armyworm status impacts and control options in Africa*. Egham.

Acheampong, L. D. *et al.* (2017) ‘Assessing the information seeking behaviour and utilization of rice farmers in the Ejisu Juaben Municipality of Ashanti Region of Ghana’, *Agriculture & Food Security*. BioMed Central, 6(38), pp. 1–9. doi: 10.1186/s40066-017-0114-8.

Adekunle, A. A. and Fatunbi, A. O. (2014) ‘A new theory of change in African Agriculture’, *Middle-East Journal of Scientific Research*, 21(7), pp. 1083–1096. doi: 10.5829/idosi.mejsr.2014.21.07.21564.

Adolwa, I. S. *et al.* (2017) ‘A comparative analysis of agricultural knowledge and innovation systems in Kenya and Ghana: sustainable agricultural intensification in the rural–urban interface’, *Agriculture and Human Values*, 34(2), pp. 453–472. doi: https://doi.org/10.1007/s10460-016-9725-0.

Ahmed, Y. A. *et al.* (2019) ‘Social media for knowledge-sharing: a systematic literature review’, *Telematics and Informatics*, 37, pp. 72–112. doi: 10.1016/j.tele.2018.01.015.

Ajani, E. N. (2014) ‘Promoting the use of Information and Communication Technologies (ICTs) for agricultural transformation in sub-Saharan Africa: implications for policy’, *Journal of Agricultural & Food Information*, 15(1), pp. 42–53. doi: 10.1080/10496505.2013.858049.

Aker, J. C. (2011) ‘Dial “ A ” for agriculture : a review of information and communication technologies for agricultural extension in developing countries’, *Agricultural Economics*, 42(6), pp. 631–647. doi: 10.1111/j.1574-0862.2011.00545.x.

Aker, J. C., Ghosh, I. and Burrell, J. (2016) ‘The promise (and pitfalls) of ICT for agriculture initiatives’, *Agricultural Economics*, 47, pp. 35–48. doi: 10.1111/agec.12301.

Alemna, A. A. and Sam, J. (2006) ‘Critical issues in information and communication technologies for rural development in Ghana’, *Information Development*, 22(4), pp. 236–241. doi: 10.1177/0266666906074181.

Alexiou, K. and Zamenopoulos, T. (2008) ‘Design as a social process: a complex systems perspective’, *Futures*, 40, pp. 586–595. doi: 10.1016/j.futures.2007.11.001.

Ali, J. (2012) ‘Factors affecting the adoption of Information and Communication Technologies (ICTs) for farming decisions’, *Journal of Agricultural and Food Information*, 13(1), pp. 78–96. doi: 10.1080/10496505.2012.636980.

Ali, M. and Bailur, S. (2007) ‘The challenge of “sustainability” in ICT4D-is bricolage the answer?’, in *The 9th International Conference on Social Implications of Computers in Developing Countries*. Sao Paulo.

Allen, T. *et al.* (2019) ‘A Delphi approach to develop sustainable food system metrics’, *Social Indicators Research*, 141(3), pp. 1307–1339. doi: 10.1007/s11205-018-1865-8.

Amadu, F. O. and McNamara, P. E. (2014) 'How do social networks influence the performance of extension workers? Peer effects of community knowledge workers' agricultural extension in Uganda'. Urbana.

Anderson, J. R. (2008) *Background paper for the World Bank development report 2008: agricultural advisory services*. Washington D.C.

Angelucci, F. (2012) 'Analysis of incentives and disincentives for maize in Ghana. Technical notes series, MAFAP'. Rome.

Asante, B. O., Sefa, V. A. and Sarpong, D. B. (2011) 'Determinants of small scale farmers' decision to join farmer based organizations in Ghana', *African Journal of Agricultural Research*, 6(10), pp. 2273–2279.

Asiedu-darko, E. (2013) 'Agricultural extension delivery in Ghana: a case study of factors affecting it in Ashanti, Eastern and Northern regions of Ghana', *Journal of Agricultural Extension and Rural Development*, 5(2), pp. 37–41. doi: 10.5897/JAERD12.121.

Asiedu-Darko, E. and Bekoe, S. (2014) 'ICTs as enabler in the dissemination of agricultural technologies: a study in the East Akim District, Eastern Ghana', *Asian Journal of Agricultural Extension, Economics & Sociology*, 3(3), pp. 224–232. doi: 10.9734/ajaees/2014/7661.

Avgerou, C. (2017) 'Theoretical framing of ICT4D research', in Choudrie, J. and Islam, S. (eds) *Information and Communication Technologies for Development*. New York: Springer, pp. 10–23.

Bailur, S. and Masiero, S. (2012) 'The complex position of the intermediary in telecenters and community multimedia centers', *Information Technologies and International Development*, 8(1), pp. 27–42.

Ballew, B. S. (2009) 'Elsevier's Scopus® database', *Journal of Electronic Resources in Medical Libraries*, 6(3), pp. 245–252. doi: 10.1080/15424060903167252.

Barber, J., Mangnus, E. and Bitzer, V. (2016) *Harnessing ICT for agricultural extension. KIT working paper*. Amsterdam.

Barimah, P. T., Doso, S. and Twumasi-ankrah, B. (2014) 'Impact of climate change on maize production in Ghana. A review', *Journal of Agricultural Science and Applications*, 3(4), pp. 89–93. doi: 10.14511/jasa.2014.030402.

BBC (2017) *Fall armyworms threaten Africa's crops*. Available at: https://www.bbc.com/news/av/world-africa-40792309/fall-armyworms-threaten-africa-s-crops (Accessed: 23 August 2019).

Bell, M. (2015) *Information and communication technologies for agricultural extension and advisory services: ICT – Powering behavior change for a brighter agricultural future*. California.

Benitez-Capistros, F., Hugé, J. and Koedam, N. (2014) 'Environmental impacts on the Galapagos Islands: identification of interactions, perceptions and steps ahead', *Ecological Indicators*, 38(2014), pp. 113–123. doi: 10.1016/j.ecolind.2013.10.019.

Bennett, C. F. (1996) 'Rationale for public funding of agricultural extension programs', *Journal of Agricultural & Food Information*, 3(4), pp. 3–25. doi: 10.1300/J108v03n04_02.

Bennett, W. L. and Segerberg, A. (2012) 'The logic of connective action: Digital media and the personalization of contentious politics', *Information, Communication & Society*, 15(5), pp. 739–768. doi: 10.1080/1369118X.2012.670661.

Berkes, F., Colding, J. and Folke, C. (2003) *Navigating Social-ecological Systems: Building Resilience for Complexity* *and Change*. Cambridge: Cambridge University Press.

Bernard, R., Dulle, F. and Ngalapa, H. (2014) 'Assessment of information needs of rice farmers in Tanzania: a case study of Kilombero District, Morogoro', *Libray Philosophy and Practice*.

Bicsi, B. (2002) *Network Design Basics for Cabling Professionals*. New York: McGraw-Hill.

Boczkowski, P. (1999) 'Mutual shaping of users and technologies in a national virtual community', *Journal of Communication*, 49(2), pp. 86–108. doi: 10.1111/j.1460-2466.1999.tb02795.x.

De Bruijn, M. (2014) 'Connecting in mobile communities: an African case study', *Media, Culture & Society*, 36(3), pp. 319–335. doi: 10.1177/0163443714521088.

Buytaert, W. *et al.* (2014) 'Citizen science in hydrology and water resources: opportunities for knowledge generation, ecosystem service management and sustainable development', *Frontiers in Earth Science*, 2(26), pp. 1–21. doi: 10.3389/feart.2014.00026.

Carolan, B. V. (2014a) 'Diffusion', in *Social Network Analysis and Education: Theory, Methods & Applications*. Thousand Oaks: SAGE Publications, Inc., pp. 239–260. doi: https://dx.doi.org/10.4135/9781452270104.

Carolan, B. V. (2014b) 'Structural measures for complete networks', in *Social Network Analysis and Education: Theory, Methods & Applications*. Thousand Oaks: SAGE Publications, Inc., pp. 97–110. doi: 10.4135/9781452270104.n5.

Chapman, R. and Slaymaker, T. (2002) *ICTs and rural development: review of the literature, current interventions and opportunities for action*. London.

Chesbrough, H., Van Haverbeke, W. and West, J. (2006) *Open Innovation: Researching a New Paradigm*. Oxford: Oxford University Press.

Chu, H. C. and Hwang, G. J. (2008) 'A Delphi-based approach to developing expert systems with the cooperation of multiple experts', *Expert Systems with Applications*, 34(4), pp. 2826–2840. doi: 10.1016/j.eswa.2007.05.034.

Cieslik, K. J. *et al.* (2018) 'Addressing socio-ecological development challenges in the digital age: exploring the potential of Environmental Virtual Observatories for Connective Action (EVOCA)', *NJAS - Wageningen Journal of Life Sciences*, 86–87(Special Issue), pp. 2–11. doi: 10.1016/j.njas.2018.07.006.

Cinnamon, J. (2020) 'Data inequalities and why they matter for development', *Information Technology for Development*, 26(2), pp. 214–233.

Cofré-bravo, G., Klerkx, L. and Engler, A. (2019) 'Combinations of bonding, bridging, and linking social capital for farm innovation: how farmers configure different support networks', *Journal of Rural Studies*, 69(21), pp. 609–636. doi: 10.1016/j.jrurstud.2019.04.004.

Colfer, L. J. and Baldwin, C. Y. (2016) 'The mirroring hypothesis: theory, evidence and exceptions', *Industrial and Corporate Change*, 25(5), pp. 709–738. doi: 10.1093/icc/dtw027.

communicationtheory.org (2020) *Patterns of communication*. Available at: https://www.communicationtheory.org/patterns-of-communication/ (Accessed: 15 February 2020).

Crane, T. A. (2010) 'Of models and meanings: cultural resilience in social-ecological systems', *Ecology and Society*, 15(4), pp. 19–34. doi: 19.

Creswell, J. W. and Plano Clark, V. l (2011) *Designing and Conducting Mixed Methods Research*. Second. California: Sage.

Van Crowder, L. and Anderson, J. (1997) 'Linking research, extension and education: why is the problem so persistent and pervasive?', *European Journal of Agriculture and Extension*, 3(4), pp. 241–249. doi: https://doi.org/10.1080/13892249785300061.

CTA (2016) 'Lesson for sustainability: failing to scale ICT4Ag-enabled services'. Wageningen.

Daane, J. (2010) 'Enhancing performance of agricultural innovation systems', *Rural Development News*, pp. 76–82.

DAES (2011) 'Agricultural extension approaches being Implemented in Ghana'. Accra.

Damtew, E. *et al.* (2018) 'Diagnosis of management of bacterial wilt and late blight in potato in Ethiopia: a systems thinking perspective', *NJAS - Wageningen Journal of Life Sciences*, 86–87(Special Issue), pp. 12–24. doi: 10.1016/j.njas.2018.03.003.

Danes, M. H. G. I. *et al.* (2014) *Mobiles for agricultural development. Exporing trends, challenges and policy options for the Dutch Government*. Wageningen.

Daude, S., Chado, S. S. and Igbashal, A. A. (2009) 'Agricultural information source utilised by farmers in Benue State, Nigeria', *Agricultural Information Sources*, 5(1), pp. 39–48.

Davis, K. E. (2008) 'Extension in sub-Saharan Africa: overview and assessment of past and current models, and future prospect', *Journal of International Agricultural and Extension Education*, 15(3), pp. 15–28.

Day, R. *et al.* (2017) 'Fall armyworm: impacts and implications for Africa', *Outlooks on Pest Management*, 28(5), pp. 196–201. doi: 10.1564/v28.

Dell, S. and Sawahel, W. (2020) *African universities urged to put classes online urgently*, *University World News Weekly Newsletter*. Available at: https://www.universityworldnews.com/post.php?story=20200320093558384 (Accessed: 10 August 2020).

Dhiab, H., Labarthe, P. and Laurent, C. (2020) 'How the performance rationales of organisations providing farm advice explain persistent difficulties in addressing societal goals in agriculture', *Food Policy*, 95, pp. 1–12. doi: 10.1016/j.foodpol.2020.101914.

Dittoh, F., Van Aart, C. and De Boer, V. (2013) 'Voice-based marketing for agricultural products: a case study in rural Northern Ghana', in *ACM International Conference Proceeding Series*, pp. 21–24. doi: 10.1145/2517899.2517924.

Doria, M. de F. *et al.* (2009) 'Using expert elicitation to define successful adaptation to climate change', *Environmental Science and Policy*, 12(7), pp. 810–819. doi: 10.1016/j.envsci.2009.04.001.

Duncombe, R. (2016) 'Mobile phones for agricultural and rural development: a literature review and suggestions for future research', *European Journal of Development Research*, 28(2), pp. 213–235. doi: 10.1057/ejdr.2014.60.

Dutta, R. (2009) 'Information needs and information-seeking behavior in developing countries: a review of the research', *International Information & Library Review*, 41(1), pp. 44–51. doi: 10.1016/j.iilr.2008.12.001.

Fabregas, R., Kremer, M. and Schilbach, F. (2019) 'Realizing the potential of digital development: the case of agricultural advice', *Science*, 366(6471), pp. 1–9. doi: 10.1126/science.aay3038.

Farr, C. M., Reed, S. E. and Pejchar, L. (2018) 'Social network analysis identifies key participants in conservation development', *Environmental Management*, 61, pp. 732–740. doi: 10.1007/s00267-018-1017-6.

Fielke, S., Taylor, B. and Jakku, E. (2020) 'Digitalisation of agricultural knowledge and advice networks: a state-of-the-art review', *Agricultural Systems*, 180, pp. 1–11. doi: 10.1016/j.agsy.2019.102763.

Gakuru, M., Winters, K. and Stepman, F. (2009) 'Innovative farmer advisory services using ICT', in *Africa Perspective on the role of Mobile Technologies in fostering Social Development*. Maputo, pp. 1–13.

Geels, F. W. (2011) 'Environmental innovation and societal transitions the multi-level perspective on sustainability transitions: responses to seven criticisms', *Environmental Innovation and Societal Transitions*, 1(1), pp. 24–40. doi: 10.1016/j.eist.2011.02.002.

Geng, S., Hess, C. E. and Auburn, J. (1990) 'Sustainable agricultural systems: concepts and definitions', *Journal of Agronomy and Crop science*, 165, pp. 73–85.

Gershon, I. *et al.* (2013) 'Introduction: the newness of new media', *Culture, Theory and Critique*, 54(3), pp. 259–264. doi: 10.1080/14735784.2013.852732.

Godwin, J., Hevi, W. and Day, R. (2017) *Fall armyworm response in Ghana: stakeholder workshop*. Accra.

Goffman, E. (1959) *The presentation of self in everyday life*. New York: Anchor Books.

Granovetter, M. S. (1973) 'The strength of weak ties', *American Journal of Sociology*, 78, pp. 1360–1380.

Van der Haak, B., Parks, M. and Castells, M. (2012) 'The future of journalism: networked journalism in the networked digital age', *International Journal of Communication*, 6, pp. 2923–2938.

Hage, E. and Noseleit, F. (2018) 'It takes at least two to tango: a population-level perspective on interrelated patterns of media use', *Journal of Computer-Mediated Communication*, 23(4), pp. 222–242. doi: 10.1093/jcmc/zmy011.

Hakanson, L., Caessens, P. and MacAulay, S. (2011) 'InnovationXchange: a case study in innovation intermediation', *Innovation: Management, Policy and Practice*, 13(2), pp. 261–274.

Halliday, M. A. K. (1994) 'Language as social semiotic', in *Language and literacy in social practice*. Exeter: Short Run Press Ltd, pp. 22–43.

Hamilton, E. R., Rosenberg, J. M. and Akcaoglu, M. (2016) 'The Substitution Augmentation Modification Redefinition (SAMR) Model: a critical review and suggestions for its use', *TechTrends*, 60(5), pp. 433–441. doi: 10.1007/s11528-016-0091-y.

Hansen, J. P. *et al.* (2014) 'ICT and social media as drivers of multi-actor innovation in agriculture', in *World Congress on Computers in Agriculture*, pp. 1–8. doi: 10.13140/2.1.3549.8242.

Hasson, F., Keeney, S. and McKenna, H. (2000) 'Research guidelines for the Delphi survey technique', *Journal of Advanced Nursing*, 32(4), pp. 1008–1015. doi: 10.1046/j.1365-2648.2000.t01-1-01567.x.

Haythornthwaite, C. (2002) 'Strong, weak, and latent ties and the impact of new media', *The Information Society*, 18(5), pp. 385–401.

Heeks, R. (2002) *Failure, success and improvisation of information systems projects in developing countries*, *Development Informatics Working Paper Series*. 11. Manchester. doi: 10.1016/0736-5853(84)90003-0.

Heeks, R. (2009) *The ICT4D 2.0 manifesto: where next for ICTs and international development?*, *Development Informatics Working Paper Series*. 42. Manchester. doi: 10.1016/0736-5853(84)90003-0.

Heeks, R. (2018) *Information and Communication Technology for Development (ICT4D)*. Abingdon: Routledge. doi: 10.4324/9781315652603.

Howells, J. (2006) 'Intermediation and the role of intermediaries in innovation', *Research Policy*, 35, pp. 715–728. doi: 10.1016/j.respol.2006.03.005.

Ipe, M. (2003) 'Knowledge sharing in organizations: a conceptual framework.', *Human Resource Development Review*, 2(4), pp. 337–359. doi: 10.1177/1534484303257985.

ITU (2010) *World telecommunication/ICT development report*. Geneva.

Jones, R. H. *et al.* (2006) 'Interactional dynamics in on-line and face-to-face peer-tutoring sessions for second language writers', *Journal of Second Language Writing*, 15, pp. 1–23. doi: 10.1016/j.jslw.2005.12.001.

Kane, G. C. *et al.* (2014a) 'Theory and review what's different about social media networks? A framework and research agenda', *MIS Quarterly*, 38(1), pp. 275–304. doi: 10.25300/MISQ/2014/38.1.13.

Kane, G. C. *et al.* (2014b) 'Theory and review what's different about social media networks? A framework and research agenda', *MIS Quarterly*, 38(1), pp. 275–304.

Karmakar, R. *et al.* (2016) 'Potential effects of climate change on soil properties: a review', *Science International*, 4(2), pp. 51–73. doi: 10.17311/sciintl.2016.51.73.

Karpouzoglou, T. *et al.* (2016) 'Environmental Virtual Observatories (EVOs): prospects for knowledge co-creation and resilience in the information age', *Current Opinion in Environmental Sustainability*, 18, pp. 40–48. doi: 10.1016/j.cosust.2015.07.015.

Kassie, M. *et al.* (2020) 'Economic impacts of fall armyworm and its management strategies: evidence from southern Ethiopia', *European Review of Agricultural Economics*, 47(4), pp. 1473–1501. doi: 10.1093/erae/jbz048.

Kaushik, P. *et al.* (2018) 'Social media for enhancing stakeholders' innovation networks in Ontario, Canada', *Journal of Agricultural & Food Information*, 0(0), pp. 1–23. doi: 10.1080/10496505.2018.1430579.

Kilelu, C. W. *et al.* (2011) 'Beyond knowledge brokering: an exploratory study on innovation intermediaries in an evolving smallholder agricultural system in Kenya', *Knowledge Management for Development Journal*, 7(1), pp. 84–108. doi: 10.1080/19474199.2011.593859.

Kivimaa, P. *et al.* (2019) 'Towards a typology of intermediaries in sustainability transitions: a systematic review and a research agenda', *Research Policy*, 48(4), pp. 1062–1075. doi: 10.1016/j.respol.2018.10.006.

Klerkx, L. *et al.* (2012) 'Advances in knowledge brokering in the agricultural sector: towards innovation system facilitation', *IDS Bulletin*, 43(5), pp. 53–60.

Klerkx, L. and Gildemacher, P. (2012) 'The role of innovation brokers in agricultural innovation systems', in *Agricultural Innovation Systems: An Investment Sourcebook*, pp. 221–230. doi: 10.1787/9789264167445-19-en.

Klerkx, L., Hall, A. and Leeuwis, C. (2009) *Strengthening agricultural innovation capacity: are innovation brokers the answer?* Maastricht.

Klerkx, L. and Leeuwis, C. (2008) 'Institutionalizing end-user demand steering in agricultural R & D: farmer levy funding of R & D in The Netherlands', *Research Policy*, 37, pp. 460–472. doi: 10.1016/j.respol.2007.11.007.

Klerkx, L. and Leeuwis, C. (2009) 'Shaping collective functions in privatized agricultural knowledge and information systems: the positioning and embedding of a network broker in the Dutch dairy sector', *The Journal of Agricultural Education and Extension*, 15(1), pp. 81–105. doi: 10.1080/13892240802617445.

Klerkx, L., van Mierlo, B. and Leeuwis, C. (2012) 'Evolution of systems approaches to agricultural innovation: concepts, analysis and interventions', in Darnhofer, I., Gibbon, D., and Dedieu, B. (eds) *Farming Systems Research into the 21st Century: The New Dynamic*. Dordrecht: Springer, pp. 457–483. doi:

https://doi.org/10.1007/978-94-007-4503-2_20.

Klerkx, L. and Proctor, A. (2013) 'Land use policy beyond fragmentation and disconnect: networks for knowledge exchange in the English land management advisory system', *Land Use Policy*, 30, pp. 13–24. doi: 10.1016/j.landusepol.2012.02.003.

Knoke, D. and Yang, S. (2011) 'Network fundamentals', in *Social Network Analysis*. SAGE Publications, Inc., pp. 4–15. doi: 10.4135/9781412985864.n2.

Koutsouris, A. (2012) 'Facilitating agricultural innovation systems: a critical realist approach', *Studies in Agricultural Economics*, 114, pp. 64–70.

Kress, G. (1985) *Linguistic processes in Sociocultural Practice*. Oxford: Oxford University Press.

Krone, M., Schumacher, K. P. and Dannenberg, P. (2014) 'The impact of mobile phones on knowledge access and transfer of small-scale horticultural farmers in Tanzania', *Journal of the Geographical Society of Berlin*, 145(3), pp. 158–161. doi: 10.12854/erde-145-14.

Labarthe, P. and Moumouni, I. (2008) 'Privatization of extension and collective procedures for the production of knowledge. Lessons from a comparison between South and North', in *8th European IFSA Symposium*. Clemont-Ferrand, pp. 833–843.

Lambert, V. A. and Lambert, C. E. (2012) 'Qualitative descriptive research: an acceptable design', *Pacific Rim International Journal of Nursing Research*, 16(4), pp. 255–256.

Lambrecht, I. *et al.* (2015) 'Ex-ante appraisal of agricultural research and extension: a choice experiment on climbing beans in Burundi', *Outlook on Agriculture*, 44(1), pp. 61–67. doi: 10.5367/oa.2015.0199.

Lambrecht, I. and Ragasa, C. (2016) 'Do development projects crowd out private-sector activities? A survival analysis of contract farming participation in Northern Ghana'. Washington D.C.

Lammeren, R. Van *et al.* (2017) 'Social media: the new resource', in *Research in Landscape Architecture: Methods and Methodology*. Abingdon: Routledge, pp. 136–160.

Landström, H. and Harirchi, G. (2018) 'The social structure of entrepreneurship as a scientific field', *Research Policy*, 47(3), pp. 650–662. doi: 10.1016/j.respol.2018.01.013.

Leeuwis, C. (1993) *Of Computers Myths and Modelling: The Social Construction of Diversity, Knowledge, Information and Communication Technologies in Dutch Horticulture and Agricultural Extension*. Wageningen: Wageningen University and Research Centre.

Leeuwis, C. (2004) *Communication for Rural Innovation: Rethinking Agricultural Extension*. Oxford: Blackwell Science.

Leeuwis, C. (2010) 'Changing views of agricultural innovation: implications for communicative intervention and science', in Palis, F. G. et al. (eds) *Research to Impact: Case Studies for Natural Resource Management for Irrigated Rice in Asia*. Los Baños: International Rice Research Institute, pp. 15–32.

Leeuwis, C. (2013) 'Coupled performance and change in the making'. Wageningen: Wageningen University and Research Centre.

Leeuwis, C. *et al.* (2018) 'Reflections on the potential of virtual citizen science platforms to address collective action challenges: lessons and implications for future research', *NJAS - Wageningen Journal of Life Sciences*, 86–87(Special Issue), pp. 146–157. doi: 10.1016/j.njas.2018.07.008.

Leeuwis, C. and Aarts, N. (2011) 'Rethinking communication in innovation processes: creating space for change in complex systems', *The Journal of Agricultural Education and Extension*, 17(1), pp. 21–36. doi: 10.1080/1389224X.2011.536344.

Lie, R. and Servaes, J. (2015) 'Disciplines in the field of communication for development and social change', *Communication Theory*, 25(2), pp. 244–258. doi: 10.1111/comt.12065.

Lister, M. *et al.* (2003) *New Media: A Critical Introduction*. New York: Routledge.

Livondo, J. *et al.* (2015) 'Factors affecting communication channels preference information on adoption of agricultural technology for striga control the case of Bugoma County Kenya', *International Journal of Current Research*, 7(11), pp. 23057–23062.

Lwoga, E. T. *et al.* (2010) 'Information needs and information seeking behaviour of small-scale farmers in Tanzania', *Innovation*, 40, pp. 82–103.

Lwoga, E. T. *et al.* (2013) 'Access and use of agricultural information and knowledge in Tanzania', *Library Review*, 60(5), pp. 383–395. doi: 10.1108/00242531111135263.

MacCormack, A., Baldwin, C. and Rusnak, J. (2012) 'Exploring the duality between product and organizational architectures: a test of the "mirroring" hypothesis', *Research Policy*, 41(8), pp. 1309–1324. doi: 10.1016/j.respol.2012.04.011.

Macnaghten, P. *et al.* (2014) 'Responsible innovation across borders: tensions, paradoxes and possibilities', *Journal of Responsible Innovation*, 1(2), pp. 191–199. doi: 10.1080/23299460.2014.922249.

Mann, L. (2017) 'Left to other peoples' devices ? A political economy perspective on the big data revolution in development', *Development and Change*, 49(1), pp. 3–36. doi: 10.1111/dech.12347.

Marais, M. (2011) 'An analysis of the factors affecting the sustainability of ICT4D initiatives', in *ICT for Development People and Practice. IDIA 2011 Conference Proceedings*. Lima, pp. 100–120.

Marchewka, J. T. and Kostiwa, K. (2007) 'An application of the UTAUT Model for understanding student perceptions using course management software', *Communications of the IIMA*, 7(2), pp. 93–104.

Martin, B. L. and Hall, H. (2011) 'Mobile phones and rural livelihoods: diffusion, uses, and perceived impacts among farmers in rural Uganda', *Information Technologies & International Development*, 7(4), pp. 17–34.

Materia, V. C., Giarè, F. and Klerkx, L. (2015) 'Increasing knowledge flows between the agricultural research and advisory system in Italy: combining virtual and non-virtual interaction in communities of practice', *The Journal of Agricultural Education and Extension*, 21(3), pp. 203–218. doi: 10.1080/1389224X.2014.928226.

McCampbell, M. *et al.* (forthcoming) 'A problematization of in- and ex-clusion: Trade-offs and nuances in how digitalization affects agricultural development', in *Making Knowledge Work. Practices and Politcs of Inclusive Development and Innovation*. London: Routledge.

Mccole, D. *et al.* (2014) 'Addressing the challenges of extension and advisory services in Uganda: the Grameen Foundation's Community Knowledge Worker Program', *Journal of International Agricultural and Extension Education*, 21(1), pp. 6–18. doi: 10.5191/jiaee.2014.20101.

McIntrye, B. D. *et al.* (2009) *International assessment of agricultural knowledge, science and technology for development. Sub-Saharan Africa report*, *Island Press*. Washington D.C.

McNamara, P. E. *et al.* (2012) *Strengthening pluralistic agricultural extension in Ghana: a MEAS rapid scoping mission*. Accra.

MEST (2019) *MEST portifolio Accra*. Available at: https://meltwater.org/incubator/portfolio/?tag=mest-accra#filters (Accessed: 17 September 2019).

Misaki, E., Gaiani, S. and Tedre, M. (2018) 'Challenges facing sub - Saharan small - scale farmers in accessing farming information through mobile phones: a systematic literature review', *Electronic Journal of Information Systems in Developing Countries*, 84, pp. 1–12. doi: 10.1002/isd2.12034.

MOFA (2001) 'Ministry of Food and Agricultures' handbook on decentralisation'. Accra.

MOFA (2007) 'Food and Agriculture Sector Development Policy'. Accra.

Molony, T. (2006) 'I dont trust the phone; It always lies': trust and information and communication technologies in Tanzanian micro- and small- enterprises', *Information Technologies and International Development*, 3(4), pp. 67–83. doi: 10.1162/itid.2007.3.4.67.

Moyo, D. (2009) *Dead Aid: Why aid is not working and how there is a better way for Africa*. Vancouver: Douglas & Mcintyre.

Munthali, N. *et al.* (2018) 'Innovation intermediation in a digital age. Comparing public and private new-ICT platforms for agricultural extension in Ghana', *NJAS - Wageningen Journal of Life Sciences*, 86–87(Special Issue), pp. 64–76. doi: 10.1016/j.njas.2018.05.001.

MyJoyOnline (2017) *Rampaging soldiers: fall armyworm causes destruction on farms*. Available at: https://www.myjoyonline.com/news/2017/September-13th/rampaging-soldiers-fall-armyworm-causes-destruction-on-farms.php (Accessed: 23 August 2019).

OECD (2018) 'Bridging the digital gender divide'.

Olson, M. (1965) *The Logic of Collective Action: Public Goods and the Theory of Groups*. Cambridge: Harvard University Press.

Van Osch, W. and Coursaris, C. (2013) 'Organizational social media: a comprehensive framework and research agenda', in *46th Hawaii International Conference on Systems Sciences*. Wailea, pp. 700–707. doi: 10.1109/HICSS.2013.439.

Van Paassen, A. *et al.* (2013) 'Choice-making in facilitation of agricultural innovation platforms in different contexts in West Africa : experiences from Benin , Ghana and Mali', *Knowledge Management for Development Journal*, 9(3), pp. 79–94.

Perez-Perdomo, S. A., Klerkx, L. and Leeuwis, C. (2010) 'Innovation brokers and their roles on value-chain network innovation: preliminary findings and a research agenda', in *Innovation and Sustainable Development in Agriculture and Food*. Montpellier, pp. 33–52. doi: 10.5121/ijmvsc.2015.6104.

Phillips, T., Klerkx, L. and Mcentee, M. (2018) 'An investigation of social media' s roles in knowledge exchange by farmers', in *European IFSA Symposium*, pp. 1–5. Available at: http://ifsa.boku.ac.at/cms/fileadmin/Proceeding2018/1_Phillips.pdf.

Polit, D. F. and Tatano, C. (2010) 'Generalization in quantitative and qualitative research: myths and strategies', *International Journal of Nursing Studies*, 47(11), pp. 1451–1458. doi: 10.1016/j.ijnurstu.2010.06.004.

Pretty, J., Toulmin, C. and Williams, S. (2011) 'Sustainable intensification in African agriculture', *International Journal of Agricultural Sustainability*, 9(1), pp. 5–24. doi: 10.3763/ijas.2010.0583.

Proulx, S. and Heaton, L. (2011) 'Forms of user contribution in online communities: mechanisms of mutual recognition between contributor', in Pierson, J., Mante-Meijer, E., and Loos, E. (eds) *New Media Technologies and User Empowerment*. Bruxelles: Peter lang, pp. 67–81.

Qiang, C. Z. *et al.* (2012) *Mobile applications for agriculture and rural development*. Washington D.C.

Rahman, M. A., Lalon, S. B. and Surya, M. H. (2016) 'Information sources preferred by the farmers in receiving farm information', *International Scholars Journal*, 3(12), pp. 258–262.

Randhawa, K., Wilden, R. and Gudergan, S. (2018) 'Open service innovation: the role of intermediary capabilities', *Journal of Product Innovation Management*, 35(5), pp. 808–838. doi: 10.1111/jpim.12460.

Renken, J. and Heeks, R. (2018) 'Social network analysis and ICT4D research: principles, relevance and practice', *Electronic Journal of Informaton Systems in Developing Countries*, 84, pp. 1–13. doi: 10.1002/isd2.12036.

Robert, C. (2018) '3 stages of ICT4D solution maturity: from pilots to professionalization', *ICTworks*. Available at: https://www.ictworks.org/ict4d-solution-maturity/#.X0eFe-gzbIU.

Röling, N. (1990) 'The agricultural research-technology transfer interface: a knowledge systems perspective', in Kaimowitz, D. (ed.) *Making the Link: Agricultural Research and Technology Transfer in Developing Countries*. Boulder: Westview Press, pp. 1–42.

Scarbrough, H. (1992) *Technology and Organization: Power, Meaning and Design*. London: Routledge.

Schmidt, C. *et al.* (2010) 'Impact of low-cost, on-demand, information access in a remote Ghanaian village', *ACM International Conference Proceeding Series*, 8(2), pp. 85–100. doi: 10.1145/2369220.2369261.

Schroth, G. *et al.* (2016) 'Vulnerability to climate change of cocoa in West Africa: patterns, opportunities and limits to adaptation', *Science of the Total Environment*, 556, pp. 231–241. doi: 10.1016/j.scitotenv.2016.03.024.

Schut, M. *et al.* (2015) 'RAAIS: Rapid Appraisal of Agricultural Innovation Systems (Part I). A diagnostic tool for integrated analysis of complex problems and innovation capacity', *Agricultural Systems*. The Authors, 132, pp. 1–11. doi: 10.1016/j.agsy.2014.08.009.

Schwartz-shea, P. (2015) 'Interpretive social science', in Gibbons, M. (ed.) *The Encyclopedia of Political Thought*. First. New Jersey: John Wiley & Sons, pp. 1–6.

Sein, M. K. *et al.* (2019) 'A holistic perspective on the theoretical foundations for ICT4D research', *Information Technology for Development*, 25(1), pp. 7–25. doi: 10.1080/02681102.2018.1503589.

Sexton, M. and Lu, S. L. (2009) 'The challenges of creating actionable knowledge: an action research perspective', *Construction Management and Economics*, 27(7), pp. 683–694. doi: 10.1080/01446190903037702.

Sigman, V. (2015) *Agricultural extension policy forum: Ghana. Report on the policy reform forum.* Accra.

Sova, C. *et al.* (2014) *Climate change adaptation policy in Ghana: priorities for the agriculture sector*. Copenhagen.

Srivastava, P. and Hopwood, N. (2017) 'A practical iterative framework for qualitative data analysis', *International Journal of Qualitative Methods*, 8(1), pp. 76–84. doi: 10.1177/160940690900800107.

Starasts, A. M. (2004) *Battling the Knowledge Factor: a Study of Farmers' Information Seeking, Learning and Knowledge Process with an Online Environment in Queensland*. University of Southern Queensland.

Stevens, M. *et al.* (2014) 'Taking participatory citizen science to extremes', *IEEE Pervasive Computing*, pp. 20–29. doi: 10.1109/MPRV.2014.37.

Stevens, T. M. *et al.* (2016) 'Social media as a new playing field for the governance of agro-food sustainability', *Current Opinion in Environmental Sustainability*, 18, pp. 99–106. doi: 10.1016/j.cosust.2015.11.010.

Stewart, J. K. and Hyysalo, S. (2008) 'Intermediaries, users and social learning in technological innovation', *International Journal of Innovation Management*, 12(3), pp. 295–325.

Stilgoe, J., Owen, R. and Macnaghten, P. (2013) 'Developing a framework for responsible innovation', *Research Policy*, 42(9), pp. 1568–1580. doi: 10.1016/j.respol.2013.05.008.

Stone, G. D. (2011) 'Contradictions in the last mile: suicide, culture, and e-agriculture in rural India', *Science Technology & Human Values*, 36(6), pp. 759–790. doi: Doi 10.1177/0162243910374808.

Sulaiman, R. V. *et al.* (2012) 'Necessary, but not sufficient: critiquing the role of information and communication technology in putting knowledge into use', *The Journal of Agricultural Education and Extension*, 18(4), pp. 331–346. doi: 10.1080/1389224X.2012.691782.

Swanson, B. E. and Rajalahti, R. (2010) 'Strengthening agricultural extension and advisory systems: procedures for assessing, transforming, and evaluating extension systems'. Washington D.C.

Tafesse, S. *et al.* (2018) 'Farmers' knowledge and practices of potato disease management in Ethiopia', *NJAS - Wageningen Journal of Life Sciences*, 86–87(Special Issue), pp. 25–38. doi: 10.1016/j.njas.2018.03.004.

Thomas, K. W. and Kilmann, R. H. (2008) *Thomas-Kilmann Conflict Mode Instrument Profile and Interpretive report*. doi: 10.1037/t02326-000.

Toepfer, S. *et al.* (2019) 'Communication , information sharing , and advisory services to raise awareness for fall armyworm detection and area wide management by farmers', *Journal of Plant Diseases and Protection*, 126(2), pp. 103–106. doi: 10.1007/s41348-018-0202-4.

Tologbonse, D., Fashola, O. and Obadiah, M. (2008) 'Policy issues in meeting rice farmers' agricultural information needs in Niger State', *Journal of Agicultural Extension*, 12(2), pp. 84–94.

Tong, A., Sainsbury, P. and Craig, J. (2007) 'Consolidated criteria for reporting qualitative research (COREQ): a 32-item checklist for interviews and focus groups', *International Journal for Quality in Health Care*, 19(6), pp. 349–357.

Toyama, K. (2009) 'ICT4D research and potential sustainability', *Workshop on Human-Centered Computing in International Development*. Boston.

Toyama, K. (2011) 'Technology as amplifier in international development', in *iconference*. Seattle, pp. 75–82.

United Nations (2020) *Sustainable Development Goal 9: Investing in ICT access and quality education to promote lasting peace*. Available at: https://www.un.org/sustainabledevelopment/blog/2017/06/sustainable-development-goal-9-investing-in-ict-access-and-quality-education-to-promote-lasting-peace/ (Accessed: 26 May 2020).

Unwin, T. (1974) *ICT4D Information and Communication Technology for Development*. Cambridge: Cambridge University Press.

viamo (2020) *Mobile surveys*. Available at: https://viamo.io/services/mobile-surveys/ (Accessed: 15 July 2020).

Vidanapathirana, N. P. (2012) 'Agricultural information systems and their applications for development of agriculture and rural community, a review study', in *The 35th Information Systems Research Seminar in Scandinavia-IRIS*, pp. 1–14. Available at: https://www.academia.edu/2980504/Agricultural_information_systems_and_their_applications_for_development_of_agriculture_and_rural_community_a_review_study.

Vitos, M. *et al.* (2013) 'Making local knowledge matter: supporting non-literate people to monitor poaching in Congo', in *3rd ACM Symposium on Computing for Development*. Available at:

doi:10.1145/2442882.2442884.

Van Vliet, A. J. H., Bron, W. A. and Mulder, S. (2014) 'The how and why of societal publications for citizen science projects and scientists', *International Journal of Biometeorol*, 58, pp. 565–577. doi: 10.1007/s00484-014-0821-9.

VOA (2018) *Scientists search for sustainable solutions to stop fall armyworm*. Available at: https://www.voanews.com/a/scientists-search-for-sustainable-solutions-to-stop-fall-armyworm/4556091.html (Accessed: 23 August 2019).

Walsham, G. (2017) 'ICT4D research: reflections on history and future agenda', *Information Technology for Development*. Taylor & Francis, 23(1), pp. 18–41. doi: 10.1080/02681102.2016.1246406.

Wasserman, S. and Faust, K. (1994) *Social Network Analysis*. Cambridge: Cambridge University Press.

Williams, R. and Edge, D. (1996) 'The social shaping of technology', *Research Policy*, 25, pp. 856–899. doi: 10.1016/0048-7333(96)00885-2.

Winch, G. M. *et al.* (2007) 'The organization of innovation brokers: an international review', *Technology Analysis and Strategic Management*, 19(6), pp. 747–763. doi: 10.1080/09537320701711223.

Witteveen, L. *et al.* (2017) 'Design and development of a digital farmer field school. Experiences with a digital learning environment for cocoa production and certification in Sierra Leone', *Telematics and Informatics*, 34(8), pp. 1673–1684. doi: 10.1016/j.tele.2017.07.013.

World Bank (2011) *An evaluation of the World Bank Group activities: Capturing technology for development*. Washington D.C.

World Bank (2012) *Agricultural Innovation Systems: An Investment Sourcebook*. Washington D.C.: The World Bank. doi: 10.1596/978-0-8213-8684-2.

World Bank (2014) *Mobile at the base of the pyramid: Ghana, Mozambique, Nigeria, Zambia*. Washington D.C.

World Bank (2017) 'Ghana: agriculture sector policy note; transforming agriculture for economic growth, job creation and food security'.

World Bank (2018) 'Messaging apps for development', *Apps For Development*. Available at: http://appsfordevelopment.challengepost.com/.

Wright, H. J. *et al.* (2016) 'Using ICT to strengthen agricultural extension systems for plant health', *Journal of Agricultural & Food Information*, 17(1), pp. 23–36. doi: 10.1080/10496505.2015.1120214.

Zheng, Y. and Walsham, G. (2008) 'Inequality of what? Social exclusion in the e-society as capability deprivation', *Information Technology & People*, 21(3), pp. 222–243. doi: 10.1108/09593840810896000.

About the author

Nyamwaya Munthali is Zambian and was born in the city of Lusaka on 29th April, 1983. She has lived most of her life in Zambia where she attained a BA in mass communication, with a minor in development studies, at the University of Zambia. While she pursued an MSc and PhD, in international development studies - biased to communication and innovation, at Wageningen University and Research Centre in the Netherlands.

She has worked extensively as a development practitioner. She has over eight years of experience working in the Zambian agriculture sector on livelihood enhancing, and business and social enterprise development projects, specifically contributing as a project manager and contributing to the development and implementation of practical monitoring, evaluation and communication systems. Additionally, in the space of mobile technology innovations she has worked on a number of information and communication technology for development (ICT4D) projects.

Her research interests that involve field work in Zambia, Tanzania, India and mostly recently Ghana relate to the social situatedness of (ICT) technology, and the potential and role of strategic (digital) communication mechanisms to foster development as well as the pervasive effects of these innovations.

List of publications

Academic

Published

Nyamwaya Munthali, Rico Lie, Annemarie van Paassen, Ron van Lammeren, Richard Asare and Cees Leeuwis, 2018

Innovation intermediation in a digital age. Comparing public and private new ICT platforms for agricultural extension in Ghana

NJAS – Wageningen Journal of Life Sciences 86-87(2018) 64-76

Forthcoming

Sarah Cummings, **Nyamwaya Munthali** and Peter Shapland

Decolonising knowledge production and use among academics in the domain of international development studies

Forthcoming - in Making Knowledge work: Process, Practices, and Politics of Inclusive Innovation. London. Routledge.

Šarūnas Jomantas, **Nyamwaya Munthali**, Annemarie van Paassen, Conny Almekinders, Anna Wood, Christina Alokit, Birgitta Oppong-Mensah, Willis Ochilo and Dannie Romney

Mobilising knowledge in the agricultural advisory system: the case of ICT-facilitated plant doctor chat groups

Forthcoming - in Making Knowledge work: Process, Practices, and Politics of Inclusive Innovation. London. Routledge.

Submitted

Nyamwaya Munthali, Annemarie van Paassen, Cees Leeuwis, Rico Lie, Ron van Lammeren, Norman Aguilar-Gallegos and Birgitta Oppong-Mensah

Social media platforms, open communication and problem solving at the interface of research and extension in Ghana: a substantive, structural and relational analysis

Revised and re-submitted - Agricultural Systems Journal

Other

Policy brief

Munguzwe Hichaambwa and **Nyamwaya Munthali**, 2015

Can market agents play a significant role in sustainable horticultural supply chains development in Zambia? An assessment based on the Lima Links horticultural price information system.

http://www.iapri.org.zm/research-reports/policy-briefs

Completed training and supervision plan

Nyamwaya Munthali
Wageningen School of Social Sciences (WASS)

Name of the learning activity	Department/Institute	Year	ECTS*
A) Project related competences			
EVOCA framework course	WASS	2016	6
Tackling Transparency: the Methodological Challenges of Research on Disclosing Sustainability	WASS/SENSE	2016	2,2
Extreme citizen science training	WASS/KTI & UCL (other UK university)	2016	1,5
PhD proposal writing	WUR	2016	6
Companion Modelling: facilitating multi-stakeholder processes	WASS, SENSE, PE&RC	2016	1,5
Master class social network analysis	WASS	2019	0,3
B) General research related competences			
WASS introductory course	WASS	2016	1
Research methodology: From topic to proposal	WASS	2016	4
Interpretive research methods and methodologies	WASS	2016	4
Qualitative data analysis - ATLAS.ti	WASS	2016	1
'Connectivity for sustainable extension and intensification in food crop farming systems – Ghana'	WASS/KTI - EVOCA partner workshop presentation	2016	0,5
Scientific writing	WGS	2018	1,8
'Social media platforms' contribution to enhancing interaction in Ghana's Agricultural Knowledge and Innovation Systems'	WASS/KTI - EVOCA end of project workshop	2019	0,5
C) Career related competences/personal development			
Competence assessment	WGS	2016	0,3
Data management plan	WUR Library	2016	0,4
'Can market agents play a significant role in sustainable horticultural supply chains development in Zambia? a case study of the lima links horticultural price information system'	CRS/ESRI ICT4D Conference Kenya	2016	1
Organising Wageningen PhD symposium	WGS	2018	3
'Innovation intermediation in the digital age. Comparing public and private ICT platforms for agricultural advisory communication in Ghana'	Etmaal 2018 transcultural exchanges and communication flows Belgium	2018	1
'An innovation systems perspective of extension in a networked digital age'	IAMCR 2020 online conference	2020	1
Total			37

*One credit according to ECTS is on average equivalent to 28 hours of study load

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