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List of abbreviations

AKCs	Agriculture Knowledge Centers
ANT	Actor Network Theory
ATA	Agricultural Transformation Agency
CSA	Central Statistics Agency
FAO	Food and Agriculture Organization
ICT	Information Communication Technologies
ILRI	International Livestock Research Institute
IPMS	Improving Productivity and Market Success of Ethiopian Farmers
ITU	International Communication Union
IWMI	International Water Management Institute
LIVES	Livestock and Irrigation Value Chains for Ethiopian Smallholders
MoANR	Ministry of Agriculture and Natural Resources
TPB	Theory of Planned Behavior

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Executive summary

Effective agriculture extension services require a continuous transformation and introduction of new and effective interventions, approaches, methods, and tools. Information Communication Technologies (ICT) are given immense expectations to address some of the challenges of agriculture extension by improving the capacity and effectiveness of extension advisors through new modes of communication and easier ways of accessing up-to-date and relevant information. There is ample knowledge on adoption rates, use intensity, and impact of ICTs for agriculture extension, specifically in a farmers' context. However, there is limited research on experts' perceptions of ICT's usefulness, as well as organizational dimensions that facilitate ICT use. In particular, the interdependency between ICT tools and the social and organizational aspects in the context of agriculture extension is poorly understood.

This thesis aims to provide evidence on the implementation process of ICT initiatives in agriculture extension organizations and their use. The three specific objectives of the thesis are the following: (i) to provide empirical evidence on the complex interaction of social and technical actors and their assemblage to set up an ICT-based initiatives called Agricultural Knowledge Centers (AKCs); (ii) to provide empirical evidence on experts' perceptions and their use of ICTs in agriculture extension offices; and (iii) to bring insights on organizational characteristics that facilitate or hinder the learning of an organization for successfully applying ICTs in agriculture extension services.

This thesis analyzes the innovation process of ICT-based initiatives in agriculture extension by building on the definition of innovation as an alignment of hardware (technical devices, bodily skills), software (mode of thinking, discourse, perceptions) and orgware (rules, structure, and standards). The thesis adopted a research approach that can be broadly labeled as an interpretive research approach that allows for understanding a phenomenon by interpreting stakeholders' and research participants' experiences. It relied on a case study methodology and review of existing knowledge on ICTs in agriculture extension. The case studies are AKCs located in agriculture extension offices in South Wollo, in the Amhara region of Ethiopia. The research-for-development project, 'Livestock and Irrigation Value Chains for Ethiopian Smallholders' (LIVES) from the International Livestock Research Institute (ILRI), piloted AKCs to contribute to the government's effort to strengthen the extension system.

This thesis contains three empirical chapters in addition to the introduction and general discussion. The first empirical chapter analyzes the process of establishing AKCs in five extension organizations in South Wollo by capturing the role of human actors (employees of the project, experts in the extension offices, and the ICT managers) and the role of the non-human actors (computers, internet connectivity, texts, and office infrastructure) in carrying out the AKC initiative. The Actor Network Theory (ANT) framed the analysis of the results. The findings show how people and technology came together to establish AKCs that provide access to digital knowledge. Conditions that contributed to creating and stabilizing the AKC actor network were the following: (i) the presence of an actor to facilitate the process, (ii) alignment of interests among actors in the network, (iii) building the capacities and motivation of the various actors to execute their roles, and (iv) availability of computers with strong internet connections.

The second empirical chapter analyzes extension experts' perceptions of ICT's usefulness for their extension job and how they used ICTs in four AKCs in South Wollo. The three concepts from the Theory of Planned Behavior: attitude, social norms, and perceived behavioral control framed the analysis of the results. Extension experts had a positive attitude towards the usefulness of ICTs for personal benefits. However, they did not perceive ICTs as useful for searching and exchanging agricultural information because the rigid extension approach used in their organizations allows primarily for specific printed knowledge resources. The results show that while access to the ICT hardware is a prerequisite, it is not a guarantee that extension experts will apply ICTs for professional use. For ICTs to be used by agriculture extension experts, there needs to be greater flexibility for experts' response to farmers' needs and favorable conditions that facilitate self-initiated knowledge-seeking behavior among extension experts.

The third empirical chapter analyzes the organizational characteristics identified in the existing literature for accelerating or hindering ICT use for agriculture extension. The qualitative review of 49 articles highlights that most of the scientific studies focus on individuals' characteristics to explain ICT use and only partially investigate organizational aspects. Organizational characteristics identified in these 49 articles were further analyzed using the seven dimensions of the learning organization concept. The analysis showed that opportunities for training and creating structures to encourage learning were prominent characteristics limiting or supporting ICT use. However, the literature documented no evidence on characteristics such as collaboration, leadership style, and empowerment for creating a shared vision for improving services via ICT use. The review results illustrate the importance of strategizing ICT use in agricultural advisory

organizations and following principles of organizational learning for capacity development at an individual, team, and organizational level.

Based on the three empirical chapters, chapter five discusses that optimal ICT use for agriculture extension can be achieved when the introduction of technology is supported by new rules and organizational structures, and when the intended purpose fits the shared way of thinking and the future vision employees have for their extension work. This section highlights that successful ICT use in agriculture extension organizations requires not only the technical devices, individuals' attitudes, or institutions, but also the alignment of all the three dimensions. Therefore, aiming to improve the extension services only through the provision of ICT devices would be too simplistic; it ignores the complex interaction of the various components.

This thesis makes the following recommendations for the design and implementation of future ICT-based initiatives in Ethiopia and other countries with a similar context: (i) a project initiator should create awareness on the purpose of ICT for agriculture extension and develop the capacity of targeted beneficiaries on ICT use; (ii) organizations that aim to utilize ICT should create organizational conditions that facilitate learning at the levels of the individual, team, and organization; (iii) development projects and programs should recognize and stimulate interaction between innovation components to successfully implement ICT in agriculture extension and ensure their utilization; and (iv) the government should create an enabling environment that provides support structures for knowledge sharing and information exchange to respond to farmers' needs.

Zusammenfassung

Effektive landwirtschaftliche Beratungsdienste erfordern eine kontinuierliche Transformation und Einführung neuer und effektiver Interventionen, Ansätze, Methoden und Instrumente. Informations- und Kommunikationstechnologien (IKT) sind eines der Instrumente, die mit großen Erwartungen verbunden sind, um die Kompetenz und Effektivität der landwirtschaftlichen Beratungskräfte zu erhöhen, indem sie neue Kommunikationsformen und einfachere Möglichkeiten des Zugangs zu aktuellen und relevanten Informationen verbessern. Es gibt umfassendes Wissen zu den Übernahmeraten, die zur Nutzungsintensität und den Auswirkungen von IKT in der Landwirtschaft. Allerdings ist bisher nur wenig erforscht, wie Beratungskräfte den Nutzen von IKT wahrnehmen und wie organisatorische Merkmale, die die Nutzung von IKT fördern können. Insbesondere die Wechselwirkung zwischen IKT-Instrumenten und den sozialen und organisatorischen Aspekten im Rahmen der landwirtschaftlichen Beratung ist unzureichend untersucht.

Vor diesem Hintergrund zielt diese Dissertation darauf ab, Erkenntnisse über die Umsetzung von IKT-Initiativen in landwirtschaftlichen Beratungsorganisationen und deren Nutzung zu liefern. Die drei spezifischen Ziele der Arbeit sind: (i) empirische Erkenntnisse über die komplexe Interaktion zwischen sozialen und technischen Akteuren und ihrer Assemblage zur Gründung einer IKT-basierten Initiative namens Agricultural Knowledge Centers (AKCs) zu liefern; (ii) empirische Erkenntnisse über die Wahrnehmung von Beratungskräften und ihre Nutzung von IKT in landwirtschaftlichen Beratungsorganisationen zu liefern; und (iii) Erkenntnisse über organisatorische Merkmale zu liefern, die die erfolgreiche Anwendung von IKT-Instrumente für landwirtschaftliche Beratungsdienste erleichtern oder behindern.

Diese Arbeit analysiert den Innovationsprozess von IKT-basierten Initiativen in der landwirtschaftlichen Beratung aufbauend auf der Definition von Innovation als eine Abstimmung von Hardware (technische Geräte, körperliche Fähigkeiten), Software (Denkweisen, Diskurse, Wahrnehmungen) und Orgware (Regeln, Strukturen und Standards). Die Arbeit nutzt hierzu den Forschungsansatz, der allgemein als interpretativer Forschungsansatz bezeichnet werden kann. Dieser Ansatz ermöglicht es, ein Phänomen durch die Interpretation der Erfahrungen von Forschungsteilnehmenden zu verstehen. Dabei wurde eine Fallstudienmethodik und die Recherche zu vorhandenem Wissen über IKT in der landwirtschaftlichen Beratung eingesetzt. Die Fallstudien wurden in AKCs in South Wollo, Amhara Region in Äthiopien durchgeführt. Das Entwicklungsforschungsprojekt "Wertschöpfungsketten für Viehzucht und Bewässerung für

äthiopische Kleinbauern " (LIVES) des International Livestock Research Institute (ILRI) pilotierte AKCs, um die Bestrebungen der Regierung zur Stärkung des Beratungssystems zu unterstützen.

Diese Arbeit enthält drei empirische Kapitel sowie eine Einleitung und eine allgemeine Diskussion. Das erste empirische Kapitel analysiert den Prozess der Gründung von AKCs in fünf Beratungsorganisationen in South Wollo, indem es die Rolle menschlicher Akteure wie dem Projektpersonal, dem Beratungspersonal und dem IKT-Manager sowie die Rolle der nicht-menschlichen Akteure wie Computer, Internetkonnektivität, Texte und Büroinfrastruktur bei der Durchführung der AKC-Initiative erfasst. Die Akteur-Netzwerk-Theorie (ANT) diente als konzeptioneller Rahmen für die Analyse der Ergebnisse. Die Ergebnisse zeigen, wie Menschen und Technologie zusammenkamen, um die AKCs zu gründen und Zugang zu digitalem Wissen zu schaffen. Bedingungen, die zur Schaffung und Stabilisierung des AKC-Akteursnetzwerks beigetragen haben, waren (i) die Anwesenheit eines Akteurs, um den Prozess zu erleichtern, (ii) die Abstimmung der Interessen zwischen den Akteuren im Netzwerk, (iii) der Aufbau der Kompetenzen und der Motivation der verschiedenen Akteure zur Wahrnehmung ihrer Aufgaben sowie (iv) die Verfügbarkeit von Computern mit guten Internetverbindungen.

Das zweite empirische Kapitel analysiert die Wahrnehmungen von Beratungskräften über den Nutzen von IKT für ihre Arbeit und wie sie IKT in vier AKCs in South Wollo verwendeten. Die drei Konzepte aus der Theorie des geplanten Verhaltens: Einstellung, soziale Normen und wahrgenommene Verhaltenskontrolle rahmen die Analyse der Ergebnisse ein. Die Beratungskräfte hatten eine positive Haltung gegenüber der Nützlichkeit von IKT für den persönlichen Gebrauch. Sie sahen die IKT jedoch nicht als nützlich für die Suche und den Austausch landwirtschaftlicher Fachinformationen an, da der unflexible Beratungsansatz in Äthiopien nur die Verwendung ausgewählter gedruckter Wissensressourcen erlaubt. Die Ergebnisse zeigen, dass der Zugriff auf die IKT Hardware zwar Voraussetzung, aber keine Garantie für die Anwendung von IKT durch Beratungskräfte für den beruflichen Einsatz ist. Damit IKT in der landwirtschaftlichen Beratung eingesetzt werden können, benötigen die Beratungskräfte einerseits einer höhere Flexibilität, um die Bedürfnisse der Landwirte zu berücksichtigen und andererseits müssen organisatorische Rahmenbedingungen für ein proaktives wissensorientiertes Verhalten der Beratungskräfte geschaffen werden.

Das dritte empirische Kapitel analysiert anhand einer Literaturrecherche organisatorische Merkmale, die den Einsatz von IKT in der landwirtschaftlichen Beratung vorantreiben oder behindern. Die qualitative Durchsicht von 49 Artikeln zeigte, dass sich die meisten wissenschaftlichen Studien auf die Merkmale von Individuen konzentrieren, die die Nutzung von

IKT beeinflussen. Weniger Studien untersuchen hingegen die organisatorischen Aspekte. Die identifizierten organisatorischen Merkmale wurden anhand der sieben Dimensionen des Konzepts der Lernenden Organisation weiter analysiert. Die Analyse zeigte, dass Weiterbildung und die Schaffung von lernfördernden Strukturen herausragende Merkmale sind, die die Nutzung von IKT positiv beeinflussen. Allerdings wurden die Merkmale der Zusammenarbeit, des Führungsstils und der Ermächtigung zur Schaffung einer gemeinsamen Vision, die die Dienstleistungen durch die Nutzung von IKT verbessert, in der Literatur kaum untersucht. Die Ergebnisse der Literaturstudie verdeutlichen die Wichtigkeit einer Strategie der IKT-Nutzung in landwirtschaftlichen Beratungsorganisationen und die Beachtung von Prinzipien des Organisationslernens für die Kompetenzentwicklung auf individueller, team- und organisatorischer Ebene. Aufbauend auf den drei empirischen Kapiteln analysiert Kapitel fünf die Wechselwirkung zwischen Technologie und Gesellschaft, um zu erklären, warum IKT in der landwirtschaftlichen Beratung (nicht) erfolgreich eingesetzt werden. Diese Wechselwirkung verdeutlicht, dass ein erfolgreicher Einsatz von IKT in landwirtschaftlichen Beratungsorganisationen nicht nur technische Geräte, die Einstellung des Einzelnen oder Institutionen erfordert, sondern auch die Abstimmung aller Dimensionen von Hardware, Software und Orgware. Daher ist der Versuch, die Beratungsdienste allein durch die Bereitstellung von IKT-Geräten zu verbessern, simplifiziert; die komplexen Interaktionsprozesse der verschiedenen Komponenten werden dabei ignoriert. Die Ergebnisse der Arbeit bestätigen, dass eine erfolgreiche Nutzung von IKT für die landwirtschaftliche Nutzung die Anpassung technischer Geräte an neue soziale und organisatorische Strukturen erfordert.

Diese Arbeit gibt die folgenden Empfehlungen für die Konzeption und Umsetzung zukünftiger IKT-basierter Initiativen in landwirtschaftlichen Beratungsorganisationen in Äthiopien und anderen Ländern mit einem ähnlichen Kontext: (i) der Projektinitiator sollte das Bewusstsein für den Zweck der IKT in der landwirtschaftlichen Beratung schaffen und die digitale Kompetenz der Zielgruppen entwickeln; (ii) Organisationen, die die IKT nutzen wollen, sollten organisatorische Voraussetzungen schaffen, die das Lernen auf der Ebene von Individuen, Teams und Organisationen erleichtern; (iii) Entwicklungsprojekte und -programme sollten die Interaktion zwischen Innovationskomponenten erkennen und fördern, um IKT erfolgreich in der landwirtschaftlichen Beratung einzusetzen und deren Nutzung sicherzustellen; und (iv) Regierungen sollten ein förderndes Umfeld schaffen, das Anreize für den Wissens- und Informationsaustausch gibt und Beratungskräften die Flexibilität zur Berücksichtigung der Bedürfnisse der Landwirte ermöglicht.

1 Introduction

1.1 Background

Agriculture extension service, as a driver for agriculture development, plays a vital role in enabling farmers to deal with the changing environment (Faure, Desjeux, & Gasselin, 2012; OECD, 2015). The objective of agriculture extension is to help people form sound opinions and make good decisions by consciously using agricultural information they acquire through the extension service (Van den Ban & Hawkins 1996). In particular, agriculture extension is about assisting and building farmers' capacity to develop sustainable solutions to their problems by themselves (Hoffmann, Gerster-Bentaya, Christinck, & Lemma, 2009). Agriculture extension services draw heavily on communication methods and tools to reach their set objectives (Leeuwis & Van den Ban, 2004).

In the digitalization era, the use of Information and Communication Technologies (ICT) in the agriculture sector is receiving great focus for stimulating agricultural growth, economic transformation, and reducing poverty (Malabo Montpellier Panel, 2019; Trendov, Varas, & Zeng, 2019). Communication technologies such as mobile phones and internet applications hold massive potential for transforming the agriculture sector by improving communication, increasing participation, disseminating information, improving capacities in exchanging and sharing knowledge and skills (FAO, 2018). Government and non-government organizations in developing countries invest a significant amount of funds for digital technologies (Heeks, 2010; World Bank, 2016). In the last decade, the diversity of ICT services in agriculture have augmented around the world. Agriculture scholars and practitioners use ICT to disseminate information related to agronomic practices and livestock production, facilitate participatory advisory services, and support precision agriculture (CTA, 2019).

The Ethiopian government uses the agriculture extension system as a key policy instrument for increasing economic growth, agricultural development, and poverty reduction. Accordingly, Ethiopia has invested significantly in its extension system. A substantial amount of public money was allocated to agriculture extension, specifically for personnel and infrastructure costs over the last three decades. Moreover, the country has one of the highest extension agent-to-farmer ratios globally. While substantial progress has been made over the last 30 years, the Ethiopian extension still faces several challenges to support farmers in improving agricultural production (Berhanu & Poulton, 2014; Davis, Swanson, & Amudavi, 2009). In addition, the vast, scattered geographic areas with distinct agroecology throughout the country imply limited access

to specific knowledge sources and scant resources to deliver quality extension service (Davis et al., 2020).

With regard to the structure of agriculture extension in Ethiopia, a Participatory Extension System is employed since 2010 (ATA 2014). The system is structured from the MoANR at the national level to the regional Bureau of Agricultural Development (BoAD), then to the zone, districts, and Kebelle, which is the lowest administration unit. In principle, the district extension offices are supposed to play a key role in extension service provision. However, in fact the regional bureaus play a central role in planning, budget allocation, and overseeing the implementation of the agricultural extension (Leta, 2018).

In the effort to improve the agriculture sector, the Ethiopian government set a policy supporting ICT development for improving access to agricultural information to accelerate agricultural transformation (Lixi and Dahan, 2014). As a result, many government and non-government organizations piloted and promoted ICT based projects for improving agriculture advisory services. Examples of ICT-based projects that targeted farmers include agriculture information hotline 8028 (to disseminate agronomic advisory services to farmers and extension professionals) (ATA, 2017), locally produced participatory videos (Digital Green, 2017), livestock market information via SMS-based mobile apps (LMIS, 2019), and participatory farm radio programs (FRI, 2019). In contrast, fewer projects aimed at piloting ICT-based initiatives to improve extension staff's capacity or facilitate knowledge exchange. Examples of such projects are *Improving Productivity and Market Success of Ethiopian Farmers (IPMS)* (2004-2012) and *Livestock and Irrigation Value Chains for Ethiopian Smallholders* (LIVES) (2013-2018). Both projects were implemented by the International Livestock Research Institute (ILRI) in Ethiopia and funded by the Canadian development aid program.

The IPMS and LIVES projects set up Agriculture Knowledge Centers (AKCs), which are facilities that provide access to computers and internet for extension staff (ILRI, 2013), in their respective project sites. This was inspired by the recommendation from Davis' et al. (2009) to develop *woreda (district) resource centers,* a physical space in district extension offices to encourage knowledge exchange among extension experts and provide opportunities for accessing information resources. In the frame of the two projects, AKCs were designed for agricultural extension experts working not only at district level but also at zonal and regional extension offices. The ultimate project objective in setting up the AKCS was to improve extension

service quality by increasing access to up-to-date and relevant knowledge resources through digital and printed media via the AKCs.

1.2 Problem statement

Advisors in agriculture extension organizations usually work under unfavorable conditions with poor infrastructure, low staff capacity, and scarce capital to invest in new technologies (Swanson & Rajalahti, 2010, p121). Addressing advisors' challenges calls for continuous transformation and introduction of new and effective technical interventions, approaches, methods, and tools (World Bank, 2011). Since the past decade, ICT offer great potential to improve advisors' service delivery by introducing new communication modes and easier access to up-to-date and relevant information and knowledge into service delivery. However, so far, we still know little about how digital technologies are embedded in the social, technical and organizational processes of agriculture extension organizations mainly because of the following reasons:

(i) Although both the technological and social aspects of ICT and their influence on human actions have been studied extensively, research on the role of human and non-human actors and their assemblage that ultimately enable the establishment of ICT services is scarce (Adaba & Ayoung, 2017; Cordella & Hesse, 2014; Heeks & Molla, 2009; Sulaiman, Hall, Kalaivani, Dorai, & Reddy, 2012). Investigating the interdependency of actors involved in ICT project implementation, their changing roles, and their interaction can bring profound insights to the establishment and translation process. Similarly, in Ethiopia, understanding the role of actors involved in AKC establishment process and their changing interests provides lessons for designing and implementing viable ICT programs in the agriculture sector.

(ii) Empirical studies investigating behavioral aspects such as motivation, attitude, and perception towards ICT usefulness for advisory work, are scant (Strong, Ganpat, Harder, Irby, & Lindner, 2014; Tata & Mcnamara, 2016). Numerous scholars identified the crucial role users' perception has in determining whether they would use ICT for the intended purpose (Verdegem & De Marez, 2011; Meijer, Catacutan, Ajayi, Sileshi, & Nieuwenhuis, 2015). Similarly, in Ethiopia, understanding extension experts' perception of ICT usefulness and the organizational aspects that facilitate or hinder their use can bring insights to exploit the potential of ICT based initiatives, such as AKCs, in transforming the agriculture extension service delivery.

(iii) Literature on ICT for agriculture extension focuses predominately on analyzing individual characteristics and tangible organizational factors related to infrastructure and new tools, new services and/or employees for ICT use (Andoh-Baidoo, 2016). In contrast, fewer studies documented how agriculture extension organizations learn and adapt to change their service delivery to ICT-based extension service. A discussion about organizational learning in the context of ICT for agriculture extension can be an opportunity to draw attention to the learning and change process induced by ICT in agriculture extension organizations.

1.3 Study objectives

This thesis aims to understand the implementation and use of ICT-based initiatives in agriculture extension offices and produce empirical evidence to substantiate the claim that access to technology alone does not ensure its usability for acquiring agricultural information and knowledge (Sulaiman et al., 2012). Instead, it is the technology's alignment with the beneficiaries' knowledge and perception about the usefulness, and the social and organizational arrangement including the formal and informal rules in the context (Leeuwis, 2013; Heeks & Stanforth, 2015). To this end, the thesis presents two case studies from Ethiopia: The first case study explores how social and technical actors assemble to establish AKCs in the context of public agriculture extension offices. The study looks at how human actors such as the project staff, extension staff, and ICT manager as well as non-human actors such as computers, internet connectivity, texts, and office infrastructure interacted while establishing the AKCs. In so doing, the study identifies the various actors involved in the process, their role at the different stages and their interests to actively participate in the process. The second case study explores agriculture extension experts' pattern of ICT use and their perception of ICT usefulness for their extension work. This characteristics that support/hinder learning in order to integrate ICT in advisory services. This study puts particular emphasis on understanding organization characteristics that enable or hinder organizations to learn using ICT for extension service.

The evidence generated from this thesis can be beneficial to improve the design and modification of ICT-based services offered in public extension offices and to scale-up pilot projects sustainably and profitably both in Ethiopia and other countries with similar context. In particular, the evidence is in the Ethiopian public extension system's interest to learn strategies that improve leveraging ICT potential for facilitating agriculture development (National Plan Commission 2016; ATA 2017).

1.4 Conceptual framework

Contemporary literature focuses on understanding the interdependency between technology and society to explain why technologies are (not) effectively used in society (Leeuwis, 2013; Smits, 2002). Technologies become innovations that work when they are aligned with new social and organizational arrangements, such as new rules, perceptions, agreements, identities and social relationships (Leeuwis & Van den Ban, 2004; Leeuwis & Aarts, 2011). The alignment process entails continuous interaction and adaptation between the technology, the social and organizational components.

Smits (2002) defines innovation 'as the result of the successful combination of hardware (technical devices), software (new modes of thinking), and orgware (new rules, standards)'. The bio-material dimension of innovation (hardware) refers to the tangible material equipment such as technology in the form of a new technical device. The symbolic dimension of innovation (software) refers to the new knowledge (in terms of manuals, digital content, tacit knowledge involved in the innovation), meanings, visions, discourses (a new way of thinking), learning processes. The social dimension of innovation (orgware) refers to the organizational and institutional conditions such as rules, regulations, and standards that influence an innovation (Kilelu, Klerkx, & Leeuwis, 2013; Klerkx & Leeuwis, 2009; Leeuwis, 2013; Smits, 2002).

An innovation process describes the alignment procedure of the three dimensions of innovation. Innovation processes are non-linear and interactive, where science, technology, and society co-evolve together (Smits, 2002). Innovation processes emphasize understanding the people involved in the process, what they think, what they value, how they behave and how they interact with each other (Cavalli, 2007) to put new technology into use and to disseminate it at a wider scale.

This thesis builds on Smits (2002) definition of innovation to interpret and discuss the results of the three empirical chapters. Thus, the process of establishing and using ICTs in the context of agriculture extension organizations is captured through the elaboration of the alignment procedures of the three dimensions of innovation.

1.5 Methodology

1.5.1 Description of the study area

Ethiopia, with a population of 105 million, is the second populous country in Sub-Saharan Africa (World Bank, 2019). Agriculture plays a vital role in Ethiopia's political, economic, and social development. In the Ethiopian economy, agriculture contributes to 34% of the country's gross domestic product (GDP) and 71% of employment (ATA, 2019). Over the past two decades, the Ethiopian Government and its development partners have made coordinated efforts to improve food security and agricultural productivity in the country by transforming the smallholder subsistence agriculture sector into a market-oriented agriculture sector. To contribute to the larger goal of developing the agriculture sector, two consecutive research for development projects of the International Livestock Research Institute in Ethiopia piloted AKCs. The first project, IPMS (2004-2012), piloted 28 AKCs, and its successor LIVES (2013-2018), piloted 42 AKCs.

South Wollo is one of the ten administrative zones in Amhara region in which the LIVES project was active. The total zonal population is about 2.5 million, of which the majority (2.2 million) residents inhabit rural areas (CSA, 2007). Agriculture is the main economic activity in the zone, and farmers are predominately engaged in mixed-crop and livestock farming systems. To support the agriculture development in South Wollo zone, the LIVES project engaged in various interventions, including enhancing the knowledge management system in five agriculture extension offices by introducing AKCs. The AKCs were set up in extension offices to enhance access to knowledge via digital facilities. LIVES supplied computers with an internet connection, TV with DVD player, photo cameras, printers, and LCD projectors in each of the AKCs in the extension offices. LIVES project staff encouraged extension experts to browse, capture, store, and share relevant agricultural information among their peers using the centers' facilities.

Unlike the other two zones in Amhara region where LIVES project initiated AKCs, those in South Wollo zone were still functional and active during the field research (July - November 2016). Therefore, this project site offered a greater opportunity to capture perceptions and experiences on ICT use and reconstructing the process of establishing the AKCs. The five agricultural extension offices in South Wollo zone, where AKCs were established, were: Kalu district agriculture office, Teuledere district agriculture office, Dessie urban agriculture office,

Dessie Zuria district agriculture office, and South Wollo Zonal agriculture office (Figure 1.5.1).

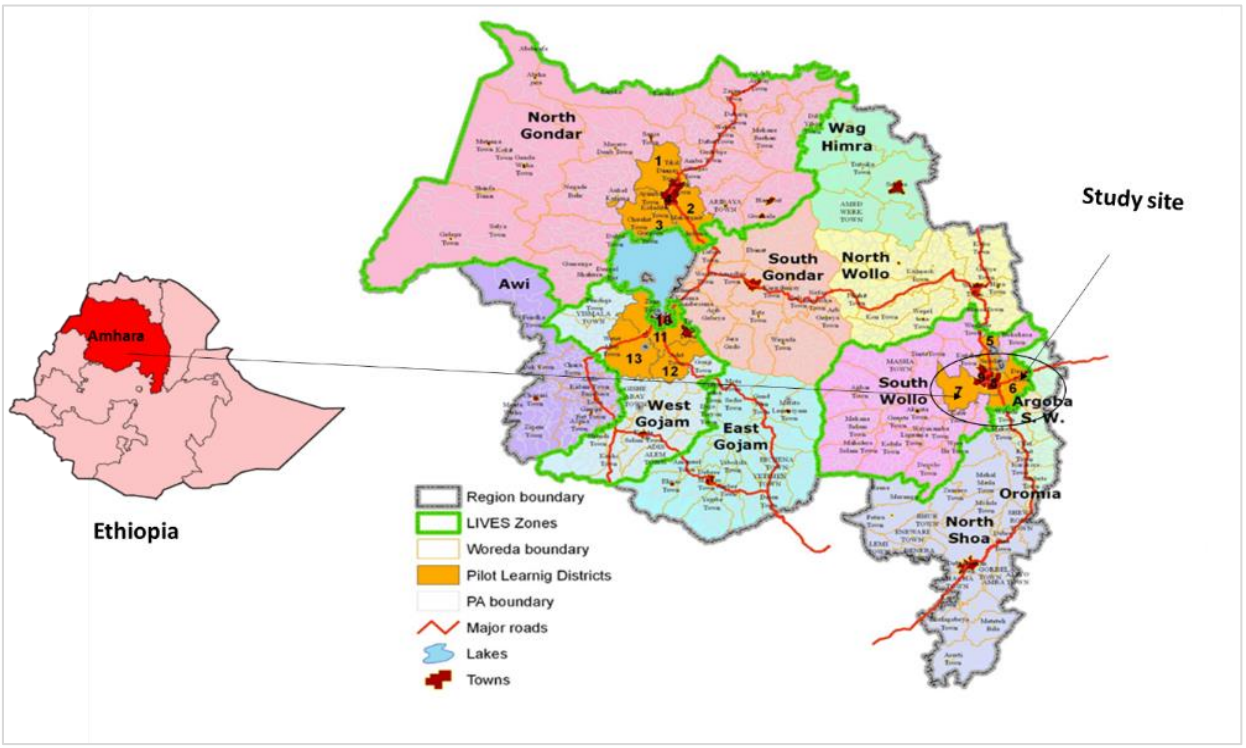

Figure 1.5.1 Map of the study area

source: LIVES Project

1.5.2 Data collection and analysis

This thesis adopted a research approach that can be broadly labeled as interpretive research (Walsham, 2006). Interpretive methods allow understanding of a phenomenon by interpreting stakeholders' and research participants' experiences (Klein & Myers, 1999; Walsham, 2006; Walsham & Sahay, 2006). A mixed-method approach that combines qualitative and quantitative methods was used for comprehensive data collection and analysis (Creswell, 2013). During the data collection, interview questions for the field data were formulated in English, then translated to Amharic, Ethiopia's national language. Responses were captured with notebooks and voice recorders and later translated and transcribed to English. The field data were collected between July and October 2016.

For analyzing the AKC establishment process, data were collected using in-depth interviews, archive project documents, and participatory observation. For the in-depth interviews, purposive snowball sampling was used to identify study participants who experienced or knew about the AKC establishment process. The first interviewee was the LIVES zonal coordinator.

Afterwards, through snowballing, twenty-four study participants who were involved in the AKC establishment and management were identified. The interviews were face-to-face in the interviewees' respective workplaces for twenty-two of the study participants, while it was via telephone for three of them. The interviews lasted between 45 and 90 minutes. Documentary evidence from the LIVES project, such as project proposal, project implementation plan, and zonal assessment reports were other data sources. Participant observation to further understand the process of AKC management and use in the extension offices encouraged additional discussion with the center managers. The qualitative data analysis was guided by the Actor Network Theory concept, particularly the four moments of translation. Once the open coding was completed, the four moments of translation concept guided the category development and interpretation of the results. ATLAS.ti qualitative data analysis software was used to assist the open coding and category development.

Data collection for the exploratory study on users' perceptions was conducted in three steps. Step one was key informant interviews of nine respondents who were purposely selected for their knowledge about the AKC services. The goal was to get general information on services offered, management of AKCs, and users' profiles. Step two was in-depth interviews with 24 extension experts who were purposely selected because of their frequent use of AKC services. The goal was to understand the pattern of use and their opinion about the usefulness of the services for extension work. Step three was survey that aimed to quantify the frequency of ICT use, the satisfaction level with services available, the perception of ICT usefulness for extension delivery, and the perceptions of organizational factors that enable and constrain ICT use in the extension organization. In total, 72 out of 90 extension experts who use AKC services participated in survey. The qualitative data analysis was guided by the three concepts of the Theory of Planned Behavior: attitude, social norms, and behavioral control. The quantitative data were analyzed by computing descriptive statistics.

Information sources for the systematic literature review were published journal articles. The research databases, Scopus and CAB, were used to identify relevant articles on agriculture extension organization and ICT use. Specific search terms and synonyms informed by preliminary exploratory research were used to run a query in May 2019. The query identified 423 Journal articles written in English. The identified articles were screened based on the inclusion and exclusion criteria developed before the screening process. Accordingly, we selected and downloaded 49 full-text articles for further analysis. The analysis took place in three steps. In step one, the articles identified were characterized based on the year of publication, geographic region

focus, type of research, and type of ICT. In step two, through iterative descriptive coding that involved several cycles, the factors that contribute to ICT use were identified and categorized. In step three, the factors related to organizational characteristics that were identified in step two were analyzed and interpreted based on the analytical framework, the seven dimensions of learning organizations.

1.6 Outline of the dissertation

The thesis is structured in a cumulative manner in five chapters, including this introductory Chapter 1. Chapters 2 to 4 are individual articles where Chapter 2 presents the study on how AKCs were established in five extension organizations in South Wollo. The study explores the assemblage and relationships between various actors including people, technology, and documents that played a role in shaping the AKCs. Chapter 3 presents the study on the perceptions and attitudes of extension experts towards the usefulness of ICT for extension service. The chapter mainly draws the reader's attention to advisors' perception, social, and organizational factors that constrain or facilitate ICT use in the AKCs. Chapter 4 draws from the findings of Chapters 2 and 3 and goes deeper into understanding organizational characteristics identified by recent literature in the context of agriculture extension organizations. The chapter identifies all types of organizational aspects documented in the literature that contribute to ICT use. It then investigates these organizational characteristics through the learning organization's lens, particularly the seven dimensions of a learning organization. Chapter 5 brings together insights from the empirical studies in the form of a general discussion where key results and limitations are discussed. Also, implications of the results to academia and practice are presented.

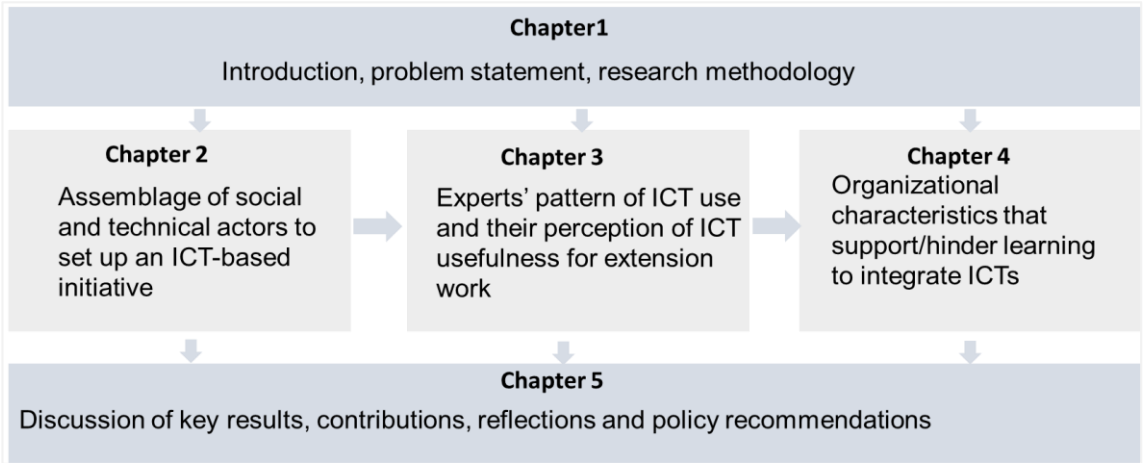

Figure 1.6.1 Thesis outline

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2 ICT for agriculture extension: Actor Network Theory for understanding the establishment of Agricultural Knowledge Centers in South Wollo, Ethiopia

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Abstract

This study aims at understanding how various actors interacted in establishing and managing an Information Communication Technology (ICT)- based initiative called Agricultural Knowledge Centers (AKCs) in Ethiopia. In addition, it explores the diverging and shared interests of the actors in the benefits of the AKCs. We gathered and analyzed data from in-depth interviews in five extension offices in the South Wollo zone, Ethiopia, and supplemented it with project documents and observations. We used the Actor Network Theory (ANT), specifically the four moments of translation to analyze the results. The findings show how people and technology came together to establish the AKCs and to provide extension experts access to digital knowledge. Factors that contributed to creating and stabilizing the AKC actor network included an actor's presence to facilitate the process, alignment of interests among actors in the network, building the capacities and motivation of the various actors to execute their roles, and availability of computers with strong internet connections. These findings contribute to practical and policy debates on harnessing ICT's potential for facilitating socioeconomic development in the Global South; and to the theoretical discussions on the merits of the ANT perspective in analyzing the adoption of technological innovations.

Keywords: Information communication technology (ICT); agricultural knowledge center; ICT based services, sociotechnical, actor network theory (ANT); translation; Ethiopia

2.1 Introduction

Information Communication Technologies (ICTs) are given a key role in accelerating global development goals. They facilitate information dissemination, improve feedback mechanisms, and encourage participation to strengthen social development initiatives (Heeks & Stanforth, 2015; United Nations, 2015; ITU, 2017). While ICTs are receiving such general attention globally, Ethiopia emphasizes applying ICT in the agriculture sector, the largest economic sector (National Plan Commission, 2016). Accordingly, many ICT-based development programs using mobile phones, computers, radio and video are flourishing to contribute to agricultural growth and development (Lixi & Dahan, 2014). For instance, agriculture information hotline 8028 (ATA, 2017), locally produced participatory video (Digital Green, 2017), ICT based agriculture resource centers referred to as “Agriculture Knowledge Centers (AKCs)” (ILRI, 2013).

The Agricultural Knowledge Centers (AKCs) were designed to provide agricultural extension experts access to computers and internet services in public extension offices in Ethiopia. The International Livestock Research Institute in Ethiopia piloted AKCs as part of a bigger project, LIVES (Livestock Irrigation and Value Chains for Ethiopian Smallholders), that ran from 2013-2018. The AKC concept is inspired by the telecenter model, a facility that provides access to networked computers and other ICT to people without any personal access (Best & Kumar, 2008). In Ethiopia, despite the efforts to make AKCs functional and sustainable, documented experiences show that those efforts have not succeeded (Lemma, Tesfaye, Gebremedhin, Tegegne, Hoekstra, 2016; Birke et al., 2019). Lessons about designing and implementing viable ICT programs in the future can be learned from understanding the process of establishing the AKCs and examining the interactions with the various actors engaged in the process.

In this study, we analyze the roles of the human actors such as the project staff, the extension office staff, the ICT manager, and the non-human actors such as the computers, internet connectivity, texts and office infrastructure to establish AKCs. We analyze the shared and different interests and look at how the actors' interactions impacted the ICT service provision. AKCs in five agricultural extension offices in South Wollo Ethiopia were chosen for the study. To attain our objective, we used the Actor Network Theory (ANT), specifically the four phases of translation, to bring visibility to both the human and non-human actors and their assemblage in a non-deterministic way (Rhodes 2009; Adaba & Ayoung, 2017). We chose ANT, as it helps to shift the focus onto the action rather than onto the actor (Crawford, 2004).

This study contributes to the literature on ICT for development in three ways. First, it presents the assemblage of the various actors, both human and non-human, in shaping the implementation and use of innovations. Second, the findings have implications for realizing telecenters' potential in agriculture extension offices in similar settings. Third, the paper adds knowledge to the analytical and practical value of the ANT to study innovation adoption.

2.2 Literature review

Access to ICT is linked to opportunities to overcome challenges faced in agriculture development, particularly access to information. Shared models for ICT access for digital information through one or more ICT in rural areas have been implemented in many developing countries in Asia, Africa and Latin America. “Telecenter” is a general term applied to facilities which provide access to networked computers and other ICT to people without any personal access (Best & Kumar, 2008; Braathen et al., 2012; Pick et al., 2014). Types of Telecenter differ in certain factors, including funding sources, business models, objectives and ownership (Pick et al., 2014).

Technology-based initiatives such as telecenter involve the interaction of professional, political, technical and economic actors that mutually shape each other (Bijker & Law,1992). Technological aspects of ICT and their influence on human actions have been extensively explored (Attwood, Diga, Braathen, & May, 2013). Similarly, how social aspects influence telecenter services' management and use has been studied (Lwoga, 2010; Pick et al., 2014; Mamba & Isabirye, 2015). However, research on the role of social and technical actors and their interactions that enable the establishment of ICT services is scarce (Heeks & Molla, 2008; Sulaiman et al., 2012; Cordella & Hesse, 2014; Adaba & Ayoung, 2017).

In science and technology studies, it is important to document a detailed description of events in flux, to understand how something did or did not come into being (Callon, 1986; Law, 1991; Latour, 1992). Some scholars, including Thapa (2011) Avgerou (2010), Diaz Andrade & Urquhart (2010), Heeks & Stanforth (2015), Carolan (2017) and Gunawong & Gao (2017) highlight the need for more insights that focus on the interaction of actors (human or non-human), and the change of interests and identities in the course of ICT project implementation.

Using Actor Network Theory as an analytical framework

Actor Network Theory (ANT) is a relational, materialist research approach that offers an explicit

way of conceptualizing technology as one of the ‘actors’ in the actor-network (Walsham & Sahay, 2006). This theory gives attention to unpredictable ends and development processes of programs or projects (Latour, 1992, 2005). In ANT, anything- human (e.g., individual or groups) or non-human (e.g., technology artifacts, texts, plants, animals) that changes the circumstances of a given setting is an actor (Latour, 2005).

The ANT focuses on describing how a stable network of aligned interests is created and maintained, or alternatively, examines why such networks fail to establish themselves. Networks are a build-up of activities performed by the actors out of which they are composed (Crawford 2004). Conversely, the term ‘network’ brings with it expectations that there will be a designation of interconnected points; however, this is not the case for ANT, where actors' interconnectedness is not enough. What is important is the sort of actions flowing between the actors and the produced effect (Latour, 2004).

Crawford (2004) has identified six critical aspects to analyze actor-networks: (1) how networks overcome resistance, become stronger internally and gain coherence and consistency (stabilize); (2) how networks juxtapose elements and transform (translate) them; (3) how networks prevent others from being durable; (4) how networks enlist others to invest (enrol); (5) how networks bestow qualities and motivation (establish roles and scripts); and (6) how networks become functionally indispensable.

Translation is a central concept in ANT that guides the reconstruction of a complex network of actors (Diaz Andrade and Urquhart, 2010) through its four phases, also called “moments” (Callon, 1986). Table 2.2.1 summarizes definitions of the four phases (i) problematization (ii) interessement, (iii) enrollment and (iv) mobilization along with other key terms and concepts of ANT. To establish a stable actor network, the four phases of translation need to be realized in full; otherwise, it never stabilizes (Diaz Andrade & Urquhart, 2010). Reconstructing the translation phases allows for a clear view of the actors and their diverse goals, contradictory interests and interaction processes. In practice, the phases can overlap during the network formation (Callon,1986).

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Table 2.2.1 Description of ANT key concepts, phrases and terms used

Key concepts and terms	Definition
Translation	The process where one set of actors translates (displaces) goals, interests, problems, solutions and identities of other sets of actors in order to realign the other actors' interests with their own (Callon, 1986).
Problematization phase	The initiator defines problems, objectives and roles of other actors in the context (Callon, 1986).
Interessement phase	Initiator tries to convince the actors that the interest defined is in line with their own interest using different devices and actions such as negotiations to impose and stabilize the interests identified during the problematization phase (Callon, 1986).
Enrollment Phase	Different actors organize themselves, take responsibilities to start implementation, and therefore try to make a stable network. The phase gives visibility to the strategies the initiator defined, such as hierarchy, authority and power. There is a need to relate to the roles of the other actors, as the argument presented and persuasion during the interessement is never enough (Callon, 1986).
Mobilization Phase	Actors identified by the initiator and those that joined the network during the consecutive phases become spokespersons representing the network. (Callon, 1986). In this phase, the actor network becomes durable, and relations between actors become irreversible, allowing the network to behave as if it was a single actor or a 'black box' (Latour, 1987)
Device	A term for necessary actors such as standards, budgets and meetings to convince others to join the network (Callon, 1986)
Actor	A term for both human beings and non-human elements that cause others to change or become dependent (Walsham, 1997).
Actor network	A term that explains a heterogeneous network of aligned interests, including people, organizations, and standards to satisfy the actors' diverse aims (Walsham, 1997).
Black box	A technical term for a device or a system or an object that has a frozen network, often with properties of irreversibility (Walsham, 1997).
Focal actor/Initiator	The term for the actor who initiates the network and has the capacity to establish and control a new actor-network (Callon, 1986).

Various scholars in the field of ICT and development have used the Actor Network Theory (ANT) approach to study actors' interaction and network formation. For instance, Rhodes (2009) analyzed the power relationship of donor, local authorities, project facilitator, bank account, church land and building and legal status in the formation of a rural women's association telecenter actor network; Diaz Andrade and Urquhart (2010) examined the phases of a rural ICT project implementation and provided a unique and useful understanding of varying interests and actions of actors that created unstable actor network; Adaba and Ayoung (2017) analyzed how a

mobile network operator built up an actor network composed of multiple players, including mobile networks, power supply, mobile money users and bank agents, in the development of a mobile money service in Ghana; Cordella and Hesse (2014) analyzed the negotiation processes among various actors to implement an e-government project, and how the interaction of the actors involved changed the project over time. The studies above demonstrate the advantages of using ANT as an analytical framework to gain a deeper understanding of interactions and negotiations that take place during the implementation of ICT projects.

We identified three main criticisms of ANT: (1) its heuristic stance between human and non-human actors and treating them equally, (2) its limitations in explaining and interpreting data and therefore failing to give evidence that can be empirically verified (Walsham, 1997) and (3) its focus on addressing local and contingent effects, but too little attention to broader social structures that influence the local (Walsham, 2017). Nevertheless, we believe ANT's translation phases are the most applicable concept to meet our objectives of making visible all of the actors and their diverse goals, contradictory interests and interaction processes in the AKC establishment and management.

2.3 Research context and methods

2.3.1 Overview of ICT penetration in Ethiopia

Following the enactment of the national ICT policy in 2007 that is dedicated to advance the ICT sector, the accessibility of ICT has shown significant growth in Ethiopia (Adam, 2012). Though the ICT sector in Ethiopia is growing, it is still lagging compared to neighboring Kenya, Sudan, and Uganda (ITU, 2017). The global ICT index of Ethiopia in 2017 shows that mobile phone penetration is 51%, which is less than that of the African average of 75%. The internet use is 15%, which is less than the African average of 16%. The fixed broadband penetration is higher than the African average, but mobile broadband penetration is about five times smaller than the African average of 23%.

Regardless of the slowly emerging ICT accessibility, Ethiopia's agricultural extension strategy promotes a digitalized and ICT-based extension communication system to enhance the effectiveness of conventional extension methods, such as training sessions, meetings, and social gatherings (MoANR, 2017). This strategy integrates best practices and innovations into ICT-based initiatives piloted by different programs and projects to develop the agriculture sector. The

experiences of ‘Woreda Knowledge Centers’ was one of the promising ICT-based initiatives taken up in the new agricultural extension strategy (MoANR, 2017 p.16).

During the implementation of the project “Improving Productivity and Market Success for Ethiopian Smallholders” (IPMS) from 2005- 2012, the project staff piloted the Woreda Knowledge Centers in the project sites. Woreda Knowledge Centers provided access to knowledge resources on agriculture through printed books, computers, CDs and the internet for extension experts in the district agriculture offices. IPMS defined the centers as ‘information resource centers or venues that facilitate access to knowledge by providing the functions of traditional library, digital library, resource center, online access point, and informal meeting venue’ (Lemma, Sehai, & Hoekstra, 2011). To develop the emerging computing and browsing skills of extension experts, the IPMS project staff conducted multiple training workshops on computer skill development and encouraged using the Woreda Knowledge Centers for learning and sharing knowledge. After IPMS phased out in 2012, the successor project, LIVES, planned and facilitated further pilots of knowledge centers in 42 project sites. LIVES named the centers ‘Agricultural Knowledge Centers.’ Figure 2.3.1 summarizes the timeline of the AKCs’ establishment process in the LIVES project.

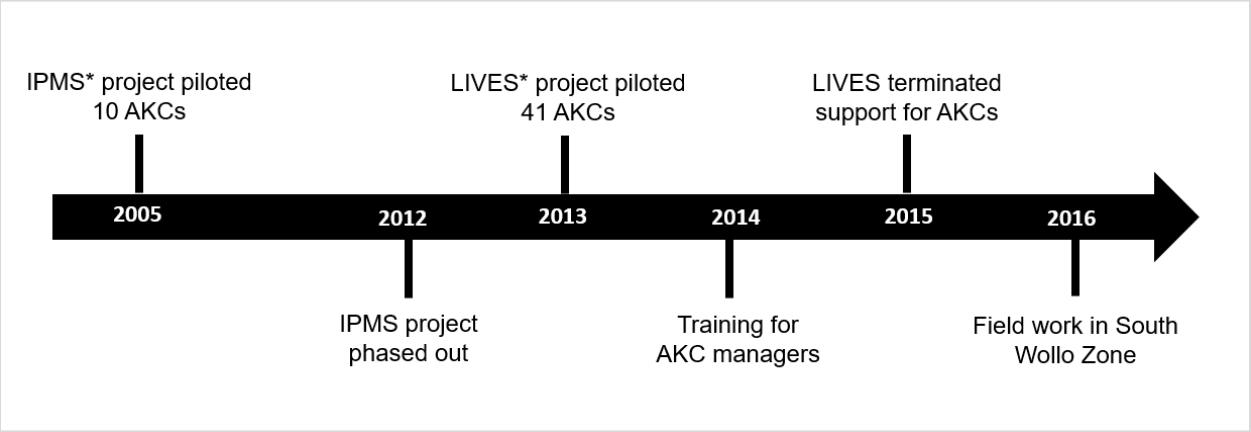

Figure 2.3.1 Time line of AKC establishment process

2.3.2 Study design

In this study, we adopted a research approach that can be broadly labeled as an interpretive qualitative research approach (Walsham, 2006). Interpretive methods allow for understanding a phenomenon through the interpretation of stakeholders’ and research participants’ experiences (Klein & Myers, 1999; Walsham, 2006; Walsham & Sahay, 2006). Many information system studies have adopted interpretive methods due to the type of research questions and challenges the methods can tackle (Walsham & Sahay, 2006). Additionally, studies on ICT for development

research that use ANT as an analytical tool have used the interpretive approach (Adaba & Ayoung, 2017; Diaz Andrade & Urquhart, 2010; Rhodes, 2009). This is because interpretive methods are particularly suitable for explaining the complex sociotechnical interaction process by documenting human thoughts, actions and interactions (Klein & Myers, 1999).

2.3.3 Study site

We conducted empirical research in five extension offices which belong to the public Ethiopian extension system in the South Wollo zone. The criteria for site selection were, (i) a project site where LIVES had established AKCs and already finished the planned two years' financial and technical support at the time of data collection. This was important to gain understanding of the status of the network after the initiator left; (ii) a project site with several extension offices where AKCs are established in different locations, to get information from organizations with differing character. Accordingly, of the 10 zones where the project had been implemented, we selected the South Wollo zone.

South Wollo is one of the ten administrative zones in the Amhara region and consists of seventeen districts. The zonal population is about 2.5 million in total, of which the majority (2.2 million) are in rural areas (CSA 2007). Agriculture is the zone's main economic activity, and farmers are engaged in mixed crop, livestock farming systems.

The zonal and district agriculture offices in South Wollo provide extension support to smallholder farmers. They use mainly printed manuals produced in the local language, Amharic, on new production techniques and agronomic and animal husbandry practices. Use of computers and online information resources for extension-related work in the offices is rare, especially in district agriculture offices. Prior to the LIVES project, experts in all of the targeted offices had no access to ICT services such as the internet.

To support agricultural development in the zone, the LIVES project engaged in enhancing the knowledge management system by introducing a new approach based on ICT, the Agricultural Knowledge Centers. Each AKC offered extension experts digital facilities, including computers with an internet connection, a TV with DVD player, a photo camera, a printer, and an LCD projector. The five extension offices selected for the field study were: The Kalu district agriculture office, the Teuledere district agriculture office, the Dessie Urban agriculture office, the Dessie Zuria district agriculture office, and the South Wollo zonal agriculture office.

2.3.4 Data collection

In qualitative research, interviews are key to access research participants' experiences (Yin, 2016). We used a narrative interview technique to encourage and stimulate the respondents in reconstructing the events (Moen, 2006; Muylaert, Sarubbi, Gallo, Neto & Reis, 2014).

The purposive sampling technique allows for identifying and selecting knowledgeable respondents in the phenomenon of interest (Palinkas et al., 2015). The interview process started with the LIVES zonal coordinator in South Wollo and traced individuals involved in establishing AKCs in South Wollo zone.

We collected data between July and October 2016. We interviewed a total of 25 individuals: Office heads, extension experts, AKC managers, and experts at each extension office, as well as LIVES project staff at the national and zonal levels who had been involved in the establishment process (Table 2.3.4). We used open questions that encouraged the respondents to recall the AKC establishment process. Questions such as 'How did you become aware of the AKC's establishment?' 'How did the establishment process start?' were used at the beginning, followed by specific questions to trace the process and the actors involved in the various phases. We conducted the interviews in Amharic, the local language, tape-recorded and later translated and transcribed them into English. Most of the interviews (22) took place in the interviewees' respective workplaces and lasted between 45 to 90 minutes. We conducted telephone interviews with three respondents who had moved to another region.

Other data sources we used were different forms of documentary evidence from the LIVES project, such as the project proposal, project implementation plan, and zonal assessment reports. At the national level, the LIVES project staff gave us permission to access e-mail communications and letters exchanged with regional, zonal and district offices to facilitate setting up the AKCs in the South Wollo zone. The secondary data allowed for triangulation of the interview data. Additionally, we did participant observations to understand further the process of AKC management and its use in the respective extension offices. The observations encouraged further discussion with the center managers. At the end of the data collection, we presented the preliminary findings and conducted discussions with the LIVES project staff at the national level.

Table 2.3.1 Organizational affiliation of interviewees

Interviewee role	Organizations						
	Kalu	Teuledere	Dessie Urban	Dessie Zuria	South Wollo zone	LIVES project	Number of interviews
AKC managers	2	1	1	2	2		8
Extension office head facilitating AKC establishment	1	1	2	1	1		6
LIVES staff facilitating AKC establishment					1	3	4
Extension expert facilitating AKC establishment*	2	2	1	1	1		7
Total	**5**	**4**	**4**	**4**	**5**	**3**	**25**

*Only those experts who were assigned as contact persons for the LIVES project intervention were interviewed

2.3.5 Data analysis

We checked the validity of the data by examining the information from multiple sources and checked the consistency of the narratives in the transcribed data. To analyze the transcribed data, we followed the coding guideline of grounded theory (Corbin and Strauss, 2014). The guideline is relevant for all researchers and not just for those practicing grounded theory (Yin, 2016). Accordingly, we followed the guideline's first two steps, open coding and axial coding, to give meaning to our data. We left out the last step, selective coding, as this study does not aim to generate theory.

During the open coding, we identified concepts that included actors, actions, interactions and events. Once the open coding was completed, we revised for overlaps and merged similar codes. Afterwards, we developed categories using axial coding. The categories developed were actor role, actor interest, establishment strategies and challenges. The translation concept of ANT guided the category development and interpretation of the results. We used ATLAS.ti qualitative data analysis software to assist open coding and category development. Table 2.3.2 shows an example of the data analysis process.

Table 2.3.2 Example of data analysis process using sample quotes

Sample quote	Code	Category
“Only after I organized a visit to previous project site and the decision makers observed how extension experts have access to up to date information via computers and internet, they decided to allocate room for AKC and assign AKC manager”	Advantages of ICTs	Strategy to convince actors
“Even though the extension organization recognized the ownership of the AKCs and their management, whenever there is a problem with the computers, electricity, internet connectivity in the AKCs, the AKC manager calls me”	-Technology related challenge -Interaction between actors	The role of actors in dealing with technology
“The Office head asked me to take the responsibility of managing the AKC as an additional responsibility then I agreed ”	Interaction between actors	The role of actors in enrolling other actors
“I took the position with the anticipation that when our livestock department becomes autonomous office the AKC equipment will come with us and our new office will use modern ICT services”	Advantages of ICT	Actor’s interest to join the actor network
“The internet connectivity is very slow and takes too long to download a document and experts are discouraged to come to AKC”	Interaction between actors	Connectivity issues challenging the enrollment

2.4 Results

The following sections trace the process of the AKC actor network formation by describing the four phases of translation.

2.4.1 Problematization

The problematization phase provided insights into how the focal actor re-defined the problem and identified the key human and non-human actors.

The LIVES project document stated that the project aims to improve the generation, access, flow, and use of relevant knowledge within and amongst the different agriculture value chain levels. One of the knowledge management activities proposed to meet this objective was the establishment of agricultural knowledge resource centers in public extension offices (ILRI, 2011). Consequently, the LIVES document defined poor access, flow and use of agricultural knowledge as problems and suggested AKCs as the solution to improve access and use in zonal and district agriculture extension offices. The project planned to provide ICT devices (hardware, software) and a budget for internet fee and knowledge resources. In South Wollo, the zonal LIVES coordinator became the spokesperson for the project document and identified other key actors to provide AKC services in targeted extension offices. Key actors identified were: a room for AKC, ICT devices (computers, printers, network cables, projectors), broadband internet, a skilled AKC manager, extension experts as users of the service, decision makers (district and zonal office heads, regional bureau head), the LIVES project staff at the national, regional and zonal levels. The zonal coordinator had to convince the identified actors to accept the problematization and establish the AKC as an Obligatory Passage Point (OPP) to provide ICT based services. Table 2.4.1 describes the key actors' interest in establishing AKCs.

Table 2.4.1 Key actors identified during the case study

	Key Actors	Interests and tasks
Human actors	LIVES project staff	To implement the project objective of establishing AKCs in extension organizations by negotiating and collaborating with other actors and improving the access, flow and use of agricultural information
	Officials in public extension offices at the regional bureau	To encourage the use of innovative tools to improve extension service delivery at the grassroots level
	Officials at extension offices at zonal and district offices	To modernize the extension service delivery in their extension offices without allocating own budget
	AKC manager	To get incentives from the LIVES project or extension office for managing AKC
Non-human actors	Computers	To allow extension experts to gain knowledge and improve their capacity and skill in computer use
	Internet connectivity and speed	To facilitate access, flow and use of knowledge among extension experts through the world wide web
	AKC room	To provide a space for the ICT equipment and therefore facilitate the AKC service provision
	LIVES project document	To direct the implementation of the project goal and objectives regarding capacity development and knowledge sharing.

2.4.2 Interessement

The interessement phase provided insights into the strategies used and actions performed by the network initiator to capture the actors' interest in taking up the new roles defined for them.

In South Wollo, the focal actor, together with other project staff at the national, regional and zonal levels, organized workshops and excursions for decision-makers from regional, zonal and district offices, to show AKCs established by the previous project, IPMS, in other locations. Once the decision-makers showed interest in the potential of AKC services to facilitate the access, flow and use of agricultural knowledge, the LIVES management team at the national level set conditions for establishing AKCs. The conditions were communicated to the extension offices via formal letter, with a copy to the regional bureau of agriculture. The conditions included, provision of a room that was at least 30m^2, assignment of an AKC manager, and an agreement to continue paying the internet fee after two years. If these conditions were met, LIVES would provide ICT devices, link the AKC with broadband internet and pay internet costs for the first two years. A senior staff in the LIVES project explained; ‘Experiences from IPMS alerted us that to

institutionalize AKCs we must give more responsibility to the public extension offices from the beginning' (LIVES senior staff, national level)

To increase the accountability in meeting the conditions and collaborating the provision of AKC services, the LIVES management team requested written agreement from the district and zonal extension offices. They also requested an endorsement letter from the regional bureau that encouraged zonal and district offices to facilitate the establishment of AKCs and the provision of ICT-based services in their respective offices. The official agreement letter was a necessary actor that held three of the targeted offices, the zonal, the Teuledere district and the Kalu district offices, accountable. The fourth targeted office in Dessie Zuria district withdrew from establishing an AKC due to the lack of space, and they did not present a formal letter of agreement. However, after one year, the office head provided a room for an AKC and subsequently agreed to the LIVES conditions and set up the AKC. The zonal coordinator reflects,

> *At the beginning, office heads did not want to accept LIVES conditions. They said we do not know what LIVES want, what we know is that NGOs come, build and equip at their own cost. But I motivated them on the benefits they will get if they have knowledge resource centers in their offices and pressured them to allocate space for AKC and assign a center manager.*

Similarly, a district office head reflects;

> *The LIVES zonal coordinator explained about the AKC. We also received a letter from the regional bureau that stated we had to collaborate with the LIVES project and establish a knowledge center. We were happy to modernize our extension service by using ICTs. We wrote an agreement letter that stated our commitment to fulfill the conditions set and our willingness to cooperate with LIVES. We copied the regional bureau on the letter. (Office head in Teuledere district extension office)*

When the office head in Dessie Zuria district office could not be persuaded, the LIVES zonal coordinator started to persuade an office head in a neighboring extension office, the Dessie Urban Agriculture extension office. The persuasion was successful, and the office head presented the formal letter agreeing to the conditions and collaborated to establish an AKC.

The office heads in all of the sites were indispensable in deciding for AKC room allocation and appointing a manager who would expedite the use of computers, internet, and other services in the AKCs. An extension expert in Dessie Zuria district reflects; 'The deputy office head saw

that extension experts were using computers and the internet to support their service delivery in other offices. He regretted not accepting the LIVES conditions and requested LIVES to set up AKCs and gave his own office for AKC room.'

Non-human actors had an important role in the network. Rooms that were initially used as office spaces for the employees were appropriated to provide AKC services. Availability of the rooms prompted the LIVES project staff to deliver the ICT devices (computer, printer, TV/DVD, camera and projectors), which prompted AKC managers to maintain the devices and facilitate their use by extension experts. Also, the new broadband internet access motivated users to use the computers in the AKCs to read digital information and to communicate with experts in other organizations.

In summary, the key interessement strategies were: (i) create awareness on the importance of using ICT for accessing relevant agricultural information that supports the quality of extension service delivery, (ii) persuade the decision-makers through meetings, workshops and official agreement letters, to collaborate with LIVES to establish AKCs and (iii) facilitating access to broadband internet and covering the cost for the first two years after AKC establishment.

2.4.3 Enrollment

With the AKCs established and access to information and knowledge via ICT afforded, the interessement strategies appear to have been successful. A successful interessement strategy leads to the enrollment of diverse actors in the new actor network. The enrollment phase provided insight into the successful interactions between human and non-human actors and the inherent challenges.

The strategy for enrolling new actors, specifically users of the service, was to promote the newly established ICT services to improve access to relevant agricultural information, thus improving service to the farmers. The zonal coordinator explained:

> *The AKCs were one of the tangible interventions of the LIVES project. We promoted AKCs on every opportunity we had. We organized meetings and seminars with the extension office staff in the AKCs and promoted the potential of the ICT devices and resources for facilitating knowledge access. (LIVES zonal coordinator in South Wollo)*

Another office head explained:

> *We decided to convert the meeting hall to an AKC. The room was not in good condition, but we did not have other alternatives the first time. After one year, we had some spare funds to use for renovation of the AKC space. LIVES covered some costs of the renovation too. (Deputy office head in Teuledere district agriculture office)*

Equally, non-human actors, internet connectivity, job assignment process of AKC managers, and users' computing skill challenged actors' enrollment to the AKC actor network. Soon after the enrollment phase, the AKC managers realized that the computers' broadband internet connection did not provide the intended services. Without strong internet connectivity, extension experts had no interest in using the services in the AKCs. Therefore, the AKC managers started reducing the number of computers connected to the internet from four to two, or even sometimes to one. On the other hand, some experts had an interest in accessing the internet from their office regardless of the slow speed. To address these experts' interest, AKC managers in South Wollo zone office and Dessie Urban office extended the network cable to the experts' offices and allowed use in their respective offices when there was no one in the AKC room. An AKC manager at the zonal extension office reflected, 'When there are users here in the AKC, I disconnect the cable that distributes connection to the other offices. Of course, those experts in the offices complain when I do that.' AKC managers in the other extension offices made a similar attempt to address the experts' interest. However, the attempts failed because of the slow connectivity speed of the internet.

Users' capacity for computing skills is identified as an important precondition to benefit from the AKC services for accessing and sharing agricultural knowledge. According to an office head in one district, AKCs would have been used more if the LIVES staff had improved the extension experts' computing skills on the sites. The LIVES zonal coordinator shared similar views 'We in the project focused more on providing the ICT and furniture and expected things to go smooth. We needed to do more on planning, persuasion and capacity building. The way we did it is unsustainable.' Similarly, a former AKC manager in one of the offices thought that AKC managers lacked awareness of the AKC objectives and showed little commitment to training experts in using ICT.

Regarding the job assignment process, the respective office heads gave AKC management assignment to employees who were already full-time and who were perceived as having skills in using and managing ICT. The assignment was verbal, without any job description from the extension office or LIVES zonal coordinator.

> *When I agreed to manage the AKC, I had no written job description. However, I knew what to do. If you are a computer expert, you will know. But I was not clear with the purpose of the AKC. Later, I attended a training workshop organized by LIVES and there I got a clear understanding of the goal of the AKCs and the services to offer. (AKC manager in Teuledere district extension office)*

Office heads gave the AKC management responsibility verbally because of their limited power to create a new position that does not follow the civil service structure. Instead, the office heads convinced the selected AKC managers that their ICT knowledge was needed to improve the service delivery in the extension office. Though there was no discussion about continued benefits from managing and maintaining AKC services, the AKC managers expected rewards. When they got no rewards, they lost interest in managing the AKCs and shifted their focus to other activities. One AKC manager reflected;

> *I am a livestock expert. I got my limited computer skills through practice. I took the position with the anticipation that when our livestock department becomes autonomous, the AKC equipment comes with us. However, the plan to have a separate office is not working. Therefore, I do not want to continue being an AKC manager. The job is demanding for someone like me, who spends many days in the field. I have asked the office head to find someone to replace me. (AKC manager in Dessie urban agriculture office)*

Another AKC manager who agreed to take the responsibility because she expected individual incentives explained;

> *I took the responsibility of managing the AKC, because the office head told me that LIVES will give me some incentives like skills training and money. However, I only attended one training for three days. I am not interested in internet communication, and I do not have the skill to support others on internet use. I do not want the responsibility of managing the AKC. (AKC manager in Kalu district agriculture office)*

In summary, the internet connectivity speed translated the interaction of the ICT and the extension experts in how they used the services, and how the AKC managers interacted with the computers and the internet's speed in the AKC actor network. In addition, the limited authority of office heads to create job positions with meaningful remuneration reversed the enrollment of AKC managers into the network.

2.4.4 Mobilization

The mobilization phase provided insight into whether the actors' commitments to their newly identified roles were taken up and maintained after the focal actor left the network.

The termination of the internet connectivity fee by LIVES at the end of 2015 revealed the presence or absence of the actors' commitment to maintaining the AKC actor network. Four office heads, but not Kalu's, continued paying for internet fees from administrative reserves/or excess funds. However, no plan existed to include internet costs in their long-term budget. AKC service in Kalu stopped when payment from LIVES ended. The new office head in Kalu believed that the LIVES zonal coordinator should facilitate that the project pays the internet fees as long as the project runs.

The AKC in Teuledere served as a training space. When there was no training, it remained closed, because the manager had lost her fulltime job in the extension office. In the Zonal office and Dessie urban district, the AKCs provided internet services at the discretion of the AKC managers, but they had little time or motivation to support users. The AKC in the Dessie Zuria district, in addition to providing computer and internet services, served as an office space for two experts, due to office space shortage. However, the space shortage limited the number of computers available for use from four to two on a permanent basis. Table 2.4.2 summarizes the status of the AKC actor network in the five extension offices in South Wollo.

Table 2.4.2 Status of the AKC actor network in the five extension organizations at the time of field work

Status of the actors and their network	Kalu District	Teuledere	Dessie urban	Dessie zuria	South Wollo
AKC room	AKC room remains closed. ICTs are not used.	AKC room used mainly as a training space and on rare occasions provides ICT service	Used for providing internet service	Used for providing internet service. Also as an office space for two experts	Used for providing internet service and ICT use
AKC manager	- Does not open the AKC room - Does not want to support experts to use ICTs. - Task is additional without incentives	-No AKC manager. -Office head is searching for another person	- Opens the AKC regularly. - Has no time or interest to encourage experts to use ICTs, - Occasionally supports experts to find information online. - Task is additional without incentives	- Opens the AKC regularly - Encourages experts to use ICTs - Supports experts in solving technical problems. - Task is additional without incentives	- Opens the AKC regularly - Has no time to encourage experts to use the ICTs. - Supports experts in solving technical problems. - Task is part of the job description
Internet connection cost	The office head refused to pay the internet fee	Paid by the extension office. Office head approved.	Paid by the extension office. Office head approved.	Paid by the extension office. Office head approved.	Paid by the extension office. Office head approved.
Status of Actor network	The actor network collapsed	The actor network is unstable and reversible	The actor network is relatively stable but reversible.	The actor network is relatively stable but reversible	AKC actor network is stable but reversible.

2.5 Discussion

The fundamental principle underlying all science and technology studies is that action by one actor at the beginning is never enough to predict the path the action will take. Rather, the path depends on what successive actors do with the action (Latour, 1991). In the case of the AKCs, even though the LIVES project staff at the national level had set out a plan to meet the project objectives, the actual implementation and later outcomes were the results of negotiations and interactions among the various actors that joined the AKC actor network.

The results show that technology brought a new sociotechnical assemblage, the AKC actor network, in the agriculture extension. Heeks & Stanforth (2015) discuss that ANT was useful in opening the “black box” of technological process and allowed visibility to network associations, role of technology and translation process of actors interest identities. Similarly, studying the process allowed us to document the series of actors, events, and detours that took place to form the AKC actor network. This complex process started from problem definition to establishment to management of the AKCs in the agricultural extension offices. The strength of the will to provide ICT-based services became visible through the interests, identities, and actions of the actors that served at the different phases of the translation.

Latour (2005) noted the importance of a focal actor in the formation of an actor network. The LIVES zonal coordinator in South Wollo, a focal actor in this case, played a crucial role in transforming the existing network by persuading and enrolling other actors into the new AKC network. The network initiator enrolled ICT, particularly computers with internet connection, into the AKC network as a crucial non-human actor.

The involvement of the AKC managers played another important role in aligning the interest among actors to be able to form the network. However, the unfulfilled expectations of the AKC managers regarding the perceived incentives caused their subsequent detachment from the network. The study by Diaz Andrade and Urquhart (2010) reveals similar observations, where Telecenter managers took an active part in the initial process but left the network in a later stage. A recent development in the extension offices in South Wollo is the revision of the civil service structure, which now includes an incentivized position for an ICT expert, who would potentially join the AKC actor network and manage the services.

Our results showed how the establishment of the knowledge center shaped other actors’ engagement with ICT services and their interests and expectations. For ICT to be functional in facilitating faster communication and access to agricultural information, it is required that negotiations with different actors, than those in printed media need to be in place. This is because the nature of ICT differs from conventional extension tools such as manuals and books in their set of pre-conditions: (1) infrastructure such as electricity and connectivity need to be in place (2); those who use ICT require additional skills which includes operation of the tools and extracting the information required; and (3) ICTs require a person who manages the technological devices.

The role of hierarchy, authority, and structures in facilitating the AKC establishment process highlights the role of the contextual situations. Callon (1986) also argues that science

and technology would come to a halt if the existence of social classes and their interests are denied. For instance, the acknowledgment from the regional bureau played an instrumental role in establishing the AKC actor network. The authority of the office heads to provide a space to set up an AKC and approve a budget for connectivity fees influenced the formation and stability of the network.

Looking further, the role of power in the translation phases becomes visible, where a donor-funded project influenced the regional bureau, a public institution, to demand that other public institutions to follow through. Stanforth (2007) also contends that application of ICT projects is an inherently political process that needs continuous improvisation to address the ongoing issues, and therefore recommends the analysis of global and local networks.

Just as Diaz Andrade and Urquhart (2010) described in their analysis of users' engagement in ICT use, extension experts in South Wollo had a passive role in the establishment of the AKCs. This could have been due to their inexperience in using AKC services and their resulting lack of interest in participating. In this sense, and building on Heeks and Stanforth (2015), analyzing the network formation in ICT projects provides insights for those involved in a technological change processes. For instance, decision-makers should consider themselves as the network managers and facilitators of negotiations and interests, and technology designers or implementers should consider the users' skills and interests.

We carried out this explorative study in a specific context with a relatively small sample size, and therefore the results do not offer conclusive evidence on technology adoption in Ethiopian agriculture extension offices. However, the iterative process of data collection and triangulation increased the internal validity. A detailed interpretation of the results offered a clear view of the complexity of interactions and associations of people and technology and highlighted how society and technology shape each other.

2.6 Conclusion

This case study showed the interactions and relationships of more and less visible actors in the context of public agricultural extension offices that established and managed an ICT-based initiative for improving extension services. The ANT approach allowed us to document the contribution of heterogeneous human and non-human actors into these initiatives. The translation phases revealed main issues, including the importance of defining and strategizing for suitable ICT-based initiatives through negotiation with actors, the importance of a committed actor who facilitates interactions and negotiations, the alignment of interests among actors, the actors' ability

to execute their roles actively. We have also seen which contextual situations were favorable for creating and stabilizing new ICT-based actor networks that were intended to provide access to information and knowledge for improving agriculture extension services.

The results of this study, though specific to one context, contribute to the practical and policy-related debates on finding viable strategies for introducing ICT in the agriculture sector to bring social and economic growth in developing countries like Ethiopia. The findings highlight the need to take a sociotechnical perspective while introducing technological interventions and the importance of creating alliances with actors and their various interests to ensure sustainability after donor funding ceases. Also, the findings imply that establishing ICT based services for agricultural extension in a similar context calls for the alignment of the interests of the various actors involved. Moreover, this paper contributes to the theoretical discussion on understanding the adoption of innovations from an ANT perspective which allows for a richer account of human and non-human actors' interaction in technology adoption.

Although this study presents insights into the interaction of various actors in the development of an ICT based service, there are some limitations to acknowledge. One limitation relates to the emphasis given mainly to the local actor network in South Wollo. Future studies could investigate in-depth the interaction of the local network with the global network such as the Ministry of Agriculture and the Project coordination office at the national level. Such investigation can provide richer account on the formation of the AKC actor network and its sustainability after the project ceases. The second limitation of this study is its focus on just one study site. A further study that investigates the establishment of ICT based services in extension organizations at a national level in Ethiopia could provide further insights. In general, the results in this paper can be a stepping-stone for future studies, in Ethiopia and other countries with similar context, that use ANT concepts as a framework for analyzing the adoption of technological innovations that are based on ICT.

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3 Perceptions towards information communication technologies and their use in agricultural extension: Case study from South Wollo, Ethiopia

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Abstract

Purpose: This study examines how agricultural extension experts use Information Communication Technologies (ICTs) in extension organizations and how they perceive their usefulness for agriculture extension delivery in Ethiopia.

Design/Methodology/approach: An exploratory case study was conducted on 'Agricultural Knowledge Centers' (AKCs) in four offices of agriculture in South Wollo zone, Ethiopia. AKCs are access points for online and offline information sources. Data were collected using in-depth interviews, and a structured questionnaire, which we analyzed using descriptive statistics and the three concepts of the Theory of Planned Behavior: attitude, social norms, and perceived behavioral control.

Findings: In the study site, young male extension experts with university education predominantly used ICTs. Extension experts had a favorable attitude towards the usefulness of ICTs for personal benefits. However, they saw little use of ICTs for searching agricultural information because they thought the printed agricultural knowledge resources at their offices are sufficient for their needs. The main factors that contributed to experts' use of ICTs are, the existing extension approach, the opinion of supervisors and the internet speed.

Practical implications: While access to ICTs is a prerequisite, there is no guarantee that they will be used professionally to improve services. Users' perceived needs, skills and knowledge, and the organizational environment which encourages use should be considered when introducing ICTs.

Theoretical implication: This paper contributes to the theoretical debate on the importance of users' perception of technologies like ICTs to achieve their full potential in agricultural extension.

Originality/Value: This paper connects empirical findings on use of ICTs in agricultural extension with the literature on the contribution of behavioral factors when using technology.

Keywords: Agricultural extension, Information Communication Technologies, Information, Technology usefulness, Perception, Ethiopia

Paper type: Research paper

Chapter 3

3.1 Introduction

As a strategy to transform subsistence agriculture to a market-led one, the Ethiopian Government follows a development model that is based on training and skill transfer, technology transfer and capacity building at the different levels of the agriculture sector (MoANR 2017). Consequently, lessons learned from developing countries about the potentials of Information Communication Technologies (ICTs) in agriculture coupled with the expansion of information technology infrastructure in Ethiopia, led the government to embark on provision of access to ICTs in the agriculture sector (Lixi and Dahan 2014). Accordingly, initiatives that involved both traditional and modern ICTs have flourished to provide agricultural information to farmers and agricultural extension experts at local extension offices (Asenso-Okyere and Mekonnen 2012; Shiferaw et al. 2013).

Some examples of ICT-based initiatives that were already piloted include, (i) piloting of radio and videos by Farm Radio International (Derso and Ejiro 2015) and Digital Green (Gandhi 2017) respectively, to disseminate agricultural information to farmers and extension professionals, (ii) the piloting and promoting of a mobile phone based service where practical advice on agronomic practices of selected crops are shared free of charge (ATA 2017); and (iii) the piloting of ICT access points called Agricultural Knowledge Centers (AKCs) by the International Livestock Research Institute (ILRI) In Ethiopia. The AKCs aimed to give access to online and offline information sources and were intended for extension experts working in selected agricultural extension offices (ILRI 2011).

In spite of the flourishing ICT-based initiatives in Ethiopia and the emphasis that governmental and non-governmental organizations gave, actual utilization of ICTs in the agricultural extension offices is reported poor (Lemma et al. 2016; MoANR 2017). ILRI is interested in learning from the outcomes of use of ICTs in the AKCs in extension offices to make suggestions for scaling out such services. Furthermore, it is in the interest of the Ethiopian public extension to have evidence concerning the use of ICTs in order to improve their utilization in the extension service and ultimately leverage ICTs potential in facilitating the country's development (National Plan Commission 2016; ATA 2017).

Studies that looked into the use of ICTs in developing countries have identified factors that contribute to their utilization. These include demographic characteristics (Strong et al. 2014; Kale, Meena, and Rohilla 2016), organizational factors (Gollakota, Pick and Sathyapriya 2012), and

contextual factors (Chapman and Slaymaker 2002; Dulle and Alphonce 2016; Galloway and Mochrie 2005; Rao 2007; Verdegem and De Marez 2011; Sulaiman et al. 2012). However, few studies looked at factors dealing with motivation, attitude, and perception (Meijer et al. 2015). Along the same line, Saravanan (2010) and Verdegem and De Marez (2011) stressed the importance of understanding users' attitude and perception about the usefulness of a technology to maximize the effectiveness of ICTs in different contexts. Therefore, we conducted this study to provide an empirical evidence on the role that perceptions and attitudes play in the use of ICTs. This case study focuses on the use of ICTs in Agricultural Knowledge Centers (AKCs) in agricultural extension offices in South Wollo zone, Ethiopia. We looked at both the pattern of ICT use in the agricultural extension offices and the perceptions held by the extension experts towards the usefulness of ICTs for extension service, and what fosters or constrains their use. The evidence of this study provides insights into the importance of users' perception of ICTs' usefulness and their surrounding environment for enhanced utilization. In addition, the implications of proper communication between technology suppliers and users for successful implementation of ICT initiatives are highlighted.

3.1.1 Introduction of AKCs in Ethiopian agricultural extension system

In 2003, Ethiopia's Government initiated an e-development program, a Wide Area Network called 'WoredaNet' to bridge the urban-rural digital divide. The WoredaNet connected about 600 district administrative units with regional and federal government offices. The purpose of the program was to distribute and implement different government reform and development packages on public administration via ICTs in an effective and efficient way. The long-term objective of the program was to provide accurate and timely information to all levels of government offices and citizens (Negash and Lessa 2011). Main services in the WoredaNet were email, internet browsing, file-sharing, and video conferencing (ibid).

With the objective of extending the e-government strategy to the agriculture sector, two consecutive research for development projects of ILRI-Ethiopia piloted AKCs as access points for ICTs in agriculture extension offices. The first project '*Improving Productivity and Market Success of Ethiopian Farmers*' (IPMS) (2004-2012) piloted 28 AKCs and its successor *'Livestock and Irrigation Value Chains for Ethiopian Smallholders'* (LIVES) piloted 42 AKCs in offices of agriculture. The AKCs were based on the rural telecentre model for farmers from countries such India (Best and Kumar 2008; Pick, Gollakota, and Singh 2014), Latin America (Salvador, Sherry, and Urrutia 2005), South Africa (Braathen, Attwood, and May 2012) and Tanzania (Lwoga 2010).

However, in contrast to the aforementioned examples, the facilities were targeted for agricultural extension experts in Ethiopia instead of farmers. The two projects focused on the provision of ICT services for extension experts in zonal and district offices which support development agents at *Kebelle* (lowest administrative level) as well as farmers at village level.

The IPMS and LIVES projects focused on promoting a market-orientated agricultural development approach through (i) the introduction of improved technologies, (ii) developing the capacity of research and extension personnel in knowledge generation and dissemination, as well as (iii) piloting innovative knowledge sharing approaches such as AKCs. Together, these activities followed the overall aim to offer relevant and up to date didactic knowledge to agricultural extension experts and improve the effectiveness of extension services. Services planned in the AKCs were, provision of printed reference materials, documentary videos, space for discussion, internet services and word processing (ILRI 2011; ILRI 2013). Prior to the AKCs establishment, the extension offices offered neither access to internet-based agricultural information nor common space for acquiring other forms of agricultural knowledge resources.

The assessment on the status of AKCs in Amhara region prior to site selection for the study revealed that South Wollo is the site with multiple functional AKCs (four out of five) three years after their establishment. The other project sites in Amhara region had fewer functional AKCs due to administrative challenges.

3.2 Conceptual approach

Theoretical and empirical literature show that many factors contribute to the use of ICTs in agricultural extension. Based on existing literature, we have identified factors contributing to use of ICTs and grouped them into three categories: individual, organizational, and contextual factors (Figure 3.2.1).

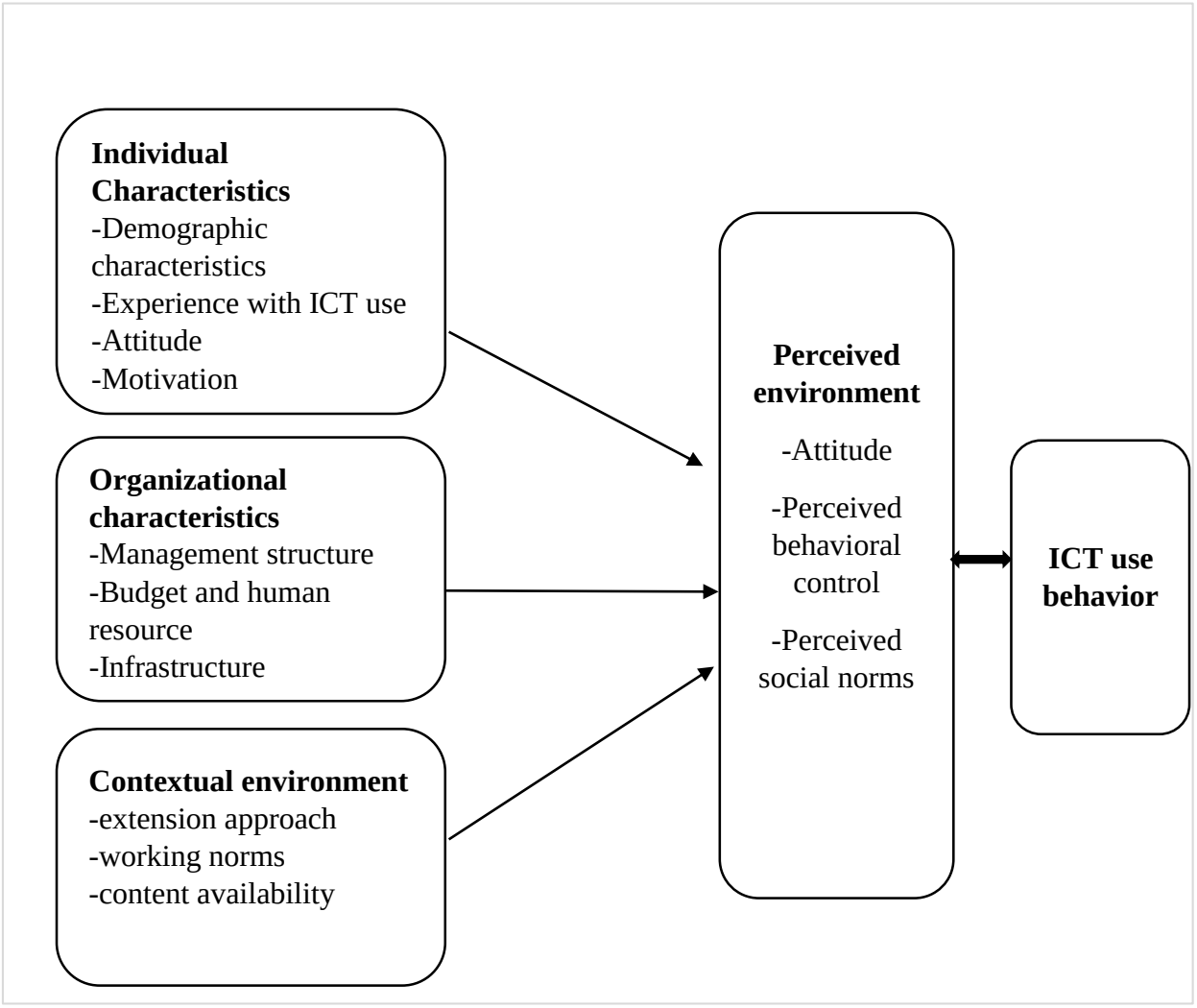

Figure 3.2.1: The three main categories of factors that contribute to perceptions of ICT use

Regarding individual factors, demographic characteristics such as skill, age, and education influence the use of ICTs (Strong et al. 2014; Kale, Meena, and Rohilla 2016). In addition, importance of an individual's motivation, attitude towards the benefits of using ICT for extension work (Strong et al. 2014) as well as the perceived beliefs of the community in which such services

are provided (Del Aguila Obra, Cámara, and Meléndez 2002) have been identified as having an impact. Verdegem and De Marez (2011) stressed the importance of a thorough understanding of users' attitude and preference towards ICTs prior to implementation of ICT programs to increase the success and impact of such programs. Similarly, findings from Saravanan (2010) show the importance of focusing on those who use the technologies and the context in which they work to increase the success of ICT use.

Organizational characteristics such as human resource management and budget allocation (Franz 1991, as cited by Zamani-Miandashti, Pezeshki-Rad and Pariab 2013) and (Gollakota, Pick and Sathyapriya 2012), availability of communication network and consistent electric power (Chavula 2014) influence an organization from reaping the full potential of ICTs. Furthermore, contextual factors such as the extension policy and availability of relevant information that stimulates the demand for knowledge plays a role on the success of ICT use (Chapman and Slaymaker 2002; Parkinson 2005; Galloway and Mochrie 2005; Rao 2007;Verdegem and De Marez 2011, Sulaiman et al. 2012).

As elaborated above, many factors contribute to the use of ICTs. However, Lewin (1951, as cited in Hoffmann et al. 2009), states that it is not the totality of the factors, but only those that are perceived by the individual that influence his/her behavior, in other words the subjective perspective. Hoffman et al. (2009) contend that an individual forms a perception about an environment or circumstances based on current information about the environment, previous knowledge or experience and anticipation of the future. Factors such as experiences, values, needs, and norms give shape to the perception of humans in the appropriateness of the technology to reach targets or expectations. Meijer et al. (2015) argue that even though scholars agree that intrinsic factors play a key role in the uptake of innovations there are still fewer empirical studies investigating these factors, particularly in the context of agriculture extension experts..

Concepts that aim at understanding a behavior or intentions to perform a certain behavior take an individual's perception as an important component. Theory of the psychological field as explained by Lewin (1951, as cited in Hoffmann et al. 2009) states that behavior is a function of the interaction of the individual and his/her perceived environment. The theory describes that the psychological environment influences the behavior of an individual more than the physical environment. Ajzen's (1991) Theory of Planned Behavior (TPB) offers a framework to predict human behavior and explain the antecedents of attitude, subjective norms and perceived behavioral control which in the end determine intentions and actions. According to this theory,

attitude describes the favorable or unfavorable personal evaluation of a behavior (e.g. extension expert's positive or negative attitude towards usefulness and compatibility of ICTs in AKCs). Social norm describes the individual's perceived social acceptance to engage in a behavior (e.g. extension expert's perception about the opinion of their supervisor and colleagues when they use ICTs in AKCs). Perceived behavioral control describes the perceived control of facilitating and constraining factors to perform a behavior (e.g. experts' perception about factors that facilitate, or hinder ICT use in AKCs). Although TPB is predominantly used for quantitative studies, the three concepts can provide a valuable structure in a qualitative study for exploring the underlying reasons of a behavior or an intention, including experiences and attitude in a richer and deeper level (Kapasiand Galloway 2014).

3.3 Methodology

3.3.1 Study design

The overall research approach relies on a case study methodology which focuses on a contemporary phenomenon in a real life situation where the boundary between the context and the phenomenon is not clear (Stake 1995). We selected this methodology as it provides a basis to understand the uniqueness and complexity of a case through interviews, which help in providing key insights into human affairs, behavioral events, and social issues (Yin 2009). The method also prioritizes the views and perspectives of study participants to understand the real-world events. We combined qualitative and quantitative data collection in a mixed methods approach (Creswell 2013) to allow for a comprehensive analysis of the research problem. The works of Whyte (2000) and Best and Kumar (2008) were used to shape the qualitative inquiries, while those of Heeks and Molla (2008) and Pick et al. (2014) were instructive for designing the quantitative interviews about the status of ICT use and perceptions.

To analyze the data, we followed Braun and Clarke's (2006) 'theory-driven' strategy that bases on the literature reviewed for identifying codes and theme. We used Atlas.ti software to identify codes and categorize the qualitative data and direct quotations to illustrate the main themes. We computed descriptive statistics from the quantitative data using SPSS software.

3.3.2 Site selection

The first author carried out the field data collection in Ethiopia between July and November 2016. The study started with assessing the status of all AKCs that the LIVES project established in three

zones of the Amhara region. After project document reviews and discussion with project staff, we made telephone interviews with 10 employees who were responsible for the AKCs in each of the sites and with three LIVES project field staff. Main assessment questions were, status of AKCs (operational or closed), financial source for internet fee (LIVES or extension office), presence or absence of AKC manager, average number of users per day, type of services available in the AKC, opening and closing time, and general profile of the users. Since the objective of the study was to explore the pattern of use and the perception about and the use of ICTs, we selected a study site with multiple functional AKCs for the case study in order to get information based on current perceptions rather than memory of past operations and use. Accordingly, we selected four extension organizations: South Wollo zonal office, Teuledere district office, Dessie Urban office, and Dessie Zuria district office

3.3.3 Data collection

We started data collection by asking key informants open questions to get general information on services offered, management of AKCs and profile of the users. Key informants were: Four AKC managers, four LIVES project focal persons in the respective offices and one LIVES project coordinator at the site. Then, based on review of key informants' results, project documents, and literature, we developed an interview guide with semi-structured interview questions for extension experts who use ICTs. The interview questions sought to understand users' experience and opinion about the usefulness of the ICT services in the AKCs as well as the factors that facilitate or constrain use. A panel of experts in extension methods reviewed the interview questions for relevance, adequacy, and clarity.

Users' registers kept by the AKC managers were instrumental for targeting our respondents. From 90 registered users in the four AKCs, we asked the AKC managers to identify those experts who use the services frequently and consistently. Accordingly, five to six experts in each office were interviewed in-depth. After pre-analysis of the results from the in-depth interviews and through the use of literature, we prepared a survey questionnaire that aimed at quantifying how often experts use ICTs, level of experts' satisfaction to the type of services available, level of agreement with the usefulness of ICTs for extension delivery, and their level of agreement with enabling and constraining factors for use. Prior to the administration of the survey, the questionnaire was reviewed by a panel of experts for clarity and relevance and pilot tested on five extension experts in the study site for flow, clarity, and comprehension. From the 90 AKC users on the list, we selected only those who used ICTs in the AKCs at the time of data collection. In

total 72 out of 90 users, including those from the in-depth interviews, participated in the survey (Table 3.3.1).

Table 3.3.1 Respondents role and data collection methods

Respondents role	Number of respondents		
	Telephone interviews	Face to face interviews	Survey
AKC managers	10	4[a]	-
Agricultural Extension Experts	-	22[b]	56
Supervisors of Extension Experts	-	8[b]	12
Administrative staff in extension offices	-	-	4
LIVES project staff	3	2	-
Total	**13**	**36**	**72**

[a] Interviewees also took part in the telephone interview

[b] Interviewees also filled the survey questionnaire

3.3.4 Data analysis

The qualitative data were recorded via digital voice recorder and notebooks, and later transcribed verbatim using a computer. We started the analysis with open coding that aimed at identifying concepts to compare relations, communalities and differences in the data. Once the coding was finalized, we checked for overlaps or similar contents and made decisions to keep them separate or put them together. Afterwards, we developed categories or themes following the three concepts of TPB to interpret the results. We analyzed the quantitative data by computing frequencies and percentages to describe the demographic characteristics, the preferred ICT services, and the frequency of use. We used percentages to describe respondents' level of agreement towards usefulness of ICTs and their assessments of external factors that influence their use of ICTs.

3.3.5 Scope of the study

The scope of this study is limited to the opinion of extension experts who used ICTs in the AKCs and their supervisors in the study sites and does not include that of farmers at village level or extension personnel at regional or *Kebelle* levels. The study does not compare and contrast results among sites and neither evaluates the demonstrated behavior against the perception nor

predicts the intention to perform a behavior. The study explores the attitudes and perceptions of extension experts towards the use of ICTs in the extension offices.

3.4 Results

3.4.1 Status of ICT use in the AKCs

About two-thirds of the employees in each of the extension offices use services in AKCs at various levels. Table 3.4.1 shows the number of AKC users versus the total number of employees in each office. Dessie Urban had a relatively higher number of ICT users in AKCs because the organization was under reform and experts were not required to go to the field and did not have other responsibilities.

Table 3.4.1: Number of respondents in contrast to the total number of staff in the extension offices of the study sites

Extension office	No. respondents (interview + survey)	Total number of staff in the offices
Zonal office	19	64
Teuledere district	18	60
Dessie Urban	21	33
Dessie Zuria district	18	61
Total	76	218

According to the center managers, almost all experts in the extension offices visited AKCs around the time of establishment as they were curious about the services. However, the number of visitors decreased to 10-15 users per month by 2016. The demographic characteristics of those who used ICTs in 2016 (Table 3.4.2) shows dominance of young, male extension experts with a university degree and less than five years work experience in the office. While some respondents learned to use the computer and internet after the establishment of the AKCs, many reported prior familiarity from their studies at the university.

Table 3.4.2 Individual demographic characteristics of respondents (n=72)

Demographic Character	Users		
		Number	**%**
Gender	Male	60	83.3
	Female	12	16.7
Job position	Expert	56	77.8
	Supervisors	12	16.7
	Support staff	4	5.6
Education level	Diploma (Certificate)	7	9.7
	University Degree	65	90.3
Age (years)	<30	31	43.1
	30-40	27	37.5
	> 40	13	18.1
Job experience in extension organization (years)	<5	43	59.7
	5 -15	22	30.6
	>15	7	9.7

Of the total respondents (n=72), frequency of visits to the AKC are, two to three times in a month for 40%, eight to twelve times in a month for 36% every day for 9% reported and once or less in a month for 15% once or less in a month and 68% have an active personal email account. Internet services experts regularly used are; browse for personal information, check social media sites for entertainment or current affairs, and exchanging emails with colleagues and friends (Figure 3.4.1). Experts use Microsoft Office applications only occasionally when computers in their department or at the secretary office do not work.

For the respondents, national websites on job vacancies are more popular than webpages on agricultural information. One AKC manager validated this claim by recounting a time when the number of users increased abruptly after an expert applied online for a job in Addis Ababa and got it. Some supervisors reported using email service in the AKCs for sending reports or receiving reporting formats from regional offices after regional experts requested to communicate via email.

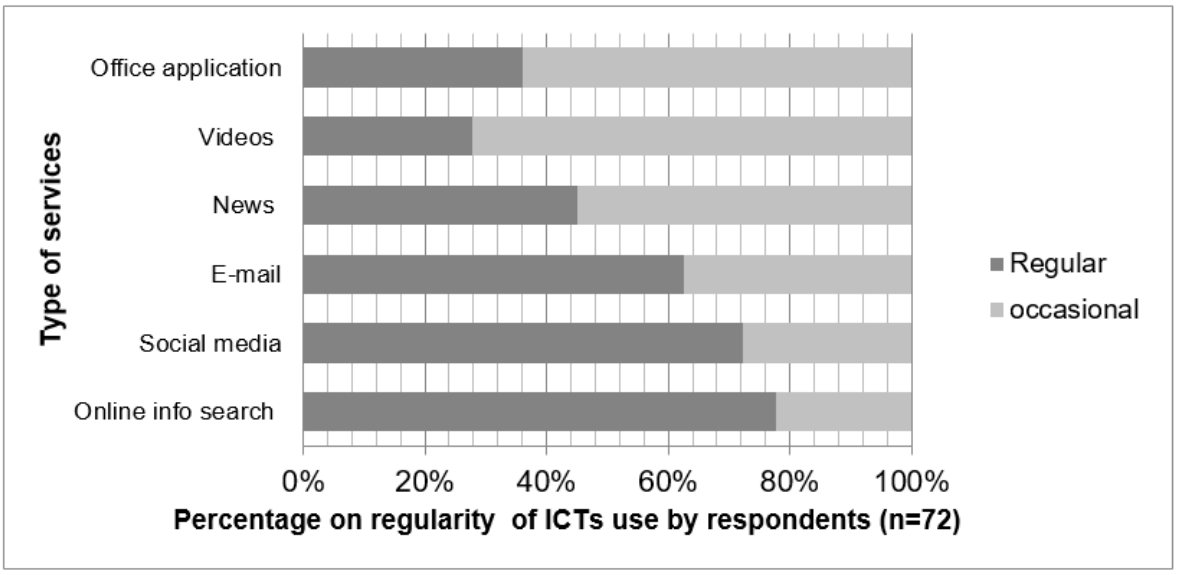

Figure 3.4.1: Type and frequency of ICTs use in the AKCs

Of the total (n=72) respondents (41%) spend one hour, (39%) spend maximum of 30 minutes, and (20%) spend more than one hour per visit to use ICTs in the AKCs. Experts preferred to visit AKC during their free time: lunch or coffee breaks or after working hours not to disturb their working time. While the time frame suited well the male experts, female experts preferred to go to their families during their free time and they asked their male colleagues to share new information they saw on the internet.

The results above show that the enthusiasm about using ICTs faded over time and the services used reduced to communication and information search for personal purposes. Half of the respondents reported using ICT services for entertainment, to follow up on current affairs, for job search and to network on social media sites in their free times. Many experts use ICTs in the AKCs for about an hour and prefer to visit AKCs during their free time.

3.4.2 Users' attitude and perception

Attitude. We identified respondents´ attitude on the usefulness of ICTs in the AKCs by assessing their subjective agreement to eight statements (Figure 3.4.2). Experts perceived six out of eight ICT services in the AKCs as useful. The services highly rated are email communication with regional offices and browsing information sources that are unrelated to agricultural extension. In contrast, ICTs' usefulness for improving knowledge in the area of specialization was rated the lowest. Experts perceived that existing manuals and guidelines in their offices satisfy their

professional needs and therefore do not see the need to browse the internet for more agricultural information. However, some claimed to browse the internet for professional information through generic pages such as Google, YouTube, and Facebook. On the contrary, they identified specific webpages for news and job vacancy announcements. Respondents thought that many of their colleagues are not using ICTs for professional purpose because they do not know how or what to search for. '*When I go to the AKC, all I see is experts using Facebook on the computers. We need to create awareness to use the services for professional purpose, too*' explained one expert.

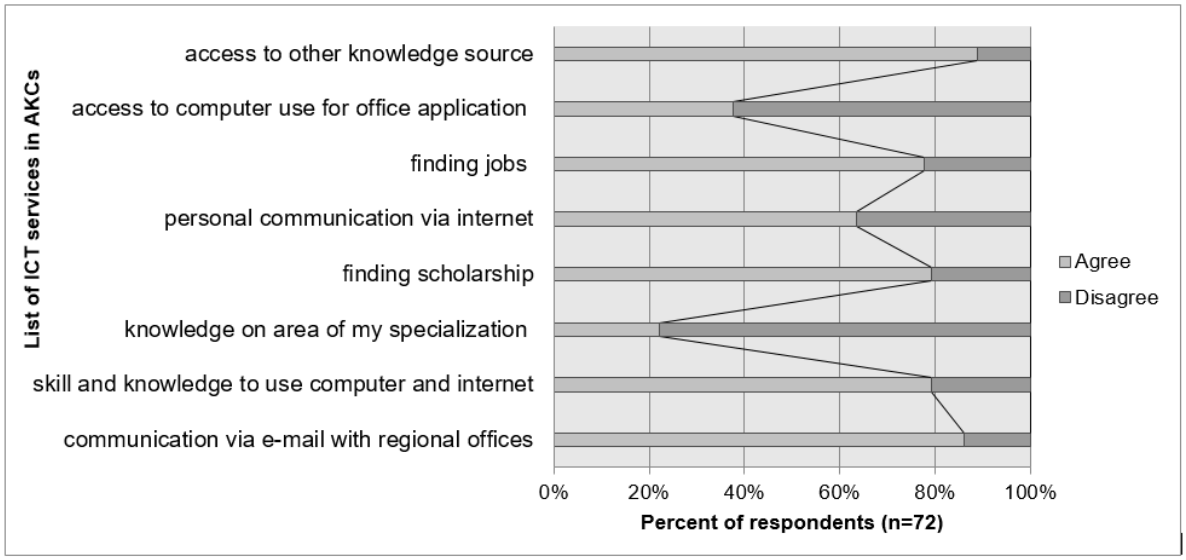

Figure 3.4.2: Perceptions of users on the usefulness of ICTs in the AKCs

The above results show that experts' lack of experience in using internet services for professional information search coupled with their belief on the sufficiency of knowledge resources in their offices influenced their attitude towards usefulness of ICTs for searching extension information.

Social norms. While experts who visit the AKCs regularly are perceived by their colleagues as being skillful and knowledgeable in gaining new and useful information from the internet, their supervisors regard ICT use as entertainment or a time-wasting activity. From twelve supervisors interviewed, four encouraged their staff to use ICTs in the AKCs while eight discouraged. One supervisor was concerned that the job would suffer if his staff visit AKCs regularly, and seven thought that experts should use ICTs during their free time. As a solution, the male experts maneuvered their time of use during breaks and after working hours, while the female experts reduced or stopped their visits. Experts thought that many supervisors are not aware of the

services offered in the AKCs or they do not care. Additionally, experts explained that the extension approach followed in their offices discourage use of ICTs to seek professional information. One expert shared her opinion '*Searching information from the internet for our work is not rewarding, as we cannot use it to advice farmers. We must follow the check list that comes from the regional office' and we must write reports according to the formats given'*.

The results above show the perception of the users on the social norms, which is influenced by a top down extension approch that does not encourage the use of ICTs for professional purpose .The unfavorable opinion of supervisors on the usefulness of ICTs contributes to experts perception on usefulness of ICTs for professional purpose. In contrast, the use of ICTs for personal purposes is accepted among peers.

Perceived behavioral controls. The respondents appreciated the vicinity of AKCs in their offices however, their use is irregular due to frequent visits to the field followed by report compilation. Experts pointed out administrative gaps in the AKCs prevent them from using the services. 'We do not know clearly the purpose of the center, how it relates to our job delivery, or if the management is committed and what regulations are there to use the services.' explained one expert. Other gaps identified were absence of recognition and incentives for AKC managers for supporting experts to use services in the AKCs, limited administrative support for AKC costs. An expert reflected,

> *The former AKC manager was enthusiastic about ICT use. He gave us training on how to use the internet, open email accounts. He shared with us different knowledge resources on a weekly session to encourage us to use ICTs in the AKC. However, the new manager is not motivated, and he does not support us when we ask for help.*

Internet connectivity and speed as well as electric surge are identifed as constraining factors to use ICTs. '*There are times that we stayed in the ICT center for hours because the internet got interrupted and the speed was very slow,*' an expert explained. To solve this constraint, AKC managers connect only one or two computers to the internet, instead of four. The reduced number of computers, however, discouraged others from visiting AKCs. For instance, a respondent stated that waiting for a free computer in the AKC is frustrating and therefore he prefers to pay extra, even though it's expensive, for a mobile internet from his personal mobile phone or goes to a café to use Wi-Fi service.

3.5 Discussion

Education level of extension experts was identified as a contributing factor for the use of ICTs also by Strong et al. (2014) and Tata and Mcnamara (2016). The exposure to ICTs in higher education institutes obviously played a role in contributing to the interest of experts to continue using ICTs in their jobs. However, in a context where access to ICT service is sporadic (Lixi and Dahan 2014) experts are discouraged from developing the habit of using ICTs beyond personal benefits.

In a world where dissemination of topical agricultural knowledge is a central concern (Sulaiman et al. 2012), ICTs offer a potential to increase transfer and use of knowledge. However, ICTs potential becomes limited unless their use is matched to the needs, perceptions and expectations of the those who will use them, and the environment in which they are put to use (Heeks 2002). The results of this study show that the potential of ICTs to offer agricultural information in the extension offices became futile as the experts perceived ICTs not to be useful for their job delivery as such. Instead, as Strong et al. (2014) also showed, personal communication needs outweighed professional knowledge search. Similarly, Sulaiman et al. (2012) stated that so far ICTs contributed to traditional communication tasks and not to facilitate networking, knowledge brokering and learning oriented monitoring. The underlying reason for the minimal use and unfavorable perception of ICTs' usefulness for professional purposes, as also explained by Hoffmann et al. (2009), could be experts' previous experiences and knowledge that formed their perception. The case of the AKCs in South Wollo zone showed a gap between the extension experts' felt needs and perceptions regarding ICTs and decision makers' understanding of experts need and perceptions.

Social networks, observed convenience, and the opinions of the management contribute to the formation of perceptions on ICTs usefulness (Gollakota et al. 2012 and Pick et al. 2014). In South Wollo, the perceived social support from colleagues and AKC managers, the opinion of supervisors as well as the norm of extension delivery played a role for the attitude of experts towards the usefulness of ICTs for extension delivery.

Spielman et al. (2010) and Cohen and Lemma (2011) discuss that to bring a reform to the current norm of extension delivery in Ethiopia, a system that supports a more dynamic and responsive service delivery needs to be in place. This system could be one that supports greater flexibility of experts' response to farmers' needs and thus, requires self-initiated knowledge-

seeking behavior among extension experts. Nurturing knowledge-seeking behavior needs transformation or adjustment of both the existing norms and rigid structures of extension delivery and experts' attitudes. An extension approach that supports knowledge-seeking behavior by providing incentives such as knowledge related performance indicators for evaluations can motivate experts to be more proactive in using ICTs (Yaduraju et al. 2015; Lemma et al. 2016) along with good infrastructure and administrative support (Dulle and Alphonce 2016). In addition, it is imperative that supervisors have a clear understanding and positive opinion about ICTs' potential in improving the knowledge of extension staff and therefore encourage experts to pro-actively seek information (Ballantyne 2009; Lwoga 2010).

Neighboring African countries like Kenya, Uganda and Tanzania have experiences in involving the public and private extension companies to encourage extension experts to use ICTs for sharing agricultural knowledge and information (Asenso-Okyere and Mekonnen 2012). Such strategies may facilitate improving perception of ICTs usefulness for the extension services.

Our findings confirm that access alone does not guarantee successful use of ICTs for the intended purposes (Sulaiman et al. 2012 and Materia, Giarè, and Klerkx 2015). We observe that LIVES plan to initiate a new behavior of seeking agricultural information via ICTs was realized differently. Extension experts developed a behavior of using ICTs for communication and personal knowledge search in the extension offices. As Klerkx and Leeuwis (2008) discussed, narrowing the gap between suppliers and users of technology through demand articulation, and building on the existing system of knowledge access in a participatory manner (Sulaiman et al. 2012) can support the realization of the intended behavior of ICT use.

Our findings prompt one to be aware of the preconditions for establishing ICT access points and for instilling self-initiated knowledge acquisition in public extension offices. Our results also reinforce the need to study intrinsic factors such as attitudes and perceptions of targeted users towards ICT innovations and their usefulness to increase and sustain their utilization. The three concepts of TPB were useful to organize and discuss the empirical findings on the extension experts' attitude and perceptions that contributed to their current use of ICTs in South Wollo zone. The concepts helped to investigate the underlying reasons behind the demonstrated attitudes and perceptions on the use of ICTs in public extension offices where transfer of technology is a common approach (Berhanu and Poulton 2014).

3.6 Conclusion

This exploratory case study reveals the situation of ICT use and perception of extension experts towards its usefulness as well as contributing factors to use the services in four extension offices of South Wollo zone. An internationally funded project introduced AKCs, as ICT access points, to agricultural knowledge and information sources with the objective of increasing experts' knowledge and improving effectiveness of extension services in Ethiopia. However, currently the AKCs are predominantly being used for personal communication and knowledge search. The attitude of users about the usefulness of ICTs for extension service delivery coupled with the established norm of extension service delivery and controlling factors in the offices influenced use of ICTs.

To harness the potential of ICTs in agricultural extension, it is indispensable that both experts and supervisors have matching attitude about the usefulness of ICTs for improving agricultural extension. In addition, supporting organizational structures, technical and infrastructural issues need to be in place. Neglecting these aspects undermines the benefits of ICTs for extension delivery and encourages diversion from the intended goal. The theoretical implication of this study, and as an addition to previous studies, is that attitudes about usefulness of ICTs as well as perceptions of norms and controlling factors contribute to the behavior of ICT use in public extension offices. We recommend further investigations on the social/psychological aspects of using ICTs, type of information users need and their availability in digital form to leverage the potential of ICTs in delivering agriculture extension. A practical implication of this study is that it is crucial to design ICT services in extension offices in a participatory way to articulate the needs and expectations, discuss the relevance and the presence of organizational environment which encourages them to benefit from ICTs' potential.

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4 What organizational characteristics contribute to ICT use in agriculture extension organizations? A literature review

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Abstract

This article presents a systematic literature review that analyzes agriculture extension organizations' characteristics that contribute to Information and Communication Technology (ICT) use for agriculture extension services. Results from the 49 articles reviewed highlight that the empirical evidence focuses on individuals' characteristics. The organizational characteristics related to the facilitation of training opportunities on ICT use and availability of systems to capture learning such as technology infrastructure, budget and incentives were prominent, while the contribution of collaboration, leadership style and empowerment towards forming a common vision for improving service delivery by introducing ICTs were underemphasized. We recommend future research on organizational learning processes and the merits of ICT in facilitating peer to peer learning for improved agriculture advisory services.

Keywords: Agriculture extension; ICT; learning organization; organizational characteristics; organizational learning

4.1 Introduction

Societal, and technological transformations in agriculture are making the sector more data-driven, information-rich, and knowledge-intensive (GFAR, 2018). Hence, the delivery of agriculture extension services is continuously adapting to changing conditions. To cope with the change, both individuals and their organizations in agriculture extension need to continuously learn and become adaptive and creative in their environment (Leeuwis & van den Ban, 2004). Factors that drive change in agriculture extension include globalization, changing role of the state, focus on decentralization, the influence of new institutional economics in development, and the emergence of Information Communication Technologies (ICT) (Haug, 1999).

Utilizing ICTs in agriculture can offer a range of opportunities, including cuts in production and transaction costs; raising production efficiencies and farm incomes; providing more information, choice and value to stakeholders; and stimulating innovations for more sustainable food production, while preserving the natural resources and biodiversity (CTA, 2019; Rao, 2007). However, unless organizations create facilitative structures to support and capture learning at different levels (individual, team, and organizational) (Marsick & Watkins, 2003), introducing ICT devices alone is insufficient to bring the anticipated improved performance. Harnessing the potential of ICT in development, therefore, calls for agriculture organizations to adapt or create new organizational cultures (Sulaiman et al., 2012; Yadav et al., 2015).

Evidence on change processes that explain how extension organizations integrate the use of ICT in their extension work is scarce, presumably because much focus goes to the adoption rates and impact of ICT (Andoh-Baidoo, 2016). Knowledge of organizational characteristics that facilitate ICT use can provide insights for improving the design and implementation of ICT programs in agriculture (Aker, Ghosh, & Burrell, 2016). Also, the knowledge of the organizational learning process will be valuable in understanding the importance of organizational culture when implementing ICT programs to improve organizational performance in agriculture extension service delivery.

Therefore, this study aims to identify organizational characteristics that contribute to the use of ICT from the existing agriculture extension literature by using the perspective of the learning organization concept. We conducted a systematic literature review to collate findings from available literature in scientific databases. The analysis of the results is guided by the seven organizational dimensions of the learning organization proposed by Marsick & Watkins (2003).

This review is intended to guide researchers and practitioners to better understand the current debate on the use and impact of ICT in agriculture extension organizations. For researchers, the study compiles available knowledge on organizational aspects in ICT use and analyses topics for further investigation. The results also contribute to ongoing scientific discussions on organizational characteristics needed for continuous change and transformation in the agriculture service delivery. For practitioners, the results provide guidance on how to create an enabling organizational culture that facilitates the design and implementation of effective ICT-based projects.

4.2 Learning organizations in the context of ICT and agricultural extension

According to Mayntz "[*O*]*organizations* are *social structures with a definable membership and an internal allocation of roles, and they pursue the aim of passing on their achievements to the outside world. They are or at least they are intended to be rationally organized*" (Mayntz 1963 in Hoffmann et al., 2009 p.85). Members in organizations device procedures for making decisions in the name of the collective, delegating individuals to the authority to act collectively, and setting a boundary between the collective and the rest of the world (Argyris & Schon, 1978).

Learning is a process of co-evolution and transformation to cope with a changing environment (Hoffmann et al., 2009; Parkinson, 2010). The ability to cope with change is understood as an "ability to learn" or, at a corporate level, to be a "learning organization" (Senge, 1990). Organizations learn by interlinking implicit knowledge from individuals' experiences that are reflected in their behavior, beliefs or attitudes, and explicit knowledge from files, documents. Learning involves knowledge acquisition, knowledge sharing, and knowledge utilization. The learning process includes feedback through monitoring results and exchanging information, services, goods, and assets with outside partners or customers (Hoffman et al., 2009).

The concept of the learning organization has gained popularity in recent organizational studies (Maden, 2012). Senge (1990) defines learning organization as 'a place where people continually expand their capacity to create the results they desire, where new and expansive patterns of thinking are nurtured, where collective aspiration is set free, and where people are continuously learning to see the whole together'. Accordingly, unique characteristics of a learning organization are the continuous learning for improvement and the capacity to transform itself at the individual, team and organizational levels (Marsick & Watkins, 2003).

Scholars have developed frameworks and models to assess the learning culture of an organization. Örtenblad (2015) proposed a basic model for the learning organization that highlights four aspects (learning at work, organizational learning, climate of learning, and learning structure). The aspects are informed by the works of (Argyris & Schon, 1978; Senge, 1990). Senge (1990) proposed five inter-related disciplines that affect organizational learning (systems thinking, personal mastery, mental mode, team learning, and shared vision). Also, Marsick & Watkins (2003) propose a practical instrument to assess characteristics such as the organization's climate, culture, system, and structure that influence the learning of individuals. This instrument, Dimensions of the Learning Organization Questionnaire (DLOQ), defines and operationalizes the seven organizational dimensions (Marsick & Watkins, 2003) (Table 4.2.1).

Extension organizations and their methods of intervention evolve in response to national and global level changes (Faure, Desjeux, & Gasselin, 2012). In agriculture extension, ICTs are used to facilitate access to technical extension advice, market information, and weather information, using mobile phone applications (Aker, 2011; Baumüller, 2018). Public computing facilities such as telecenter models (Pick, Gollakota, & Singh, 2014; Salvador, Sherry, & Urrutia, 2005), participatory video (Gandhi, 2017), and radio (Lwoga, 2010) are also popular. In a broader sense, ICT includes devices, services, and applications that range from cutting edge internet-based technologies and sensing tools to those that already existed for longer such as radio, telephone, mobile phones, television, and satellites (FAO, 2018).

Conceptual and empirical literature identified many factors that hamper or facilitate ICT use in agriculture extension services. Factors related to individual characteristics include education level, ICT skill, age, and attitude of experts (Strong, Ganpat, Harder, Irby, & Lindner, 2014). Contextual factors in the surrounding environment include extension policy and availability of relevant digital content (Sulaiman V, Hall, Kalaivani, Dorai, & Reddy, 2012). Organizational factors include organizational vision (Sulaiman et al., 2012), agricultural information quality and relevancy, organizational culture (Yadav et al., 2015), involvement of multiple groups and committed leadership style (Ballantyne, 2009; Krishna & Walsham, 2005; Lwoga, Stilwell, & Ngulube, 2011).

As elaborated above, extension organizations' success in ICT use requires enabling organizational conditions, which means an adaptation of the organizational culture to accommodate ICT. Having an organizational culture that is able to cope with change is a result of a learning process (Hoffmann et al., 2009).

Empirical research that study processes of organizational learning mainly addresses private organizations (Maden, 2012), while studies on organizational learning in public, research, and non-governmental organizations remain scarce (Parkinson, 2010). Furthermore, scholars have noted that the core dimensions of learning organizations are context- and sector-specific. In Lebanese firms, for example, Jamali & Sidani (2008) found out that significant organizational dimensions in Lebanon are different compared to dimensions of firms in western countries. Similarly, (Örtenblad & Koris, 2014) showed that significant organizational dimensions in higher education institutes are different from those organizations in the business sector. Consequently, there is a call for a more contextualized approach for studying the learning process of organizations (Örtenblad et al., 2012).

Acknowledging the variations between sectors and contexts, the use of ICTs in agriculture extension builds a special case. Agriculture organizations have to rapidly improve their capacity and mechanisms for learning to deal with the continuous challenges of environmental and social change. (Leeuwis & Van den Ban, 2004). We have not identified any study that systematically analyses the learning process of extension organizations in the context of ICT use. Considering the increasing attention these topics currently receive from research and development, this creates a research gap in learning organization literature.

In this article, we answer the question, ‘What organizational characteristics contribute to ICT use in agriculture extension organizations?’. We used a systematic literature review that collates the findings of available studies thematically and analyze the results using the seven dimensions of a learning organization, as conceptualized by Marsick & Watkins (2003) (Table 4.2.1). We are using this framework because the dimensions give a clear and inclusive definition of the concept of learning organization from an organizational culture perspective and include dimensions of learning at the levels of individuals, teams, and organizations (Yang, Watkins, & Marsick, 2004).

Table 4.2.1 Overview of the seven dimensions of a learning organization

The dimension of learning organizations	Definition
1. Create continuous learning opportunities	Learning is designed into work so that people can learn on the job; opportunities are provided for ongoing education and growth.
2. Promote inquiry and dialogue	People gain productive reasoning skills to express their views and the capacity to listen and inquire into the views of others; the culture is changed to support questioning, feedback, and experimentation.
3. Encourage collaboration and team learning	Work is designed to use groups to access different modes of thinking; groups are expected to learn together and work together; collaboration is valued by the culture and rewarded.
4. Empower people towards a collective vision	People are involved in setting, owning, and implementing a joint vision; responsibility is distributed close to decision making so that people are motivated to learn toward what they are held accountable to do.
5. Provide strategic leadership for learning	Leaders model, champion, and support learning; leadership uses learning strategically for business results.
6. Create systems to capture and share learning	Both high- and low-technology systems to share learning are created and integrated with work; access is provided; systems are maintained.
7. Connect the organization to its environment	People are helped to see the effect of their work on the entire enterprise; people scan the environment and use information to adjust work practices; the organization is linked to its communities.

Source: Marsick and Watkins (2003)

4.3 Research methods

A systematic literature review (SLR) is a rigorous approach to conducting a stand-alone review that supports the identification of evidence from various research studies undertaken within a specific topic (Fink, 2005). Literature reviews provide information on to what extent existing research has progressed towards a particular problem, identify the relations, contradictions, gaps, and inconsistencies in the literature and explore reasons, which may provide implications to policy, practice, and prescribe future research directions (Baumeister and Leary, 1997).

A literature review is called ‘systematic’ when it is explicit and uses a reproducible method to identify, evaluate and synthesize the existing body of knowledge produced by researchers, scholars, and practitioners (Okoli & Schabram, 2010). SLR goes a step further from summarizing

identified articles in that it syntheses knowledge by evaluating the findings in a structured way. SLR offers both qualitative and quantitative analysis. In this study, we used qualitative SLR of scientific articles on ICT use in agriculture extension organizations, as depicted in Figure 4.3.1.

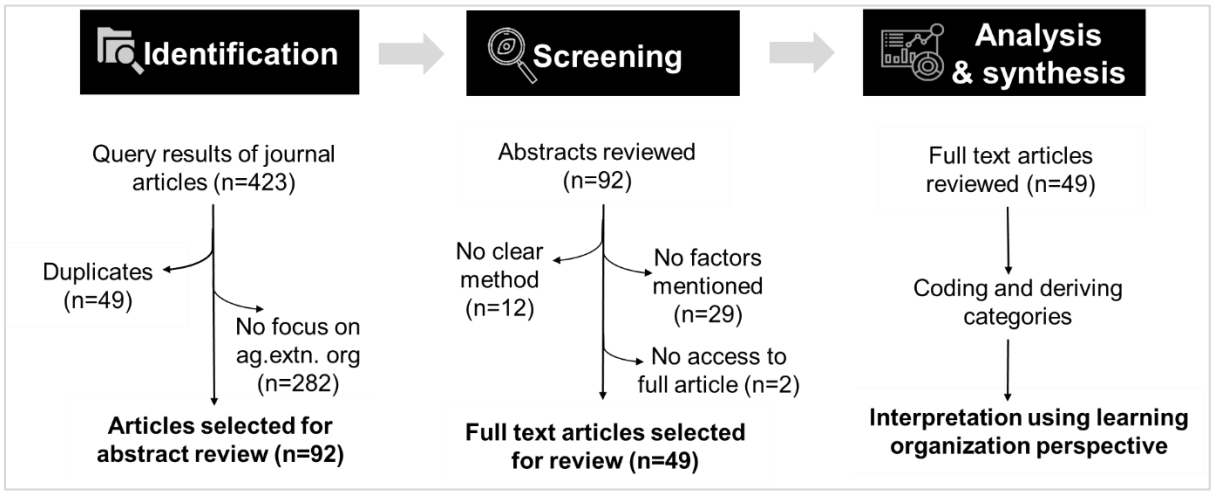

Figure 4.3.1: Schematic representation of the review method

Identification of articles

We used Scopus and CAB databases to identify relevant journal articles. We used a specific set of search terms and synonyms informed by preliminary exploratory research. The search terms were Organizational characteristics (synonyms) and Agriculture extension (synonyms) and ICT (synonyms) (Table 4.3.1). The search terms had to appear in the title (TITLE), abstract (ABS) or keywords (KEY). We ran the query in May 2019 and identified 423 journal articles in total.

Table 4.3.1 Query used to identify relevant publications

Database	Query	Total	Journal Article	English
CAB	(Ab:((ict* OR "information and communication technolog*" OR "information technolog*" OR computer OR internet OR "Mobile phone" OR video OR radio OR website) AND ("agricult* advis* servic* " OR " agricult* extension servic* " OR "agricult* extension* " OR " agricult* organization" OR "agricult* office")))	419	305	253
Scopus	TITLE-ABS-KEY ((ict* OR "information and communication technolog*" OR "information technolog*" OR computer OR internet OR "Mobile phone" OR video OR radio OR website) AND ("agricult* advis* servic* " OR " agricult* extension servic* " OR "agricult* extension* " OR " agricult* extension organization" OR "agricult* office"))	265	175	170

Article screening

After removing duplicates from Scopus and CAB, we screened the identified articles using inclusion and exclusion criteria developed before the screening process. The inclusion criteria were the article is about ICT in agriculture extension organization, the article is in English, and the article addresses factors that contribute/affect ICT use. The exclusion criteria were, the article focuses on farmers and/or researchers; the article focuses on supply of ICT; the article has no clearly defined /described methodology; full-text version of the article is not available to the authors via the publishing journal website or inquiry via library service or author contact. Accordingly, we selected and downloaded 49 full-text articles for further analysis.

Analysis and synthesis

We conducted an analysis of the 49 full-text articles in three steps. In step one we characterized the type of the articles identified (e.g. year of publication, geographic region focus, type of research, type of ICT). In step two, we conducted an iterative descriptive coding (Saldana, 2009) that involved several cycles to identify and categorize all the factors that the reviewed literature documented. Using the first two steps of the coding guidelines proposed by Corbin and Strauss (2014), we produced a codebook, which we used to identify the most salient themes mentioned

in the articles reviewed (Annex 1). In step three, we used the seven dimensions of learning organization (Table 4.2.1) as a framework to analyze the representation of categories of organizational factors in the identified literature.

4.4 Results

The results are organized into three sections. The first section describes the characteristics of the reviewed articles; the second section presents all the factors identified, and the third section analyses the categories of the organizational factors from a learning organization perspective.

4.4.1 Characterization of identified articles

The majority (n=47) of the articles reviewed focused on ICT tools in a broader sense, including computers, internet, tablet, mobile phones, etc. while two focused on specific ICT applications or services: social media and satellite imaging. Quantitative research is the predominant (n=42) type of methods used in the articles. In addition, there is an increase in the number of studies on ICT use in agriculture extension over the years, with relatively few publications per year until 2014 and a higher number of publications afterward. Many of the articles are based on cases in Sub Saharan Africa (e.g., most frequent is Nigeria n=13) and South Asia (e.g., most frequent is India n=13), compared to a smaller representation of the Caribbean and the Middle East. Figures 4.4.1 and Figure 4.4.2 illustrate the characteristics of the articles reviewed. Annex 2 presents a list of articles reviewed.

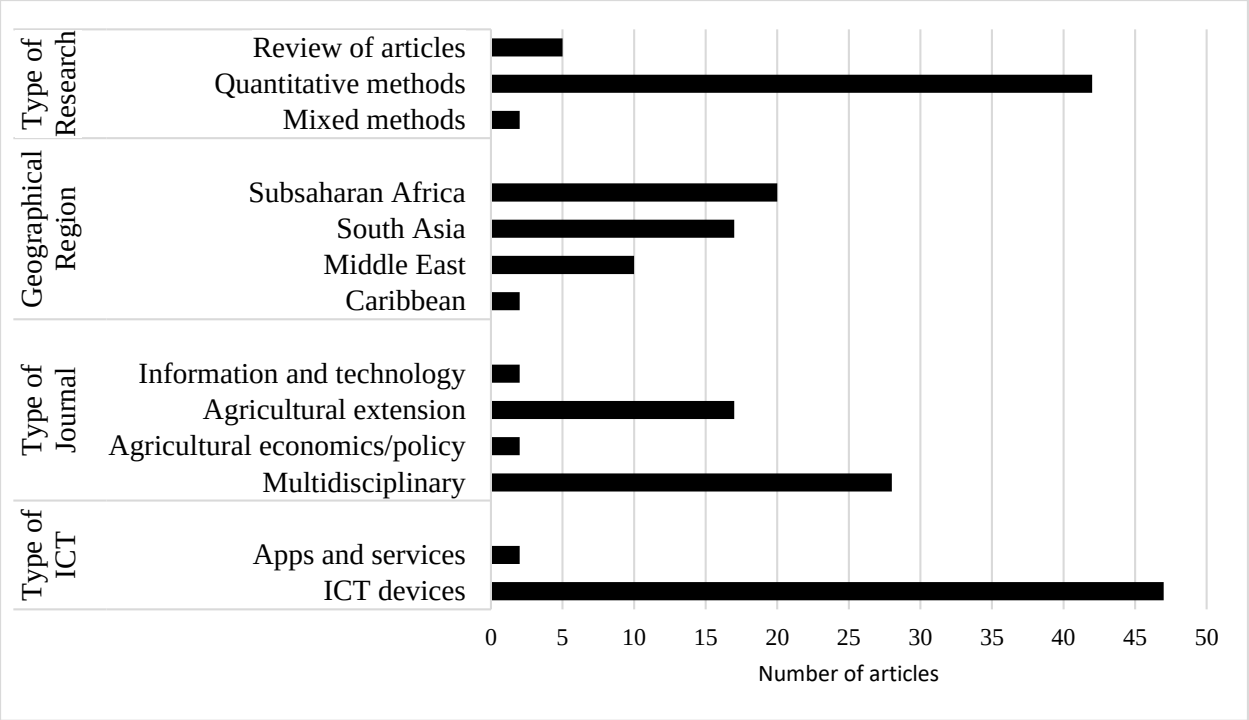

Figure 4.4.1: Characterization of the articles reviewed

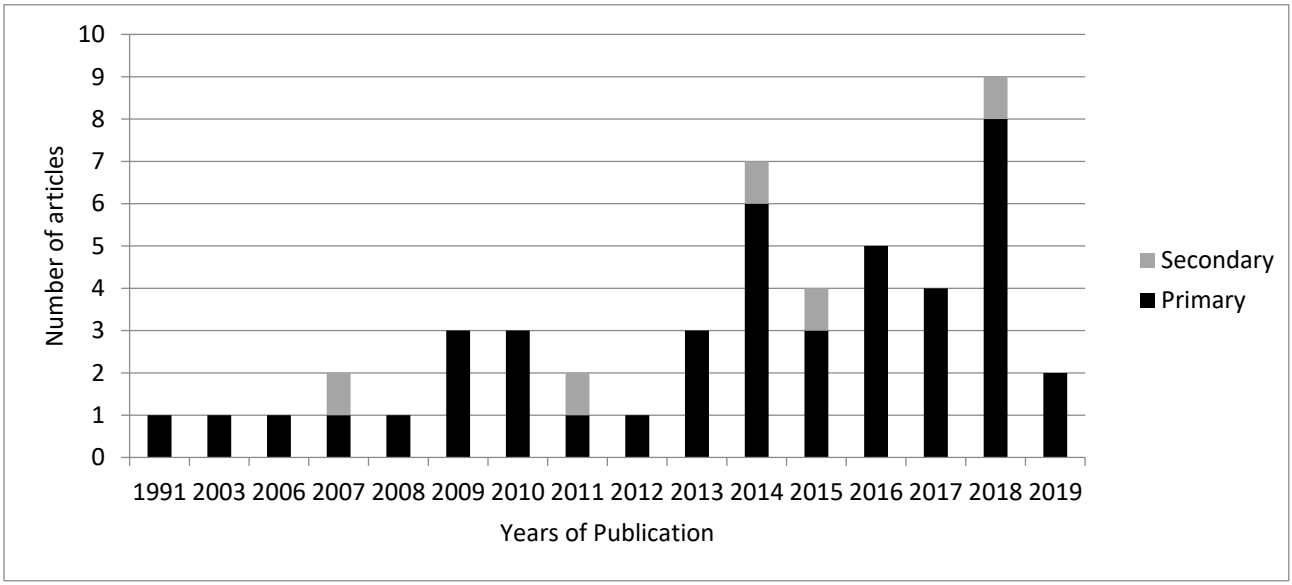

Figure 4.4.2: Years of publication of the articles reviewed and data sources

4.4.2 Identified factors affecting ICT use in agriculture extension

In an iterative process of coding and comparing descriptions of identified factors in the studies, we concluded on concise naming of factors and meaningful categories in the context of our review's results. Table 4.4.1 contains a summary of factors identified and highlights to what extent each factor is represented in the studies reviewed. We grouped the factors that were identified to affect ICT use in agriculture advisory services in the 49 papers reviewed into three categories: Individual characteristics of people in the extension organizations, organizational characteristics, and enabling environment.

Regarding the individual characteristics, extension experts' demographic characteristics, competencies, and skills on ICT, their attitudes and perceptions towards ICT use, and the perceived usefulness are mentioned in 38 of the articles reviewed. The studies report positive relationship with level of formal education, skills/experiences of using computers and attitude towards ICT use, and negative relationship with age and attitude towards ICT use (Aboh, 2008; Afzal, Al-Subaiee, & Mirza, 2016; Birke, Lemma, & Knierim, 2019; Dinar & Maron, 1991; Ganpat, Ramjattan, & Strong, 2016; Hashemi, Rad, & Chizari, 2014). Also, 33 of the articles investigate characteristics of the extension organization such as financial resources, capacity, availability of devices, and internet access. Seventeen of the literature reviewed investigated characteristics at the enabling environment including telecommunication infrastructure and network, enabling policy and availability of contextualized content (Enwelu, Enwereuzor, Asadu, Nwalieji, & Ugwuoke, 2017; Okeke, Nwalieji, & Uzuegbunam, 2015; Rad, Hashemi, & Chizari, 2015).

Table 4.4.1: Identified factors that affect ICT use in agriculture extension and number of articles in which those factors were identified

Categories	Identified factors (codes)*	Number of articles
Individual characteristics		***38***
	Knowledge, competences, and skills	19
	Demographic characteristics	25
	Attitudes and perceptions	19
Organizational characteristics		***33***
Human resources management	Training opportunities	10
	Rewards and recognition	6
	Support from Management	7
	Team interactions and collaborations	7
Finances	Investment and budget	15
Technology	Access to the internet	7
	Availability of devices	19
Extension strategy	Type of extension approach	4
	Availability of Private-public partnership	3
Enabling environment		***17***
	Telecommunication infrastructure and network	10
	Availability of relevant content	2
	Policies and regulations	8

**Annex 1 provides a detailed description of the codes and sub-codes*

4.4.3 Analysis of organizational factors from a learning organization perspective

It emerged from the review that several of the organizational factors can be subsumed to the seven dimensions of the learning organization. The following two sections present the quantitative analysis of the identified factors and the qualitative content analysis of the factors using the learning organization perspective.

4.4.3.1 Quantitative analysis of the identified factors

In addition to quantitatively analyzing the represented factors that affect ICT use in agriculture advisory services, we aim to understand identified organizational factors from the perspective of

a learning organization. Therefore, we interpreted the identified factors according to our framework of analysis for a learning organization. In Table 4.4.2, we matched each of the identified factors with the seven dimensions of a learning organization, as defined by Marsick and Watkins (2003) (Table 4.2.1).

Most of the articles reviewed focus on the importance of the organizational dimension VI 'creating systems to share learning' Articles also indicated the importance of the organizational dimension V 'strategic leadership' for facilitating the technical requirements for managing and maintaining ICT and IV 'empowerment for a collective vision.' The organizational dimension, opportunities for continuous learning (I) is also identified as a significant organizational characteristic needed for better use of ICT. While very few articles explored the significance of 'connection the organization with the environment' (VII), none of the articles captured the importance of inquiry and dialogue dimension (II).

Table 4.4.2: Number of articles that identified organizational factors according to the seven dimensions of a learning organization

Identified organizational factors	Seven dimensions of learning organization*						
	I Opportunities for continuous learning	II Promote inquiry and dialogue	III Team learning and collaboration	IV Empower to collective vision	V Provide strategic leadership	VI Create systems to share learning	VII Connect the organization to its environment
Training and capacity building	10	-	-	-	-	10	-
Incentives and encouragement	-	-		6	-	-	-
Support from Management	-	-	-	7	7	-	-
Team interaction and collaboration	-	-	7	-	-		-
Investment and budget	-	-	-	-	-	15	-
Access to internet connection	-	-	-	-	-	7	-
Availability of devices/hardware	-	-	-	-	-	19	-
Type of extension approach	-	-	-	-	-	4	-
Availability of public/private partnership	-	-	-	-	-	-	3

*based on the operationalization of the seven organizational dimensions each factor identified was matched with the dimensions presented in Table 4.2.1

4.4.3.2 Qualitative analysis of the identified factors

Dimension I. Create continuous learning opportunities

The reviewed articles referring to opportunities for continuous learning suggest that extension organizations, which introduce ICT, miss to plan and execute classroom or on the job training to develop ICT skills and therefore ICT use is limited (Allahyaria, Atashi, & Dunn, 2018; Khamoushi & Gupta, 2014). Ahmadpour, Mirdamadi, Hosseini, and Chizari (2010) noted that extension organizations choose not to develop their employees' ICT skills due to training costs and fear of losing productivity when employees are absent from their regular work. James and Lakshminarayan (2018); Yakubu, Abubakar, Atala, Muhammed, and Abdullahi (2013), Nlerum and Onowu (2014) and Tata and McNamara (2018) explained that there is a relationship between the lack of training to develop ICT skills and the attitude of extension experts towards the use of ICT. While Al-Shayaa, Al-Shenifi, and Al Abdu Hadi (2011) reported a lack of training programs, weakness of the content, and a low level of trainers capacity. In sum, all identified articles emphasize the need for but the absence of opportunities for learning in the cases that were analyzed.

Dimension II. Promote inquiry and dialogue

The dimension of promoting inquiry and dialogue explores aspects of communication, such as feedback, active listening, respect, and trust among employees in an organization to try new methods and approaches to work. None of the articles we reviewed mentioned this organizational dimension in the context of ICT use in extension organizations.

Dimension III. Encourage collaboration and team learning

The dimension of collaboration and opportunities for mutual learning focusses on equal participation, flexibility, and recognition of team members' tasks and contributions. Seven of the reviewed articles mentioned the value of collaboration in extension organizations using ICT. For example, James and Lakshminarayan (2018) reported on the presence of a relationship between an organizational climate that encourages team interaction and the extent of ICT tool utilization by extension officials. El Bilali and Allahyari (2018) reported on the collaboration gap with the end-users and beneficiaries to ensure the adequacy, relevancy, and accessibility of mobile technologies in agriculture extension organizations. Similarly, Ahmadpour et al. (2010) reported that of the seven factors that affect ICT use, the intention of collaboration, and participation in learning processes ranks in the fourth factor. Hossein, Niknami, and Hosseini Nejad (2009) also

reported that the application of ICT in agriculture extension organizations is affected by the absence of advocacy for the participation of the rural population in ICT project planning and integration of the ICT with the conventional information delivery system. The findings in these articles indicate gaps in the organizations to support collaboration and team interaction, which could influence the extent of ICT use by the targeted users. However, the studies do not explicitly discuss which aspects of interaction and collaboration are significant in ICT use.

Dimension IV. Empower people towards a collective vision

The dimension of empowerment towards a collective vision, which includes recognition for taking an initiative, support for taking risks, and giving control over resources needed, is highlighted by seven of the articles reviewed. Allahyaria et al. (2018) reported that due to the absence of encouragement from managers to use mobile phones in advisory services, knowledge exchange among extension agents is poor. Similarly, the absence of incentives to use ICT in agriculture extension is highlighted by (Tata & McNamara, 2018) and Ahmadpour et al. (2010). These studies indicate that the reward systems in the extension organizations do not encourage extension experts to develop their skills of ICT use.

Dimension V. Provide strategic leadership for learning

The dimension of strategic leadership, which includes mentoring, coaching, encouragement, and support, are explored by seven of the articles reviewed. For example, Al-Shayaa et al. (2011) reported that mangers in agriculture extension organizations have no interest in computers and therefore give little priority to develop the ICT skill of the employee even when the employees show interest. Similarly, Birke et al. (2019) reported that supervisors perceived computer and internet use as entertainment and, therefore, did not encourage their staff to use the tool. Raksha, Rao, and Meera (2015) reported that the ICT enabled agricultural extension services in India receive fewer funds far below the standard cost for ICT. These studies indicate that those leadership strategies that encourage ICT use are absent in extension organizations.

Dimension VI. Create systems to capture and share learning

The dimension, ‘create systems to capture and share learning’, comprises activities in the organization, such as facilitating two-way communication among the employee, facilitating access to information need, follow up on the skill of employee, sharing lessons learned, and measuring results of time and resources spent on training.

The majority of the articles reviewed indicate that agriculture organizations have challenges to facilitate access to information via ICT due to limited financial resources for communication and knowledge sharing. Enwelu et al. (2017) and Nlerum and Onowu (2014) reported a high cost of ICT maintenance in agriculture extension organizations in Nigeria. Ahmadpour et al. (2010) showed that the financial factor plays an important role to designing an e-learning system in agricultural extension. The bases for designing e-learning systems, such as purchasing of hardware and software equipment, internet access fees, maintenance expenses and recruitment of experts require additional investment. Similarly, Allahyaria et al. (2018) found out that initial investment and budget for facilitating mobile phone use by extension officers for information exchange was a determining factor.

Regarding ICT devices and an internet connection, the reviewed studies reported the importance of their availability in the extension organizations and accessibility for the users to share knowledge. For example, accessibility of ICT has an association with perception of extension experts towards the usability of the tools for knowledge sharing (James & Lakshminarayan, 2017) and level of their use (Okeke et al., 2015). Ahmadpour et al. (2010) reported that access to appropriate hardware ensures the implementation of e-learning programs.

The importance of monitoring the ICT skills of employees in the extension organizations was reported by ten of the reviewed articles as one of the crucial factors. For example, Khamoushi and Gupta (2014) observed that lack of in-service training facilitation for using/producing ICT was a serious factor in effective ICT use. Similarly, Lakshmi and Punima (2018) reported the need for upgrading the digital literacy of extension professionals through various capacity building programs to create e-readiness among extension professionals and organizations. Raju and Rao (2007) highlighted that monitoring capacity building and institutional strengthening activities are important for extension organizations so that they make creative use of ICT.

ICTs provide extension organizations an opportunity to update their extension approach to that of demand-driven (Raju & Rao, 2007). However, studies report challenges with introducing ICT in organizations with a top-down extension approach. For example, Birke et al. (2019) report that the top-down extension approach demotivated extension experts from using ICT for searching and sharing new knowledge as their effort is not recognized.

In summary, the above result indicates that access and availability of resources such as finances and ICT devices, as well as facilitation of training to use the digital technologies are pre-requisite for creating a system that captures and shares knowledge in ICT use.

Dimension VII Connect the Organization to its environment

The dimension, ‘connect the organization to its environment’, encourages a wider perspective of thinking, where clients’ views are considered in the decision-making process, and the organization works with other organizations.

Strong, Ganpat, Harder, Irby, and Lindner (2014) noted the need for working together of both the public and private sectors to support further ICT development and application in agriculture extension organizations. Similarly, Aker (2011) indicated that since the mobile-based applications are developed and managed by the private sector, using ICT requires a public-private partnership. Ibezim and Osondu (2014) and Allahyaria et al. (2018) reported that extension experts perceive that ICT facilitates continuous networking with researchers and other information sources. Some studies report on cases where an ICT-based extension initiative is introduced to an agriculture extension organization by an external organization (Birke et al., 2019; Raj S., 2013). However, we did not come across any explicit report on how the extension organization connected with other organizations and incorporated the views of its’ clients in deciding to introduce and use ICT for extension service delivery

4.5 Discussion

Our results show that although the topics of learning organizations, ICT, and agriculture extension organizations are prominent in the current research, literature that combines aspects of these three topics is scarce but started increasing in the last decade. Furthermore, almost all literature reviewed used quantitative research methods, which emphasized the examination of factors and their relationships. The fact that the quantitative data source of the articles reviewed relies mostly on extension experts creates a gap in knowledge of organizational processes and the role of other actors in the implementation process. Accordingly, our results indicate a scarcity of qualitative studies that use process-based approaches to capture the complexity of bringing new technology to an existing organization and the change process over time.

Regarding the identified factors, most of the articles reviewed focused on individual characteristics of the employee in the extension organizations and on tangible organizational characteristics (infrastructure, new technologies, human resource). In contrast, there is limited literature on factors such as ICT policy and telecommunication infrastructure. Chapman & Slaymaker (2002); Rao (2007); Verdegem & De Marez (2011) emphasized the importance of

enabling policy and infrastructure for ICT in agriculture extension. However, the literature reviewed seems to underemphasize investigating these factors and their impact on ICT use in agriculture extension.

Against these backdrops, we suggest further studies that investigate complex processes in organizational settings and interactions with their contextual environment. Actor-oriented research approaches, such as Actor-Network Theory (Latour, 2005) can shed light on these complexities and reveal learning opportunities for extension organizations in harnessing ICT potential.

In terms of the dimensions of learning organizations, scholars have indicated that the most visible organizational dimensions vary with the context in which organizations are situated (Hong, Snell, & Lin, 2013; Örtenblad, 2012). For instance, Maria (2003) found out that in the Malaysian public sector, four organizational dimensions - create a system to capture and share learning, strategic leadership, continuous learning, and team learning - were more important to explain the use of the introduced innovation than the other three dimensions. In the context of agriculture extension organizations, according to our review, create system to capture and share learning and create opportunities for continuous learning are the most emphasized to influence change in the use of ICT. However, the existing organizational conditions address these dimensions only partially. This points to the central role of knowledge sharing and learning in the field of agriculture advisory services (Leeuwis & Van den Ban, 2004).

Van den Ban (1997) reported that all dimensions of learning organizations might not be visible in extension organizations, specifically public extension organizations, where knowledge performance is not rewarded. In our analysis, we did not identify any article that examines the dimension dialogue and inquiry, which includes aspects of communication such as feedback, active listening, building trust, and respect. Maden (2012) noted that opportunities for dialogue are rather rare in public organizations as employees are inclined to do only what is required and hardly question the existing system for performance improvement.

Other dimensions of the learning organizations, including encourage collaboration and team learning, empower people towards a collective vision, connect the organization to its environment and, provide strategic leadership for learning have been explored to a limited extent. The reviewed articles suggest the importance of these dimensions but insufficient consideration is given. Leeuwis & Van den Ban (2004) discussed that the dimensions above appear simple and straightforward but in practice are more complicated. This is the case because there is often little

space for critical thinking, less openness to problems and mistakes and discouraging reward system to bring failure forward.

The seven dimensions of learning organizations gave structure to match and analyze the identified organizational factors in the reviewed articles. However, since all studies reviewed focused on adoption and impact and not on how the organization adapted to use ICT, the results may not have captured those factors concerned with the learning process of organizations. Therefore, the conceptual framework does not fit best for analyzing topics that focus on the adoption of innovation as such studies have little emphasis on learning processes. Moreover, the studies used other conceptual and analytical frameworks to interpret findings and therefore, the learning processes might have been tinted. Nevertheless, our analysis provides a starting point for gaining insights on which dimensions of learning organization require further investigation in the context of agriculture extension.

4.6 Conclusion

To cope with the continuous change in the agriculture extension system, extension organizations must continuously adapt to the changing conditions. By using the perspective of a learning organization, this literature review compiles evidence on organizational factors that affect ICT use in agriculture extension organizations. Our systematic review of 49 articles reveals that most of the research on extension organizations and ICT use focus on studying individual characteristics of extension experts and on tangible organizational characteristics that affect ICT use. However, there is a gap in knowledge about the complex and dynamic organizational learning processes and the role of various actors engaged in the implementation of such technologies. This calls for better understanding of organizational learning processes in extension organizations with research that (i) analyzes the complexity of bringing new ICT to extension organizations and the change process over time by using process-based approaches; (ii) analyzes the leadership style of stakeholder groups and the organizational conditions in which they function for gaining better insights about extension organizations as learning organization in the event of ICT introduction; and (iii) analyzes the merits of digital technologies in facilitating networking and collaborative learning among employees, departments and extension organizations.

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Annexes

Annex 1: Categories and codes of the factors identified in the selected papers

Categories	Sub-categories	Description	Codes/factors
Personal characteristic of extension experts	Knowledge, competences and skills	Competences and skills that affect the use of ICT by extension agents.	-Computer literacy -Knowledge about the functioning of ICT -Awareness/familiarity with the ICT -Possession of ICT - Experience with ICT use
	Demographic characteristics	Demographics characteristics that affect the use of ICT	-Age -Years of formal education -Job experience in years
	Attitudes and perceptions	Individual attitudes and values that affect ICT use	-Innovativeness promptness -Open mindedness to modern technologies -Positive/ favorable attitude toward ICT -Perception of usefulness of ICT -Perception of easiness of use -Job satisfaction
Human capacity development and management	Training opportunities	Opportunities to take part in ICT skill development courses	-In- service training facilities -Absence of training on ICT tools -Training extension agents -Capacity building -Providing training programs -Training manuals -Face to face training
	Rewards and Recognition	Rewards or recognition given to the staff performance towards organizational goal	-Performance incentive -Management incentives -Staff incentives -Rewarding ICT use
	Support from Management	Management provides support for job delivery	-Problem solving -Assigning resource person/technical expertise -Interest of management in computer and ICT
	Team interactions	employees feel that they should work as a team to meet the objectives	-Collaboration -Interaction with colleagues -collaboration between department
Financ es	Investments	Purchasing capability of extension organizations	-Purchasing computers and other ICT devices

Categories	Sub-categories	Description	Codes/factors
	Budget allocation	Capacity of organizations to covers costs for ICT skills development, maintenance or update of ICT and software	-Training cost -Maintenance expenses -Software update expenses -Internet fee -Technical support
Extension strategy	Type of Extension approach	business model or -strategic plan to conduction extension services	-Top-down approach -Participatory approach -Involvement of end users -Public-private partnership
Technology	Internet connectivity	Organization provides internet connectivity for employees	-Presence/absence of Internet connection
	ICT devices/hardware and software	Availability of ICT equipment/software in the extension organizations	-Computers -Telecenter -Mobile phone/audio-video aids -Software
Enabling Environment	Relevant content	Localized content for ICT	-Information sources -Type of information -Quality of information
	Policy and public regulations	Policy and regulation on ICT and agriculture	-Enabling policy -Rules - Government policy
	Telecommunications and network infrastructure	Infrastructure available in the context	-Presence/absence of electricity - Internet network available

Annex 2: List of papers reviewed

No.	Authors	Year	Country	Type of ICT	Type of analysis	Type of journal
1	Aboh, C. L.(2008)	2008	Nigeria	Multiple	Quantitative	Multidisciplinary
2	Afzal A., Al-Subaiee F.S., Mirza A.A.(2016)	2016	Saudi Arabia	Multiple	Quantitative	Multidisciplinary
3	Ahmadpour A., Mirdamadi M., Hosseini J.F., Chizari M.(2010)	2010	Iran	Multiple	Quantitative	Multidisciplinary
4	Aker, J. C.(2011)	2011	India	Multiple	Review	Agricultural economics/policy
5	Albert, C. O.; Onwubuya, E. A.	2013	Nigeria	Multiple	Quantitative	Multidisciplinary
6	Allahyaria M.S., Atashi M.R., Dunn E.S. (2018)	2018	Iran	Mobile phone	Quantitative	Multidisciplinary
7	Al-Shayaa M.S., Al-Shenifi M.S., AL Abdu Al Hadi H.S.(2011)	2011	Saudi Arabia	Computer and Internet	Quantitative	Multidisciplinary
8	Birke, Fanos Mekonnen; Lemma, Mamusha; Knierim, Andrea(2019)	2019	Ethiopia	Computer and Internet	Mixed	Agricultural extension
9	Bolarin O., Ayanlade A. (2010)	2010	Nigeria	Satellite imaging	Quantitative	Multidisciplinary
10	Dinar A., Marom D.(1991)	1991	Israel	Computer and Internet	Quantitative	Information and technology
11	Dissanayeke, U. I.; Wickramasuriya, H. V. A.; Wijekoon, R.(2009)	2009	Sri Lanka	Computer and Internet	Quantitative	Multidisciplinary
12	El Bilali, Hamid; Allahyari, Mohammad Sadegh (2018)	2018	Iran	Multiple	Review	Information and technology
13	Enwelu, I. A.; Enwereuzor, S. O.; Asadu, A. N.; Nwalieji, H. U.; Ugwuoke, B. C. (2017):	2017	Nigeria	Multiple	Quantitative	Agricultural extension
14	Ganpat, Wayne G.; Ramjattan, Jeet; Strong, Robert (2016):	2016	Trinidad	Multiple	Quantitative	Agricultural extension
15	Hashemi, Z. H.; Rad, G. P.; Chizari, M.(2014)	2014	Iran	Multiple	Quantitative	Multidisciplinary
16	Hosseini S.J.F., Niknami M., Hosseini Nejad G.H.(2009)	2009	Iran	Multiple	Quantitative	Multidisciplinary
17	Ibezim, G. M. C.; Osondu, C. K. (2014)	2014	Nigeria	Multiple	Quantitative	Agricultural extension
18	James, D. J.; Lakshminarayan, M. T.(2017)	2017	India	Multiple	Quantitative	Multidisciplinary
19	James, D. J.; Lakshminarayan, M. T.; James, Dishant Jojit (2018):	2018	India	Multiple	Quantitative	Multidisciplinary
20	Nlerum, F. E.; Onowu, E. O. (2014)	2014	Nigeria	Multiple	Review	Agricultural extension

No.	Authors	Year	Country	Type of ICT	Type of analysis	Type of journal
21	Okeke, M. N.; Nwalieji, H. U.; Uzuegbunam, C. O.(2015)	2015	Nigeria	Multiple	Review	Agricultural extension
22	Olaolu Micheal O., Agwu Ekwe A., Ivande Pauline D., Olaolu Tochukwu A.(2018)	2018	Nigeria	Multiple	Quantitative	Agricultural extension
23	Prodhan, F. A.; Afrad, M. S. I.(2014)	2014	Bangladesh	Multiple	Quantitative	Multidisciplinary
24	Rad, G. P.; Hashemi, Z. H.; Chizari, M. (2015):	2015	Iran	Multiple	Quantitative	Agricultural extension
25	Raj S. (2013)	2013	India	Multiple	Quantitative	Agricultural extension
26	Raksha, I.; Sreeniwasa Rao; Meera, S. N.; Vinod Kumar (2015)	2015	India	Multiple	Quantitative	Agricultural extension
27	Sepideh Khamoushi; Jancy Gupta (2014)	2014	India	Multiple	Quantitative	Agricultural extension
28	Strong, Robert; Ganpat, Wayne; Harder, Amy; Irby, Travis L.; Lindner, James R. (2014):	2014	Multiple	Multiple	Quantitative	Agricultural extension
29	Tata J.S., McNamara P.E.(2016)	2016	South Africa	Multiple	Mixed	Multidisciplinary
30	Tata, Joyous S.; McNamara, Paul E. (2018):	2018	Kenya	Multiple	Quantitative	Agricultural extension
31	Yakubu, D. H.; Abubakar, B. Z.; Atala, T. K.; Muhammed, A.; Abdullahi, M. K.(2013)	2013	Nigeria	Multiple	Quantitative	Agricultural economics/policy
32	Lakshmi, K. Bhagya; Punmia, K.S.	2018	India	Multiple	Quantitative	Multidisciplinary
33	Osei, Simon K; Entsua-Mensah, Clement	2006	Ghana	Multiple	Quantitative	Multidisciplinary
34	Anand, K; Ravichandran, V	2014	India	Multiple	Quantitative	Multidisciplinary
35	Akpabio, I. A.; Okon, D. P.; Inyang, E. B.	2007	Nigeria	Multiple	Quantitative	Agricultural extension
36	Dire, B.; Onu, J. I.; Jungur, A. A. U.; Ndaghu, A. A.; Giroh, D. Y.	2016	Nigeria	Multiple	Quantitative	Multidisciplinary
37	Jaji, M.F.O.; Abanigbe, S. A.; Abass, B. O.	2017	Nigeria	mobile phone	Quantitative	Agricultural extension
38	Wright, Holly Jane; Ochilo, Willis; Pearson, Aislinn; Finegold, Cambria; Oronje, MaryLucy; Wanjohi, James; Kamau, Rose; Holmes, Timothy; Rumsey, Abigail	2016	Kenya	Tablet	Quantitative	Multidisciplinary
39	Lawal-Adebowale, O.A; Akeredolu-Ale, B.I	2010	Nigeria	Multiple	Quantitative	Multidisciplinary
40	Meera, S.N; Jhamtani, A.; Rao, D.U.M	2003	India	Multiple	Quantitative	Multidisciplinary

No.	Authors	Year	Country	Type of ICT	Type of analysis	Type of journal
41	Thammi Raju, D.; Sudhakar Rao, B.	2007	India	Multiple	Review	Multidisciplinary
42	Rai, Ashok; Jirli, Basavaprabhu; Singh, Abhishek	2018	India	Multiple	Quantitative	Multidisciplinary
43	Mabe, Lenah Karabo; Oladele, Oladineji Idowu	2012	South Africa	Multiple	Quantitative	Multidisciplinary
44	Kamruzzaman, Md.; Chowdhury, Ataharul; van Paassen, Annemarie; Ganpat, Wayne	2018	Bangladesh	Social media	Quantitative	Agricultural extension
45	Sabir; Sugiyanto; Sukesi, Keppi; Yuliati, Yayuk	2018	Indonesia	Multiple	Quantitative	Multidisciplinary
46	Amadu, Festus O.; McNamara, Paul E.	2019	Uganda	Multiple	Quantitative	Multidisciplinary
47	Fami, H. Shabanali; Falaki, M.; Iravani, H.; Mohammadi, H. M.	2009	Iran	Multiple	Quantitative	Multidisciplinary
48	Raksha, I.; Rao, Sreeniwasa; Meera, Shaik.N	2017	India	Multiple	Quantitative	Multidisciplinary
49	Raksha; Meera, Shaik.N	2015	India	Multiple	Quantitative	Agricultural extension

5 General discussion and conclusion

5.1 Introduction

The Government of Ethiopia has continuously invested in agriculture extension in terms of personnel and infrastructure for the last three decades. However, the agriculture extension system remains inefficient in supporting farmers to increase production and productivity (Berhanu & Poulton, 2014; Davis, Swanson, & Amudavi, 2009). In the effort of strengthening the extension system, two consecutive research for development projects, Improving Productivity and Market Success of Ethiopian Farmers (IPMS) (2004-2012) and Livestock and Irrigation Value chains for Ethiopian Smallholders (LIVES) (2013-2018), piloted Agricultural Knowledge Centers (AKCs) in public extension offices. These initiatives were inspired by the recommendations from Davis et al. (2009) to develop '*woreda resource centers'* a physical space in district extension offices that offer possibilities for knowledge exchange among experts and provide opportunities for accessing agricultural information and knowledge. The projects set up the AKCs in selected district and zonal agriculture extension offices to offer relevant and up-to-date didactic knowledge for agricultural extension experts. The ultimate aim of the AKCs is to support extension experts in getting up-to-date and relevant agricultural information and knowledge resources that helps them improve their extension service delivery to farmers.

Despite the emphasis given on the contribution of AKCs towards strengthening the extension services, the utilization of the services by the targeted users is reported as limited (Lemma, Tesfaye, Gebremedhin, Tegegne, Hoekstra, 2016). Little is known about the extension experts' perception of ICT usefulness and the organizational characteristics that facilitate or hinder the ICT use in the context of the extension offices. In particular, the interdependency of the technical devices, individual perceptions, and organizational characteristics in implementing ICT for extension is poorly understood. Therefore, this thesis aims to understand better the technical, social, and organizational aspects that result in ICT use in the context of agriculture extension offices. The thesis analyzes three important and interrelated aspects. Firstly, the establishment process of the AKCs in the respective extension offices. Secondly, the targeted users' perceptions of ICT usefulness for their extension work. Thirdly, the prevailing organizational characteristics that facilitate learning in extension organizations where ICT tools are introduced as one of the extension methods.

This discussion chapter summarizes the findings of the three studies in Chapters 2, 3, and 4. Guided by the conceptual framework proposed in Section 1.4, the main results are discussed and interpreted to understand the alignment of the three dimensions of innovation, the biomaterial, symbolic and social. Also, the academic and practical implications of this study, reflections on the research approach, and present recommendations for further research and policy are discussed.

5.2 Summary of main results

Chapter two presents an explorative case study that was conducted in order to understand the interaction of various actors during the process of establishing and managing AKCs. This study analyzes the assemblage that took place between technology, social, and organizational components during the establishment of the AKCs. The chapter presents the result of data collected via in-depth interviews and observations from five extension offices in South Wollo zone and archive project documents from LIVES. The results were analyzed using the Actor Network Theory (ANT), specifically the four moments of translation: problematization, interessement, enrollment, and mobilization.

The findings of the study allow understanding on how people and technology assembled to establish the AKCs actor network in order to provide extension experts access to digital knowledge. The chapter discusses the interactions and relationships of various actors that were visible and less visible in forming a new sociotechnical assemblage, the AKC network, in the extension offices. The results highlight the conditions that contributed to creating and stabilizing the AKC actor network, including (i) the presence of an actor who facilitates the process; (ii) alignment of interests among actors in the extension offices while carrying out the project; (iii) capacity and motivation of the various actors to execute their roles; and (iv) availability of adequate infrastructure such as fast internet connection and reliable electricity.

Interpreting the results via the perspective of ANT offers a clear view of the complexity of interactions and associations of people and technology. For instance, analyzing how the human and non-human actors interacted in making space available and assigning center managers, revealed a series of actions, events, and detours actors took to stabilize the AKC actor network. The AKC actor network started with defining the problem, which was a lack of access to up-to-date and relevant agricultural information and difficulty to exchange knowledge among peers in the agricultural extension offices. Following through the four translation phases revealed actors' willingness and commitment to offer ICT-based services through their interests, identities, and actions to establish AKCs. Framing this empirical chapter with the ANT concept, specifically the

four phases of translation, brought out the interactions and iterative processes among the different actors, which shaped the AKC establishment and management process. Furthermore, the translation phases supported an in-depth understanding of the human and non-human actors' roles and actions and the creation of the new sociotechnical assemblage.

Chapter three presents an exploratory case study on understanding extension experts' perceptions of ICT's usefulness in the AKCs of the four extension offices in the South Wollo zone. A mixed-method approach was used to gather data on the users' perceptions of technology use and their actual use. Three concepts from the theory of planned behavior: attitude, social norms, and perceived behavioral control, were used to structure and interpret the results.

Perceptions of users towards the potential of ICTs for extension service, in general, were positive. However, they believed that ICT's actual usefulness is limited in their current context. Reasons identified for the limited use and the prevailing perceptions were: (i) lack of sufficient knowledge on how to use computers to retrieve agricultural information from the internet; (ii) experts field dominated working conditions, which allows little office time; and (iii) uneven internet connectivity and unreliable electric supply.

The results indicate that the potential of ICTs in extension services can be exploited when the targeted users have a positive attitude towards the usability of ICTs for agriculture extension and. In addition, there is a need for an extension system that supports a more dynamic and responsive service delivery that encourages experts to seek information and knowledge via ICT use. This transformation requires an organizational reform of the current extension approach as well as a supportive organizational structure and infrastructure. The methodological approach used in this study helped to reveal the underlying reasons for extension experts' attitudes and perceptions of ICT usefulness for their work.

Chapter four presents the results of a systematic literature review of 49 published full-text articles that focused on ICTs and agriculture extension organizations. The review study aimed at analyzing organizational characteristics that facilitate or hinder organizations from learning to use ICTs as a method for agriculture extension delivery. Sources for the retrieved articles were two scientific databases, Scopus and CAB. The studies were screened, coded, and categorized for analysis. The results present the reviewed articles' characteristics, list of individual and organizational characteristics identified, and further analysis of the organizational characteristics through the lens of a learning organization.

The results in chapter four prove that recent literature emphasizes on understanding the contribution of employees' individual characteristics including demographic characteristics, knowledge and skill, and attitude in ICT use for agriculture extension. The reviewed studies also identified tangible organizational characteristics such as budget, infrastructure availability, and their consequences on ICT use. In contrast, few studies investigated the broader enabling environment's contribution, such as ICT policy and telecommunication networks in ICT use. Concerning how extension organizations facilitate adaptation to the new communication and knowledge acquisition methods, two aspects were prominent in the literature. The first aspect emphasizes the presence or absence and consequences of (not) having opportunities for training on developing skills to use ICT. The second aspect emphasizes the need to create a system to capture and share learning by facilitating two-way communication among the employees. Other important organizational aspects, such as promoting dialogue and feedback system to develop ICT use skills, and facilitating collaborative learning to improve ICT use for agriculture extension, are scarcely explored.

The review illustrates that there is literature on agricultural extension organizations introducing ICT to improve their services; however, it is still unclear how such organizations adapt to embrace changes that come with ICT introduction. This finding highlights the need for more studies on organizational learning processes to ensure better ICTs use for advisory services. The seven dimensions of learning organizations offer a framework to assess how organizations learn by emphasizing on processes usually intangible and overlooked.

5.3 Discussion of the results

In the era of digitalization, there is a massive emphasis on exploiting the potential of digital technologies to solve communication challenges. Greater access to information for agriculture development is one of the key benefits of digital technologies (Malabo Montpellier Panel, 2019). The necessity of solving the communication challenge led to the piloting of many ICT for agriculture initiatives across the agriculture value chain (Aker, Ghosh, & Burrell, 2016). ICTs are used to enable access to timely, reliable, and accurate information on land rights, inputs, markets, and weather forecasts to farmers. ICT also offers possibilities for digital extension services on pest and disease management as well as livestock production (Aker, 2011; Baumüller, 2018).

Some studies on ICT for agriculture extension argue that there is a mixed impact of these initiatives in bringing social and economic development (Aker et al., 2016). Such studies advocate for the need to continue improving access and use of new technologies by focusing on

connectivity, quality of content, and capacity of the targeted users (Nakasone & Torero, 2016). Additionally, studies highlight that no matter how advanced and superior, technologies alone are insufficient to influence information and knowledge use (Sulaiman et al., 2012). Instead, it is the technology's alignment with the knowledge or perception of the beneficiaries about the usefulness, and the social and organizational arrangement in the context, including the formal and informal rules (Leeuwis, 2013; Heeks & Stanforth, 2015).

The results of this thesis challenge the notion that better access to ICT leads to better use of the tools for agriculture information dissemination and knowledge exchange. The empirical evidence presented affirms that access to ICT does not automatically bring better use of agricultural information and knowledge. The desired outcome happens only when ICT access is combined with favorable social and organizational conditions in the context.

In the light of the theoretical framework of this thesis, the three empirical chapters highlight that ICT use in public agriculture extension organizations is not only about access or individuals' competency, but also the alignment of different technologies, infrastructure, institutions and actors that can be summed into 'hardware', 'software', and 'orgware'. As described in the conceptual framework, the bio-material dimension, which is the 'hardware', included ICT devices available in the AKCs and internet connectivity. The symbolic dimension, which is the 'software', included the users' and managers' perceptions towards ICT usefulness and their knowledge of available digital content. The social dimension, which is the 'orgware', included the organizational structure, the decision-making process of managers, the roles and responsibilities of the AKC manager, and the scheduled opening time of the AKCs.

The results in chapter two confirm that the course of the AKC establishment was determined by how the local actors made sense of the AKCs and how they integrated AKCs in the respective organizational structure. Establishing the AKCs needed the stimulation and facilitation of new orgware components in the extension offices. The components were creating new job positions in the organizational structure, allocating AKC rooms, and signing agreements with the telecommunication service providers and the LIVES project. However, the respective offices did not have the mandate to create a new job position for an AKC manager. The absence of this component created a challenge for the alignment, especially when the project intervention ended. The other component, allocating an AKC room where ICT tools are used for information exchange created a challenge in some of the extension offices, where the rooms were deemed more useful for conducting meetings and training workshops. Here we observe the difficulty of

aligning the orgware components with the software (positive perceptions) to put the hardware (ICT) to use.

The project coordinator, who was the main actor in the network (Latour, 2005), used different strategies to address the intrinsic needs and interests of the decision-makers. The enthusiasm for modernizing the extension system by applying ICT based methods and the excitement for getting modern ICT devices from LVIES resulted in a positive perception (software) among the decision-makers. This situation led to making agreements with the LIVES project (orgware) to allocate rooms for AKCs (hardware). Here we observe that the three dimensions were aligned, therefore, AKCs were established in the extension organizations.

The actual ICT use in the AKCs for agriculture extension, however, was challenged. Chapter three presents the perception of the targeted users of the AKC services towards the usefulness of the services for their job. A generally positive perception (software) towards the potential of using digital technologies for agriculture information was observed among the study participants. The exposure to ICTs in higher education institutes played a role in forming this positive perception towards ICTs potential in facilitating job delivery. The positive expectations, however, led to the use of the ICTs for personal benefits. ICT use for work was not prominent due to the perception of the experts regarding the orgware in place. The experts perceived that the rigid extension approach that encouraged only the use of standardized and pre-prescribed manuals did not allow them to use ICTs for acquiring information that supports their extension work. These observations show how the mental modes (software) affected ICTs use for better communication and knowledge access in extension work.

Across all empirical chapters in this thesis, perceptions of experts and leaders towards the usefulness of ICTs for extension work (software) played a central role in ICT use. Hoffmann et al. (2009) noted that previous experiences and knowledge influence an individual's attitude and perception of technology. The extension service in Ethiopia, which is characterized by top-down and standardized technology transfer (Berhanu & Poulton, 2014), has influenced experts' perceptions of ICT usefulness for extension work. Understanding what information and knowledge the targeted users' value (Pick, Gollakota, & Singh, 2014), their education level and gender (Strong, Ganpat, Harder, Irby, & Lindner, 2014; Tata & McNamara, 2018), and the policy and approaches of extension service is essential for initiating knowledge-seeking behavior via ICTs.

The infrastructural situations presented in chapters two and three, such as erratic power supply and uneven internet connectivity (hardware) in the extension offices, made ICT use in the AKCs difficult. Similarly, a poorly designed incentive system (orgware) for the appointed AKC managers in the respected offices created their reluctance to make ICTs (hardware) functional and to support the extension experts in using the ICTs.

The orgware components that were captured in the two empirical case studies are tangible organizational characteristics. Other studies have also analyzed tangible orgware components, such as devices, resources, and structures (Ahmadpour et al., 2010; Gunawong & Gao, 2017; Allahyaria et al., 2018). Chapter four uses the learning organization concept to analyze the intangible and process-related organizational characteristics identified in the recent literature. The analysis brought out two less visible orgware components that limited ICT use in the extension offices. First, creating training opportunities for developing knowledge and skills in ICT use. Second, creating structures in the extension organizations to encourage on-the-job learning. However, the orgware components related to creating a collaborative environment, leadership style, and empowerment, which equally influence perception and knowledge (software) and skill (hardware) of advisors, received little emphasis in the reviewed articles. The reviewed articles emphasize one or the other dimensions of innovations rather than all three and their inter-related outcomes. Schut et al. (2016) also noted that literature on agricultural research for development places most of its emphasis on technical rather than the institutional and social dimensions of innovation.

In general, existing literature seems to focus either on individual characteristics, technological characteristics or tangible organizational characteristics that contribute to ICT use (World Bank, 2016). Similarly, reported development interventions and practice seem to focus on providing access to narrowing the digital divide as a means to ensure ICT use. However, as results of the empirical chapters reaffirm, ICT use is no longer a technical challenge but rather the combination of the technical, social and organizational arrangements (Chapman & Slaymaker, 2002; Sulaiman et al., 2012). Similarly, Dormon, Leeuwis, Fiadjoe, Sakyi-Dawson, & van Huis (2007) asserted the need for re-organizing the existing system and mobilizing experts for learning a new way of acquiring and sharing agricultural information (orgware).

An understanding of how extension organizations adapt to changes related to digital technologies and learn to use these technologies for agriculture extension would provide profound insights into the interaction of the three different components of innovation. However, it seems this is lacking.

Knowledge of how extension organization members adapt their strategies and structures (orgware), develop the knowledge and skills of their employees (software) to facilitate a change process in ICT use is scarce.

Leeuwis & Van den Ban (2004) noted that agriculture extension organizations are highly challenged to create a learning environment for advisors. According to the authors, this is because the agriculture extension organizations are characterized by little space for critical thinking, are less open to problems or mistakes, and have no reward system. However, unless these organizations learn to adapt themselves to the changes that come with ICTs, they cannot realize their full potential in improving the agriculture extension service. The learning should take place at an individual, team, and organizational level.

One way of stimulating learning at the individual and team level in the extension organizations could be introducing special rewards to encourage knowledge acquisition and knowledge sharing among the extension advisors (Yadav et al., 2015). Due to the funding limitations agriculture extension organizations usually encounter, non-monetary incentives and recognition can be options to encourage knowledge sharing and information exchange among experts.

Leeuwis (2013) asserts that the outcomes realized are not necessarily the same as those for which technology was originally intended but are the result of significant changes in the technical, social, and organizational relationships. In line with this, the findings of this thesis demonstrate how ICT interventions aiming to provide better access to up-to-date and relevant agricultural information were shaped by the interaction of the social, technical, and organizational components. The positive perceptions of experts and decision-makers towards ICT potentials and promises of modernization (chapter three) coupled with the pressure from the implementing project at national level and the agriculture bureau at the regional level (chapter two) ensured the establishment of the AKCs. However, the actual ICT use for extension was accounted to the users' perceptions towards their usefulness (chapter three) and the organizational characteristics (chapter four).

The results of the thesis reconfirm the notion that new technologies alone do not become innovations that work unless they are aligned with new social and organizational arrangements (Heeks & Stanforth, 2015; Leeuwis, 2013). Therefore, it is important that extension organizations and development programs take an innovation process perspective and focus on facilitating the

alignment of technologies with the social and organizational components. Only with the perspective of innovation process can ICT be used for extension work in a sustainable manner. Otherwise, the perceived benefits of ICT in creating new opportunities in agriculture knowledge management and accelerating innovation processes to the intended beneficiaries remain a promise.

5.4 Significance and contribution of the study to the literature

The results in this thesis have significance and contribute to the literature for the following reasons:

i. This thesis presents the iterative negotiations and interactions of human and non-human actors in ICT for extension innovation. By taking a network perspective and studying the assemblage of actors, it presents deeper insights into why complex innovations become (not) successful. This applies to innovations in ICTs and other novel technologies where there is a wider and complex involvement of multiple actors, human and non-human. In this regard, approaches such as ANT have increasing relevance for understanding innovation process.

   The Ethiopian Government has taken steps to improve access to agricultural information resources by bringing ICT closer to smallholder farmers. Within this context, some studies have evaluated the impact of ICT by looking at technological aspects such as access, infrastructure, and sustainability. However, there is still little discussion about how the thoughts, actions and interactions of actors engaged in the process influence the ultimate use of ICT. In this regard, this thesis has made progress toward the enhancement of our understanding of the interactions and negotiations of various actors in forming a new sociotechnical assemblage, the AKC actor network. These insights can inform future projects and programs in Ethiopia and other similar context, on the importance of designing and implementing ICT initiatives by aligning engaged actors' interest for a sustainable impact.

ii. Contrary to the mainstream literature on ICTs for agriculture in Ethiopia and other developing countries that focus on the technological aspects of technology adoption and impact, this study focused on the behavioral aspect, perceptions of extension experts

towards ICTs usefulness and their use for extension services. Through quantitative and qualitative research methods, the study showed that extension experts had a positive perception about ICT's usefulness as a whole, however they thought ICT has a limited relevance for their current extension work. Structural inefficiencies and resource constraints in the extension organizations as well as established institutional norms were believed to be the underlying reasons for experts' perception in this regard. These observations have multiple implications: Firstly, the findings have revealed the importance of focusing on individual perspectives of key actors to gain insights on technology use. Secondly, by shifting the focus from the end users (farmers) to intermediaries (extension experts), the study provides an understanding of technology use in the wider agriculture innovation system. The results show that access gives no guarantee that ICT improves professional services unless it is coupled with users' perceived needs, skills and knowledge, and encouraging organizational environment. Thirdly, by using the three concepts of the theory of planned behavior, attitude, social norm and perceived behavioral control, the study adds to the analytical value of these concepts for qualitatively exploring the underlying reasons for a behavior or an intention, including experiences and attitude in a more in-depth manner.

iii. To use ICT, organizations must adjust the way they are set up, managed and organized. This study is the first attempt to synthesize insights on organizational characteristics that readily allow organizations to learn and enhance ICT services in agriculture extension. By conducting a literature review of ICT use in public extension organizations and taking the perspective of the learning organization, this thesis synthesizes current knowledge on ICT in extension organizations. The findings serve as an initial step by exploring how specific learning organization characteristics such as continuous learning opportunities, promotion of inquiry-based behavior and collaborative visioning contribute to ICT use in extension organizations. In addition, the results illustrate how the learning organization concept provides a useful lens to examine organizational characteristics influencing ICT adoption. In doing so, the study offers important new insights for further investigation in the ICT for advisory service literature.

iv. The rapidly increasing availability of ICT has sparked optimism about its potential for improving extension and advisory services worldwide. At the same time, this thesis highlights the importance of a more integrative approach that aligns technological devices with the prevailing social and organizational characteristics to enhance ICT use. To that

end, the findings offer insights to development organizations at the global and the national level promoting and investing in ICT for agriculture extension programs.

5.5 Reflections on research approach and recommendations for future research

The initial planning of this research and its implementation was inspired by my personal experience as a project staff in two research for development projects IPMS and LIVES, between 2010 and 2015. As a project team member, I actively engaged in project activities related to improving agriculture information dissemination through different media, including ICTs. Therefore, developing an interest in technology use in advisory services became natural and led me to pursue an academic analysis on the topic.

For collecting data, I selected the LIVES project sites in Amhara region as the region offered the possibility to communicate with study participants in my native language Amharic. Understanding the language spoken in the study site was necessary as the study draws on an interpretive research approach that generates meaning through specific experiences and interpretations of study participants. Accordingly, I captured the experiences and interpretations without any language barrier. In addition, I did not perceive the thesis as objective, rather the interaction between myself, the empirical context, and literature have generated the understanding.

Returning to the project sites as an external researcher after a short absence from the LIVES project might have caused bias both from my side and the study participants. Knowing why the AKCs were established, I struggled not to go into an evaluation mode but instead document the process and experiences as an external observer. The use of narrative techniques and focusing on the actions helped. Still, it was impossible to completely rule out study participants' bias in their responses due to my association with the on-going LIVES project.

I conducted the fieldwork in three phases in a time span of six months, with gaps in between. The gaps allowed me to reflect, discuss experiences with supervisors, and prepare for additional information needed from respondents. Flexibility in conducting interviews was essential as the extension experts were busy with fieldwork at farmers' fields or engaged with other assignments outside of the office.

5.6 Methodological limitations of the study and recommendations for future research

At the time of fieldwork, collecting data to study the experts' interaction with the ICT equipment and the implementation process involved reconstructing events from three years ago. Therefore, the data gathered are subjected to recall bias by the study participants who narrated the events. I acknowledge the limitations of the method in recalling events from the past. In this study, I considered only the context of extension offices. However, assemblage involve interactions and collaborations at a wider geographical and organizational level. Therefore, future studies investigating the interaction of technology with the social and organizational aspects at extension office levels in districts, zones, regions, and national levels can provide more insights.

In chapter three, data were collected and analyzed only from extension experts who used ICT in the AKCs and the supervisors of those experts. The study focused on general perceptions and the underlying social and organizational factors that enable or hinder ICT use. Therefore, the study excluded experts and supervisors who did not use AKC services. In addition, the study did not capture the extent to which the availability of relevant content impacts experts' perception towards the usefulness of ICT for extension work. Therefore, further investigations in the following aspects might shed light on the efforts to enhance ICT use: (i) comparing the traits of ICT users and non-users in an extension organization and between extension organizations, (ii) the extent to which relevant information is digitally available for extension experts to make use of use of the digital facilities made available.

In chapter four, the analysis of literature on ICT in agriculture extension organizations literature showed that many studies highlighted the presence or absence of the characteristic *creating training opportunities* and slightly touched upon other characteristics. This might be because none of the studies reviewed used the learning organization as a conceptual and analytical framework. Further research investigating the characteristics of agriculture extension organizations introducing ICT might shed light on characteristics that facilitate or hinder learning. Potential areas of research include (i) analyzing the complexity of introducing ICT in extension organizations and the change process over time; (ii) analyzing the leadership style of stakeholder groups and the organizational conditions in which they function for gaining better insights into extension organizations as learning organization; (iii) analyzing the merits of digital technologies in facilitating networking and collaborative learning among employees, departments, and extension organizations.

5.7 Policy implications

The government of Ethiopia aims to enhance its efficiency across development sectors and foster the development of agriculture services through an ICT-enabled transformation plan (Lixi and Dahan, 2014). The agricultural extension strategy of Ethiopia promotes a digitalized and ICT-based extension communication system to enhance the effectiveness of conventional extension methods (MoANR, 2017). This thesis compiled three studies that explored and assessed the implementation of ICT initiatives and the use of ICTs in the context of extension organizations. The results may provide insights into the experiences of introducing and using ICTs for agriculture extension, which can be a useful input for improving policy and practice on a range of issues as described in the following.

Creating awareness on the purpose of ICT for agriculture extension and developing digital literacy of targeted beneficiaries

Targeted users' knowledge and perceptions play a vital role in how technologies are used (Leeuwis & Van den Ban, 2004). Chapter three illustrates a situation where extension experts' digital knowledge and their perceptions towards the importance of acquiring additional knowledge limited their use of the services offered. Development programs aiming at contributing to the transformation of the agriculture sector should invest both in introducing technologies and instilling a knowledge-seeking behavior and a positive attitude among the extension experts. The first step should be identifying the needs of the experts as well as the organizations regarding ICT applications. Then the next step should be creating awareness on ICTs potential and developing a training program in a participatory manner to develop advisors' capacities for better ICT use.

Creating organizational conditions that facilitate learning at the level of individual, team, and organization

The global trend in ICT use has maximized the ability of individuals and organizations to take advantage of knowledge developed in other places or for other purposes (Hall, 2007). To make use of the advantages that come with ICT in development, organizations have to adapt or create new organizational cultures (Sulaiman et al., 2012; Yadav et al., 2015). The empirical chapters of the thesis illustrate organizational characteristics that expedite or hinder ICT use. Organizational characteristics that are tangible such as budget limitation, access to devices, and presence or absence of training opportunities, are frequently emphasized. However, other subtle but equally important characteristics, such as strategic leadership processes, nurturing collaboration among

experts, and encouraging critical thinking, are less investigated. Recognizing the contribution of all organizational characteristics for ICT use is vital to realize ICT's full potential. Therefore, programs that aim to implement ICT projects in the future should ensure that extension organizations can adapt and are able to create conducive learning conditions. Decision-makers in the extension organizations should follow up on the ICT skills of the employees, encourage collaboration between the experts to exchange information and share knowledge through using ICTs. Leaders should also design a strategic leadership style that champions extension experts and provide coaching and mentoring to encourage ICTs application for knowledge use.

Recognizing and stimulating interaction between innovation components is necessary to successfully implement and utilize ICTs in agriculture extension

The importance of recognizing and stimulating interaction between technological, social and institutional components of innovation is noted as a key for promoting agriculture development (Kilelu, Klerkx, & Leeuwis, 2013; Leeuwis, 2013; Smits, 2002). This thesis illustrates the complexity of interactions and associations of people and technology in the institutional context of public extension offices in Ethiopia. The empirical chapters provide evidence that ICT enables the desired change in communication and knowledge use only when the access is synergized with favorable social and organizational conditions. Therefore, development projects and programs need to design and implement an ICT project that takes into account the interdependency of the three dimensions to foster social and economic development. Narrowing the gap between suppliers and users of technology through demand articulation (Klerkx & Leeuwis, 2008) can increase ICT use for agriculture. In particular, building on the existing system of knowledge access in a participatory manner (Sulaiman et al., 2012) can support the realization of the intended behavior of ICT use. Therefore, research and development programs should embrace a transdisciplinary approach that stimulates co-creation of innovations. New tools and methods can be applied and modified in a participatory setting according to the needs of the various actors in a specific context.

Creating an enabling environment that supports knowledge sharing and information exchange is necessary to harness ICT's potential in facilitating agriculture extension service.

Introducing ICT in public extension organizations is most effective when accompanied by policy and regulatory instruments that improve accessibility, affordability, and reach of ICT. Chapter

three illustrated the challenges of using ICT services due to the top-down transfer of technology approach by extension organizations. Another challenge related to infrastructure, such as unreliable electricity supply and uneven internet network accompanied by weak connectivity speed was also highlighted in chapter four. These issues need to be addressed at different levels: Firstly, functional and reliable infrastructure and management of ICT services require investment and technical expertise for its operation. Secondly, the potential of ICT cannot be fully realized in a top-down approach. It requires a bottom-up extension approach that allows active learning and knowledge-seeking behavior of experts. The system should encourage greater flexibility of experts' response to farmers' needs by easing the emphasis on standardized manuals.

5.8 References

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Annex 3

Declaration in lieu of an oath on independent work

according to Sec. 18(3) sentence 5 of the University of Hohenheim's Doctoral Regulations for the Faculties of Agricultural Sciences, Natural Sciences, and Business, Economics and Social Sciences

1. The dissertation submitted on the topic

Public Agriculture Extension and information communication technologies:

A case study in South Wollo, Ethiopia

is work done independently by me.

2. I only used the sources and aids listed and did not make use of any impermissible assistance from third parties. In particular, I marked all content taken word-for-word or paraphrased from other works.

3. I did not use the assistance of a commercial doctoral placement or advising agency.

4. I am aware of the importance of the declaration in lieu of oath and the criminal consequences of false or incomplete declarations in lieu of oath.

I confirm that the declaration above is correct. I declare in lieu of oath that I have declared only the truth to the best of my knowledge and have not omitted anything.

Stuttgart,08.04.2021

Fanos Birke

Place, Date

Signature