AGRO-ADVISORY SERVICES: INCLUSIVE DIGITAL SOLUTIONS FOR PROFITABLE SMALLHOLDER FARMER GROUPS IN NORTHERN UGANDA

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Paris Lodron University of Salzburg (PLUS), Austria

Technical Faculty of IT and Design

Aalborg University (AAU) in Copenhagen, Denmark

Submitted by

HILDA ADUR

Student number: s1093281

Primary Supervisor: Jannick Kirk Sorensen

Secondary Supervisor: Josef Trappel

Tutor: Rico Lie

Department of Communication Studies

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"I just need to write my thesis!"
And I conquered it, I climbed this mountain!

The digital ink has dried and the words indeed aligned
Through consistent doubts, your voices were near
Banishing any roaming fear in me
You have sown love in me.

Yours,
Grateful child!

Agro-Advisory Services: Inclusive Digital Solutions For Profitable Smallholder Farmer Groups In Northern Uganda

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AKIS - Agricultural Knowledge and Information System

RCS - Rural Communication Services

Executive Summary

In an era defined by digital connectivity, the irony of rural farmers in Northern Uganda struggling to translate their agricultural output into financial gains, let alone profits, is alarming and a potent indicator of a critical disconnect. Northern Uganda is burdened by the legacy of a 20-year war that ended in 2006 yet still suffers from poor infrastructure in education, health, and agriculture. Yet agriculture remains their sole income. Notwithstanding, farmers have arranged themselves into farmer groups to access better agricultural advice to maximize profits. Most farmer cooperatives leverage digital tools for managerial tasks. Despite these efforts, farmer cooperatives have not yet fully benefited from the vast digital opportunities. In this study, the question is, *what additional value does digital technology bring to agricultural advisory services for stakeholders in Northern Uganda?*

The study drew upon the Agricultural Knowledge and Information (AKIS) framework to understand the complex network of actors and the Rural Communication Services (RCS) framework to examine the role of communication in agricultural development. The study draws insights from twenty semi-structured interviews and focus group discussions with agricultural stakeholders.

Farmer cooperatives, extension workers, and input dealers emerged as central hubs for knowledge sharing and resource pooling, playing crucial roles in sharing information and supporting farmers. The findings also revealed the persistence of traditional communication channels like radio and face-to-face interactions, particularly in remote areas, while highlighting the increasing adoption of digital tools such as mobile applications.

Digital tools like Symos offer significant benefits to farmers, including improved market access, enhanced traceability, and streamlined production monitoring. These tools have the potential to revolutionize agricultural practices. However, challenges such as cost, limited connectivity, and the need for training and support hinder wider adoption. Additionally, concerns about data privacy, and potential inequalities necessitate careful consideration in the design and implementation of digital solutions. Takeaways are user-centered design, capacity building, and equitable partnerships in the development and deployment of digital tools. These insights are valuable for agricultural stakeholders seeking to leverage digital technologies to enhance agricultural productivity, livelihoods, and sustainability.

Introduction

> “My dear, we have harvested enough food, but we do not have cash!” my mother recently pleaded on a phone call.
>
> Growing up, I despised full-time farming, yet chores at home awaited me. How about home tasks done during daylight and gardening late evening? My heart found peace in this chosen way, though not for all. Bellies empty or full? Whether fields flourish or are bare, cash is always a distant prayer.

More than half of the rural households are depend on agriculture for their livelihoods (Atube, Malinga, Nyeko, Okello, Alarakol & Okello-Uma, 2021). According to the Uganda Bureau of Statistics (UBOS) National Housing and Population Census 2014, smallholder farmers cultivate small plots of land, use simple tools, rely on family labor, and primarily produce for their own needs with a small surplus for sale. Due to limited transportation, smallholder farmers often sell their produce at low prices at their farms. Throughout the agricultural value chain, small-scale farmers in Uganda encounter numerous obstacles, including a need for knowledge and skills to add value to their products, limited finances to invest in and utilize appropriate resources, and restricted access to markets. These challenges hinder their ability to improve productivity and expand their reach to consumers (Atube et al., 2021).

In Northern Uganda, a paradox exists where abundant agricultural harvests often fail to translate into financial stability for rural farmers. Research and technological intervention focus on savings and credit cooperatives, but little is known about agricultural cooperatives' interactors and digital tools. Maru, Berne, Beer, Ballantyne, Pesce, Kalyesubula & Chavez (2018) argue that data and information flow throughout the agricultural value chain, interconnected with financial and commodity flows. However, each stage uses data and information differently, and imperfect flows can disrupt the system (Maru et al., 2018).

Despite good intentions, government advisories are often delivered in complex language and fail to address the specific needs of individual farmers, resulting in low adoption rates (Fabregas, Kremer & Schilbach, 2019). Radio broadcasts, while widely accessible, lack personalised content and timely updates, rendering them insufficient to address the dynamic challenges farmers face in real time. Furthermore, the cost of radio talk shows can be

prohibitive for many agricultural organizations and extension services, limiting the reach and frequency of broadcasts (Kyazze, Bold, Kakande & Magala, 2018).

Inclusive agro-advisory services are accessible, usable, and beneficial to all farmers, regardless of gender, age, education, socioeconomic status, or location. It involves designing and delivering agro-advisory services in a way that considers the diverse needs, constraints, and preferences of different farmer groups, ensuring that no one is left behind.

Extension workers play a crucial role in bridging this gap. They act as intermediaries between farmers and information sources, translating complex agricultural knowledge into practical advice (Spielman, Lecoutere, Makhija & Van Campenhout, 2021). However, traditional government and external extension services (Sylla et al., 2019; Wuepper, Roleff, and Finger, 2021) have shown limitations and require modernization to meet current agricultural challenges (Amoussohoui, et al., 2024).

Their reach is limited, particularly for those farmers not participating in organised groups (Adong et al., 2012). This is where farmer cooperatives step in, offering a platform for collective bargaining power, resource sharing, and knowledge dissemination (Loevinsohn, Sumberg & Okali, 1994; Woomer, Okalebo, Palm & Smyth, 2004). Many early data services were tailored for larger, commercial farms because smallholder farmers are difficult to access (Mara et al., 2018). With Northern Uganda boasting the highest membership rates in the country, these cooperatives are uniquely positioned to leverage the potential of digital tools to transform agricultural advisory services (Adong et al., 2012).

Digital technologies offer the promise of revolutionizing the agricultural sector, providing farmers with real-time, tailored information on market prices, weather patterns, and best practices (Stevens, Winter, Shackleton & Shackleton, 2016; Kansiime, Mugagga, Mugisha & Nakato, 2021; Birner, Daum & Pray, 2021). These tools, particularly mobile phones with GPS functionality, have the potential to enhance the efficiency and effectiveness of extension services while addressing issues of cost and accountability (Fabregas et al., 2019). The widespread use of mobile phones in the region presents a unique opportunity for farmers to access this wealth of information, potentially leading to improved decision-making and increased productivity.

However, the adoption of digital tools comes with its own set of challenges. The initial cost of acquiring devices and data plans can be prohibitive for many smallholder farmers,

especially in marginalized communities with limited resources (Donner, 2008). Additionally, limited digital literacy and unreliable network infrastructure in rural areas pose significant barriers to the effective utilization of digital technologies (Myovella, Nkhoma, Gondwe, & Khonje, 2021; McCampbell, Campbell, Thornton, & Vermeulen, 2021). Despite these challenges, studies like Aker and Blumenstock (2015) have shown a positive correlation between access to digital information and improved agricultural productivity, suggesting that the initial investment in digital tools can yield significant long-term gains for farmers, outweighing the upfront costs.

This study, grounded in the theoretical frameworks of Agricultural Knowledge and Information Systems (AKIS) and Rural Communication Services (RCS), investigates the specific value that inclusive digital technology brings to agricultural advisory services for stakeholders in Northern Uganda.

Research Objective

The research objectives that drive this study are to identify primary sources of advisory information for agricultural stakeholders. Consequently, the extra advantage that comes with control and ownership of digital tools.

Research Question

Given the contention, this research addresses the following question:

What additional value does digital technology bring to agricultural advisory services for stakeholders in Northern Uganda?

The research question can be further broken down into sub-research questions:

RQ1: What are the main sources of agricultural advisory information?

RQ2: How do digital tools impact the delivery and uptake of agro- advisory services?

This study follows a design methodology utilising qualitative interviews with twenty (20) participants leveraging both traditional and digital tools for farming advice. To address RQ1, the interviews with the participants reveal their most preferred means of agricultural advisory services. Output will be a stakeholder analysis of the agricultural value chain of these farmer

cooperatives and primary sources of information sharing using the Rural Communication Services framework.

To respond to RQ2, the output will be user-centred design recommendations of agro-advisory solutions for rural farmer cooperatives. These will emerge from themes and insights from the brainstorming process with the interviewees to understand their agro-advisory needs for future design and delivery of these services.

This research aims to understand the actors and their preferred communication channels, existing challenges and opportunities to gauge the potential of digital technologies for the delivery and effectiveness of agro-advisory services. Consequently, leading to improved agricultural productivity, profitability, and overall well-being for the farmers of Northern Uganda.

Structure

This research begins by establishing a theoretical framework using AKIS and RCS to guide the investigation and answer the research questions. Then a thorough review of existing research, clarifying key concepts like the role of extension workers in sharing agricultural information.

The methodology section details the literature review process, the development of interview questions, and the rationale behind choosing a qualitative approach. It also covers sampling techniques, data collection through interviews, ethical considerations, and validation methods.

Following this, the findings and discussion section, interviews are presented and analyzed using the established theoretical foundation. The research concludes by summarising the research insights while acknowledging limitations, summarizing key points, and providing references and appendices.

Theoretical Framework

Integrating two frameworks, Agricultural Knowledge and Information Systems (AKIS), and Rural Communication Services (RCS) will provide a comprehensive approach to developing digital agro-advisory services that are socially relevant and user-centric. Combining these two frameworks ensures that the technological solutions are not only technically sound but also socially sustainable and widely accepted by the target users in the rural setting.

Agricultural Knowledge and Information Systems (AKIS)

A thriving institutional system is greater than just the total of its components (Rivera and Schram, 2022; Röling, 1989). The scholars say that a collection of institutions forms a cohesive "system" when its elements are interconnected and work together. These institutions collaborate by sharing their human, physical, and financial resources to pursue one or multiple shared objectives. Formal and informal institutions differ in their relation to laws, contracts, and other codified objects. Informal institutions are linked to social networks, customs, beliefs, and similar norms (Casson, Yeung, Basu & Wadeson, 2010; Prell, Reed, Racin & Hubacek. 2010). A social network is a pattern of friendship, support, communication, and advice that exists among members of a social system (Valente 1996; Thuo, Bell, Bravo-Ureta, Lachaud, Okello, Okoko & Puppala, 2014).

Röling (1990) defines agricultural knowledge and information systems as including farms and farmers and the connections and exchanges between them. These systems do many activities. They generate, change, send, store, find, mix, and use knowledge and information (Adolwa, Schwarze, Bellwood-Howard, Schareika, & Buerkert, 2017). The actors work together to help make decisions, solve problems, and innovate, they are in the agricultural sector of a particular country (Röling, 1990).

Agricultural Knowledge and Information Systems (AKIS) were initially viewed as having distinct boundaries and a singular purpose. However, this mechanistic "hard systems" perspective was criticized for assuming systems exist independently and can be engineered towards specific goals (Leeuwis, Röling & van den Ban, 1990). This approach is evident in adoption-diffusion and some farming systems studies (Klerkx, Van Mierlo & Leeuwis, 2012).

In response, a "soft systems" perspective emerged, emphasizing that actors perceive systems and boundaries differently based on their objectives and contexts (Checkland, 1999). This shift led the AKIS approach to focus on coordination among diverse actors within a "human activity system" with flexible boundaries. The systems concept was then used to encourage collaboration and shared understanding (e.g., Engel, 1995). Despite this shift, some organizations like FAO continued using AKIS concepts that emphasized clearer boundaries and objectives (Rivera, Qamar & Mwandemere, 2005).

AKIS evolved from the extension perspective, but Hall, Sulaiman, Clark & Yoganand (2003) criticize it for having a limited focus. They point out that AKIS primarily concentrates on actors and processes within the rural environment, neglecting the role of markets (both input and output markets), the private sector, the enabling policy environment, and other disciplines and sectors. While the AKIS framework acknowledges the importance of transferring information from farmers to research systems, it tends to imply that most technologies will be transferred predominantly from researchers to farmers (Klerkx, et al., 2012).

The AKIS (Agricultural Knowledge and Information Systems) model, which encompasses agricultural research, extension, and education, aims to integrate these three main agricultural knowledge systems (FAO, 2000; Rivera et al., 2005). In many countries, the development of modern farming began with the establishment of separate research institutes, universities, and extension services, with the expectation of collaboration to create and deliver new technologies to farmers (FAO, 2000; Rivera et al., 2005).

Within AKIS, three primary roles are identified: primary producers (collectors and researchers of data), intermediaries (collectors and translators of information), and end-users (decision-makers in agricultural entities) (Klerkx et al., 2012; Wolf, Frisch & Zilberman, 2001). Intermediaries add value to the information to meet the decision-support needs of end-users (Adolwa et al., 2016). However, in a dynamic knowledge system, these roles can overlap, with farmers acting as both producers and end-users of information (Wolf et al., 2001; Pascucci & de-Magistris, 2011).

The AKIS framework emphasises the importance of connecting institutions with farmers, the end-users of knowledge and information, to facilitate learning and improve farming practices (Rivera et al., 2005). This integration is crucial for enhancing livelihoods, fostering stability and growth, and enabling countries to compete effectively in the global agricultural market (Rivera et al., 2005).

An Agricultural Knowledge and Information System (AKIS) is a network of actors connected formally or informally through explicit or tacit knowledge exchange (Klerkx & Proctor, 2013; Röling, 1990; Wolf et al., 2001; Adolwa et al., 2012). Explicit knowledge is codified and easily transferable, while tacit knowledge is experiential, intuitive, and difficult to articulate (Röling, 1990).

Any individual or organization that applies or introduces innovative knowledge is considered an innovation actor (Spielman, Davis, Negash & Ayele, 2011). This includes both individual farmers and farm households, as well as collective action organizations like farmer associations, NGOs, and CBOs. Additionally, private sector actors like marketers, traders, and creditors play a role (Spielman et al., 2011). These actors operate within institutional structures defined as established norms, laws, and customs that guide human behavior (Prell et al., 2010).

However, existing AKIS/RD (Agricultural Knowledge and Information Systems for Rural Development) have been criticized for not fully meeting farmers' needs, particularly in terms of technology and market functionality (FAO, 2000). These systems are crucial for promoting sustainable agriculture and rural development, with their success often linked to innovation and productivity growth. There is a pressing need for these systems to better address the challenge of simultaneously increasing productivity and sustainability, while also fostering cooperation between research and other stakeholders (FAO, 2000).

Alternative AKIS/RD models have been proposed that are more comprehensive, incorporating subsystems like contextual and environmental factors (Fig 1). This expanded view includes components like policy, resources, communication, and institutional commitment, recognizing the complexity of AKIS/RD and the need for collaboration across public and private sectors.

In reality, Figure 1 would likely resemble a complex web of “crisscrossing connections”. The connections between these institutions were frequently lacking, and their ties with clients, such as farmers, were even weaker. This resulted in performance falling short of expectations, highlighting the necessity to transition from isolated AKIS agencies to better drive rural innovation more efficiently and effectively (FAO, 2000). Furthermore, it lacked acknowledgment of other involved entities like government, private sector, civil society, support systems, and markets (de Janvry and Sadoulet, 2001; Berdegué and Escobar, 2003; FAO, 2003). Additionally, the simplified diagram of the “knowledge triangle” fails to

recognize the significance of AKIS/RD for users and beneficiaries beyond rural producers. Furthermore, it implicitly underestimates the link between agriculture and rural development, although it is acknowledged that agricultural innovation is vital in itself and supports various pathways contributing to rural sector development.

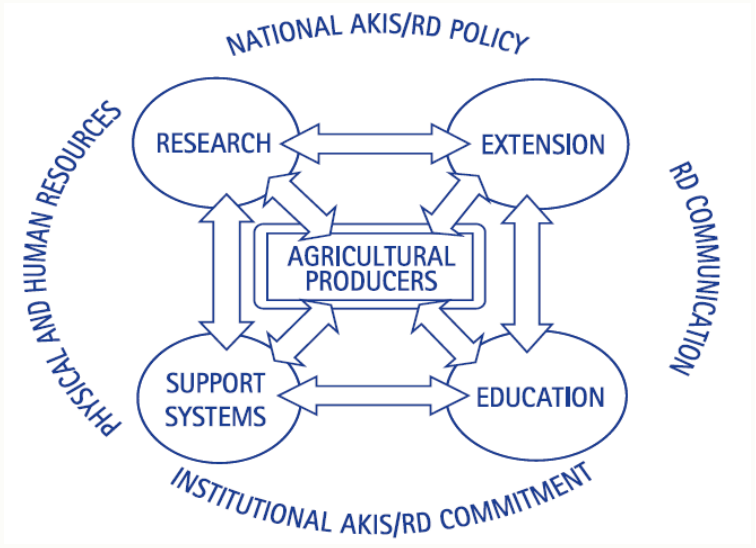

Fig 1: AKIS Framework of "crisscrossing connections"

The modern Agricultural Knowledge and Innovation Systems (see Fig 2) is a comprehensive approach to agriculture involving various stakeholders in agriculture and related fields (European Commission, 2021). These actors collaborate to generate, share, and utilise knowledge and innovation across diverse areas including agriculture, rural development, value chains, landscape management, environmental sustainability, climate resilience, biodiversity conservation, consumer engagement, and food/non-food systems (European Commission, 2021). This approach also emphasises the need for modernization, a strong Agricultural Knowledge and Innovation System (AKIS), and a robust digital strategy, as outlined by the European Commission in 2021.

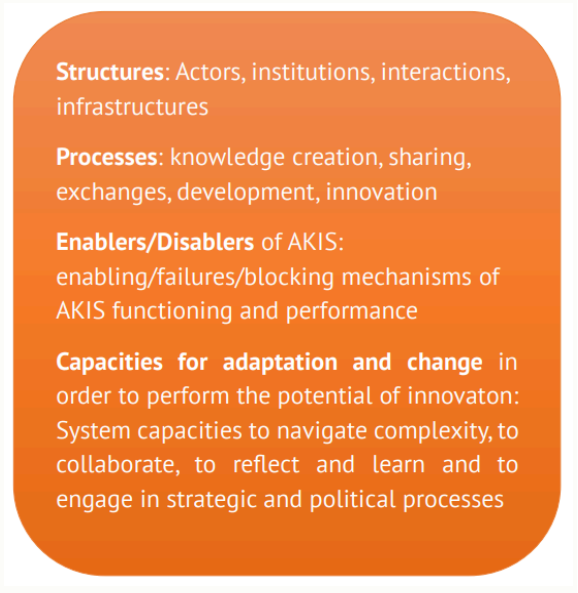

Fig 2: Modern AKIS

Digitalisation and Agricultural Knowledge and Information Systems

The development of agricultural knowledge and innovation systems (AKIS) has also been seen to be fueled by digitalisation. Different pieces of evidence with either a macro, meso, or micro perspective on knowledge and innovation systems can be discerned in this thematic cluster, which has recently emerged but is gradually becoming established (Klerkx, Jakku & Labarthe, 2019). From a macro viewpoint, some research employing innovation systems perspectives examines how innovation support structures enable digitalization, but also how these structures alter as a result of digitalization, for example by integrating big data analysis (Kamilaris et al., 2017).

According to Eastwood et al. (2017), some research also examines how AKIS for digital agriculture are shaped by a variety of new and existing actors in these systems, including service industries, multinationals that produce farming equipment and high-tech firms that manufacture drones and satellites.

A growing body of research examines how innovation systems can apply the concepts of Responsible Research and Innovation (RRI) by Owen et al., (2012) to the digitalization of agricultural production systems, value chains, and food systems (Bronson, 2018; Jirotka et al., 2017; Rose & Chilvers, 2018; Eastwood et al., 2019). This literature also explores how

transdisciplinary science can facilitate the integration of solutions that address a range of business, ethical, social, technological, and economic issues (Shepherd et al., 2018).

From a meso perspective, some research examines how learning networks are formed to support innovation in digital agriculture, based on theories of learning and communication (Eastwood et al., 2012; Kelly et al., 2017; Van Der Vorst et al., 2015). A few studies that look at how social media and digital platforms facilitate local and global information sharing and peer learning (Aker, 2011; Baumüller, 2018; Burton and Riley, 2018; Chowdhury and Hambly Odame, 2013; Jespersen et al., 2014; Kaushik et al., 2018; Kelly et al., 2017; Munthali et al., 2018).

It also explores how advisors engage with farmers to connect "digital knowledge systems" to "farmers knowledge systems" (Tsouvalis et al., 2000; Lundström and Lindblom, 2018; Bechtet, 2019).

Limitations of AKIS

Some argue that we should not predefine several stakeholders involved in AKIS. An additional model of the AKIS highlights the AKIS's national essence. On the other hand, some contend that the AKIS transcends national borders, particularly in the age of globalisation. Some argue that AKIS is about a new social contract. It's not about using tech to boost farming (Röling, 2007).

Röling explained why agricultural research failed to tap into creativity. He cited two main reasons. Farmers lacked opposing influence. Also, no middle-level markets or service groups existed. Röling in his paper suggested “listen to farmers”, the farmers have lived with nature their entire lives, and have the final say in induced innovation. Development communicators should ensure farmers have a say. This is especially true for those backing the Millennium Goals.

Give farmers negotiating power. Despite their expertise, farmers, at least in many developing nations, lack a unified voice. Farmers' lack of influence is starting to become a disadvantage. During the initial stages of the Green Revolution, farmers were essentially viewed as the lowest class in society. Scientists and administrators decided what needed to be done and then gave instructions to the farmers. Farmers need to be heard and given every chance to

contribute to the success of development. That innovation is the newly emerging quality of interaction between several stakeholders.

Röling explained that experiments are essential to finding alternatives. They offer a way out from the three harmful stories from top scientists, market fundamentalists, and top managers. Most countries are learning many important lessons. They learn them every day from experiments using various approaches. We must work harder to share knowledge through practical field experiments that introduce novel ideas. We can learn valuable lessons by admitting our failings and sharing knowledge. We can do this through practical field experiments. They can also help us come up with new ideas (FAO, 2004).

Engage those with authority to decide on agriculture and rural development frameworks. They work in education, research, and extension in fostering transformative learning. In short, working together is key to innovation. Development communication is vital for this collaboration. It does so by making knowledge co-creation through interactive learning a governance mechanism. It puts this on par with technology, hierarchy, and the market (Röling, 2007).

The AKIS Framework will help in understanding the primary sources of advisory information, mapping the existing knowledge networks and identifying potential gaps or areas for improvement, which is essential for fostering a cohesive and efficient AKIS.

Rural Communication Services (RCS)

For both urban and rural areas, information serves as the foundation for development (Harande, 2009). Communication is still key for agricultural transformation. Whether digital or not, communication is vital for rural farming communities (FAO, 1994). People have long viewed communication as a catalyst for innovation and social change in rural development worldwide, as seen in the work of Bell (1997) and FAO (2017).

For a long time, "communications" has hidden the importance of "communication" in development. In its singular form, communication refers to human social dynamics. Processes and media facilitate exchange and dialogue to promote development. But, "communications" in its plural form usually refers to the tools and outputs. They are used for integrating communication. Mixing up "communications" and "communication" mainly links public relations to roles that involve talking. It leads to associating them with behavior

change and advocacy. This neglects the focus on communication for development and change.

The report is called "Farming for the Future: Communication Efforts to Advance Family Farming" (FAO, 2014). It says RCS are ongoing two-way processes often given to rural people. They are meant to improve rural livelihoods. They do this by helping people get knowledge and information fairly. They also promote social inclusion in decision-making. And they make the links between rural institutions and local communities stronger.

RCS also includes the structured frameworks and methods. They are used to deliver Communication for Development (ComDev) in rural settings (FAO, 2017). Fraser and Restrepo-Estrada (1998) defined “ComDev as the use of communication. It uses processes, techniques, and media to help people fully understand their situation and their options to change. It aims to resolve conflicts. It works to find agreement and help people plan for change and sustainability. It also helps people gain the knowledge and skills they need to improve themselves and society. It also helps them improve the effectiveness of institutions” (Acunzo, Pafumi, Torres & Tirol, 2014). ComDev brings transformative change. The knowledge it produces and the power it fosters drive societal change (Besset, 2005).

The World Congress on Communication for Development in 2006 defined ComDev

as “...a social process based on dialogue using various methods and tools. It seeks change at different levels and involves listening, building trust, sharing knowledge and skills, shaping policies, debating, and learning for sustained and meaningful change.” (Acunzo, et al., 2014)

ComDev's participatory and comprehensive approach to development is what sets it apart from other communication methods. It does not just focus on behaviour change through one-way talk. It advocates for a holistic approach based on two-way communication. This approach sees that communication and participation are connected. They are part of the same concept (Ramirez and Quarry, 2004).

RCS are grounded in Communication for Development principles which operate on the belief that rural communities have a rich knowledge base and lifelong experiences beneficial to development (FAO, 2017). According to Niels Röling, "We need to acknowledge that the only thing we know is that we don't know. It's time to get over our overconfidence and dare to accept that we haven't done very well in terms of development." Thus, involving rural people is crucial at every stage of planning, implementation, and evaluation in a change process.

RCS also focuses on collaborating with marginalised communities. They have specific needs. These include farmers, migrants, poor areas, and indigenous populations (Berrigan, 1979).

People are often unaware of the full potential of communication for development and its key benefits. This could greatly improve its use. This collaboration improvement affects institutions, governments, and farmer groups. People are enthusiastic about digital tools in farming. They claim the tools have benefits. But, some argue that we don't understand their use well. They say we may overestimate how much they are used (Baumuller, 2018; Klerkx and Rose, 2020; Steinke et al., 2020).

To implement RCS, FAO (2022) introduced the RCS framework. It has four main parts, an end goal, and an institutionalisation dimension. The RCS framework's main goal is to boost the ability to make informed decisions and take action. It is for rural people. The guiding principles of this framework are:

1) Right to Information: Recognizing citizens' entitlement to relevant, timely, and accurate information.

2) Demand-Driven: Designing programs or services that respond to grassroots needs.

3) Gender Equitable: Promoting equal participation among users of different genders. Hafkin (2002) suggested that thinking a technology project is "gender-neutral" will help everyone. But, she said this idea is not realistic for all genders. This is because of gender dynamics in technology. Women face societal barriers when accessing and using information technology (Spence, 2010).

4) Fostering Social Inclusion: Inclusively delivering programs or services by considering all stakeholders, regardless of gender, social status, health, etc.

5) Local Context-Driven: Adapting services or programs to fit the local and socio-cultural contexts of their users.

RCS can promote this involvement through many strategies. These include raising awareness among many people and facilitating dialogue. They also include co-creating and managing communication processes and systems. These systems include many media options. They include community radio, innovation forums, mobile phones, community-driven ICTs and social media. RCS also covers the rural area structure for Communication for Development. The flexibility of these designs allows them to meet many strategic goals including

problem-solving, knowledge sharing, collaborative learning, interaction, and network building. ComDev includes initiatives based on identified needs and driven by demand.

Gaining a deeper understanding of the processes and results of RCS is only part of the picture. It's crucial to grasp how communication affects other system elements. Access to farming information can be shaped by university research priorities. It is also shaped by public media policies, network coverage, and many infrastructure and financial factors. Madon's (2000) framework shows the Internet boosts developing nations in four ways. It improves economic growth, social well-being, and political stability. The Internet also supports environmental sustainability. It emphasises intermediary institutions and government initiatives. They help the Internet's impact on socioeconomic advancement. But, it does not include trends like Big Data and Cloud Computing (Roztocki & Weistroffer, 2016).

However, it's clear that RCS is a social intervention and needs contributions from all participating entities. Understanding its purpose, functioning, and success factors helps. It makes decision-making for investment prudent. It also reduces disappointment among stakeholders. Therefore, evaluation plays a crucial role in institutional processes. In the realm of development initiatives, evaluation supports logical decision-making. It does this by assessing past achievements and guiding present and future actions (Funnel & Rogers, 2014).

Integration of Theoretical Perspectives

AKIS emphasises the importance of networks that include research institutions, extension services, farmer groups, NGOs, and private sector actors. In the context of Northern Uganda, identifying primary sources involves mapping these networks and understanding their interactions. This helps in determining how digital technologies can enhance or disrupt existing advisory information flows.

The framework suggests that effective agricultural advisory services result from collaboration among various institutions. Understanding primary information sources involves analysing how these institutions share knowledge and resources. Digital tools can potentially streamline these processes by providing platforms for real-time information exchange and collaboration.

According to Thuo et al. (2014) and Valente (1996), social networks play a crucial role in information dissemination. Digital platforms can strengthen these networks by providing

broader access to advisory services and connecting farmers with peers and experts beyond their immediate geographical area.

Röling's (1992) concept of human activity systems highlights the diversity of perspectives and objectives among actors in defining problems, identifying solutions, and implementing changes within AKIS. Autonomy can be achieved by how well digital tools align with the goals and contexts of different stakeholders. For instance, user-friendly interfaces and relevant content can empower farmers and extension workers to make informed decisions. The role of various digital platforms (e.g., mobile apps, social media, online forums) and in-person sessions in facilitating communication and knowledge sharing among stakeholders. Use participatory approaches to involve stakeholders in the design and evaluation of digital tools, ensuring they meet local needs and contexts.

The Soft Systems Thinking approach suggests that the autonomy is shaped by how actors perceive and interact with the system (Röling, 1992). Digital technologies that facilitate better communication, provide actionable insights, and support decision-making processes can enhance user's autonomy.

Digital tools support collaborative learning, interaction, and network building among farmers, suppliers, and extension workers. Digital platforms can bridge gaps between various actors in the agricultural knowledge system, from researchers to end-users. This connectivity fosters more dynamic and responsive advisory services. Digital tools can facilitate both explicit knowledge exchange (e.g., written guidelines, videos) and tacit knowledge sharing (e.g., forums, peer-to-peer communication). Enhancing the sense of agency involves ensuring that these tools support the effective transfer of both types of knowledge, recognising that tacit knowledge is context-specific and often more impactful for practical decision-making. Tools such as mobile applications and social media enable real-time communication and feedback, enhancing the relevance and timeliness of advisory information.

Conceptual Framework

The conceptual framework (see Fig 3) illustrates AKIS as a dynamic system where actors and institutions interact to create and share knowledge, leading to innovation. This process is facilitated by Rural Communication Services (RCS), which enhance knowledge exchange and collaboration.

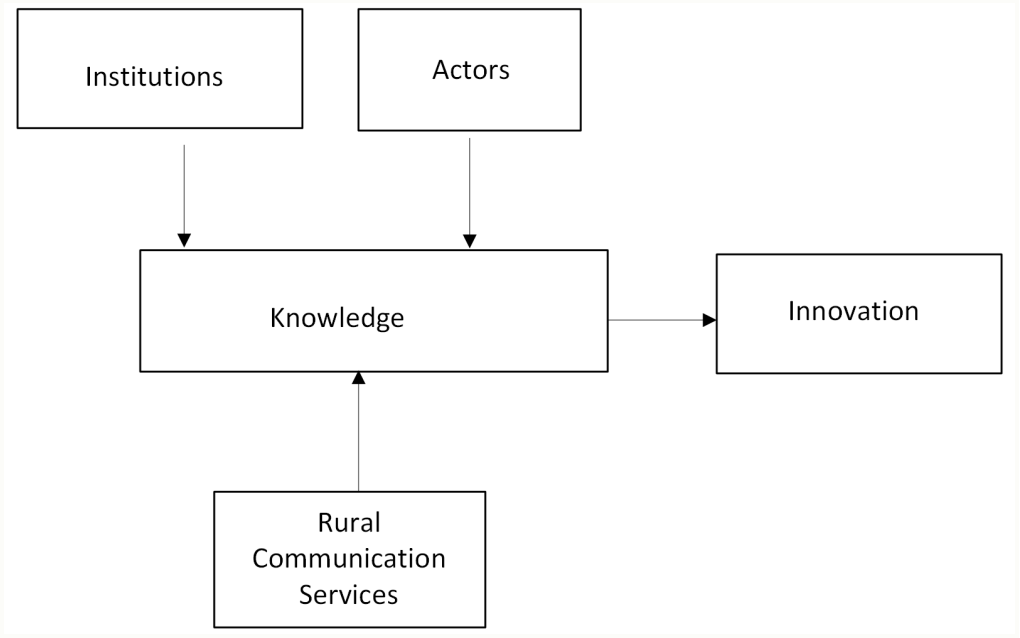

Fig 3: Conceptual Framework of AKIS and RCS

Limitations and Considerations

The framework also highlights the limitations of AKIS and future directions for research and practice.The effectiveness of digital technologies depends on their accessibility and usability among different stakeholders. Factors such as literacy, internet connectivity, and the affordability of digital tools must be considered.

Digital tools should complement rather than replace existing advisory systems, for a seamless transition and minimising disruption (Birner et al., 2009; Davis et al, 2014). Digital solutions need to be tailored to the local context, considering cultural, social, and economic factors to ensure they meet the specific needs of Northern Ugandan stakeholders.

Applying the AKIS framework to analyse the additional value of digital technology in agricultural advisory services in Northern Uganda involves understanding the existing knowledge networks, the role of formal and informal institutions, and the factors influencing the control and ownership of digital tools among stakeholders.

Digitalisation offers significant potential to enhance these systems by improving connectivity, facilitating real-time communication, and supporting data-driven decision-making, provided that challenges such as the digital divide and the need for context-specific solutions are addressed.

Literature Review

This literature review explores the potential of digital solutions, the role of extension workers and farmer cooperatives in delivering agro-advisory services to smallholder farmer groups in Northern Uganda.

Traditional versus Digital Communication Preferences

Traditional agricultural advisory services in Sub Saharan Africa are primarily delivered through extension workers through physical visits (Van Campenhout et al., 2021) either public or private (Norton & Alwang, 2020). Their reach to a large and diverse farming population is constrained by limited resources (Feder, Anderson, Birner & Deininger, 2010; Taylor & Bhasme, 2018). Feder et al. (2010) and Taylor & Bhasme (2018) contest that extensionists serving a complex group of farmers can only get generic advice or focus on larger, better-endowed households, leaving poorer farmers, women, and remote households underserved. ICTs offer women various avenues, such as peer-to-peer learning and interactions with extension agents, to access information on the appropriateness and financial benefits of emerging agricultural technologies and market opportunities (Meinzen-Dick, Quisumbing, Behrman, Biermayr-Jenzano, Wilde, Noordeloos & Beintema, 2011). However, when women have limited access to formal information channels, they often rely on informal networks, which can be gender-segregated and perpetuate information imbalances (Beaman & Dillon, 2018; Zeltzer, 2020). Additionally, if the information provided doesn't cater to women's interests, needs, or roles as farmers, it may not be engaging or effective (Smith & Chavas, 2003).

Though effective in sharing localized knowledge, peer farmer networks may not provide accurate and up-to-date information. Radio programs can reach a broad audience but suffer from scheduling conflicts, irrelevant content, and limited interaction (Aker, 2011; Mwombe et al., 2014). Poor road infrastructure further reduces farmers' prices for their produce at the farm gate (Kirumba et al., 2004). This price volatility and the lack of information sharing among farmers regarding prevailing market prices, weaken their negotiating position with traders (Kirumba et al., 2004). Farmer groups have been established to help farmers access better agricultural technologies (Gibson et al., 2008). Farmer cooperatives gain entry to more profitable markets (Aliguma et al., 2007). Most importantly, joint farmer groups improve

transportation of their produce to those markets (Mwaura et al., 2012). Farmers primarily joined these groups with the expectation of receiving support from the government or non-governmental organizations, rather than due to a community-driven initiative (Adong et al., 2012).

These limitations have highlighted the need for innovative approaches, paving the way for digital extension technology. Digital extension technology promises to address these challenges, offering tailored advice and fostering value-chain collaboration (Klerkx, Jakku & Labarthe, 2022; Gow, Chowdhury, Ramjattan & Ganpat, 2020). Nevertheless, successful implementation requires addressing common issues like feedback mechanisms, alignment with farmer needs, trust in information sources, and technical limitations (Aker et al., 2016; Fabregas et al., 2019; Steinke et al., 2021).

The traditional extension, particularly prevalent in Sub-Saharan Africa, faced challenges due to financial instability and reliance on external funding, leading to unsustainable solutions (Sylla et al., 2019; Wuepper, Roleff, & Finger 2021;). It was criticized for neglecting intermediation and collaboration with value chain actors (Munthali et al., 2022; Klerkx and Rose, 2020; Karpouzoglou et al., 2016). Research indicates that adopting digital technologies among extension workers varies considerably across regions and contexts (Spielman et al., 2021; Nakasone et al., 2014).

In response, digital extension technology has emerged as a promising solution enabling wider reach, improved efficiency, and enhanced farmer engagement (Casaburi et al., 2014; Spielman et al., 2021). While ICTs can be used to supplement or replace traditional extension methods, the term is too broad to be useful without some limitations (Torero & von Braun, 2006). Torero & von Braun (2006) define ICTs as tools and services that enable the electronic handling of information, ranging from simple calculators to sophisticated web-based services. Torero & von Braun (2006) define ICTs in the context of agricultural development as the tools and services that enable the electronic collection, handling, presentation, and sharing of information. The defining feature of ICTs is their capacity to facilitate information exchange, constrained by connectivity, user and provider capabilities, and content quality. These tools have facilitated real-time communication, data collection, and personalized advisory services, increasing farmers' awareness and adopting improved agricultural practices (Nakasone et al., 2014). For agricultural decision-making and value chain management, digital tools offer

tailored advice, address socio-economic challenges, and improve productivity (Gow et al., 2020; McCampbell et al., 2021; Klerkx, Jakku & Labarthe 2022; Coggins et al., 2022).

Mobile apps, online forums, and SMS services have become increasingly prevalent, offering farmers a a more comprehensive range of information sources than traditional methods. These platforms provide access to real-time weather forecasts, up-to-date market prices, and best practices in farming (Daum et al., 2018; Carmona et al., 2018). This can empower farmers with timely and relevant information, enabling them to make informed decisions about their crops, livestock, and marketing strategies. Improving farmers' access to price information could empower them to bargain for better prices and ultimately increase their income (Bakis, 2002). ICTs offer women various avenues, such as peer-to-peer learning and interactions with extension agents, to access information on the appropriateness and financial benefits of emerging agricultural technologies and market opportunities (Meinzen-Dick, Quisumbing, Behrman, Biermayr-Jenzano, Wilde, Noordeloos & Beintema, 2011).

However, digital sources also have their drawbacks. Not all farmers can access smartphones or reliable internet connectivity, particularly in resource-constrained settings like Northern Uganda. Digital literacy remains challenging for many farmers, requiring training and support to effectively utilize digital tools (Mendes, Paz, & Callado, 2018). Factors such as access to technology, digital literacy, institutional support, and perceptions of usefulness influence adoption rates (Barakabitze et al., 2015; Ayim et al., 2022).

Impact of Digital Tools

Building trust in digital sources and ensuring the accuracy of information is essential for their successful adoption (Steinke et al., 2021).

Empowerment and Agency

Digital tools can empower farmers and stakeholders in the agricultural sector by offering direct access to information and resources (Nwagwu & Famiyesin, 2016). This accessibility can significantly lessen their reliance on intermediaries, such as traders and mediators, who often wield control over disseminating crucial information and resources (Kirumba et al., 2004). Kirumba et al. (2004) argue that numerous the agricultural value chain intermediaries significantly increase transaction costs between farmers and the consumers. Bakis (2002)

argues that by circumventing these intermediaries, farmers gain greater autonomy in decision-making, enabling them to negotiate better prices for their produce and subsequently boost their income.

Moreover, Norton et al. (2020) argue that digital tools can be instrumental in fostering collaboration like online communities and cooperatives among farmers. These platforms empower farmers to collectively address shared challenges, exchange knowledge and resources, and advocate for their interests (Norton et al., 2020).

Cultivating agency and ownership through digital tools contributes to a more inclusive and sustainable agricultural landscape where farmers actively participate in shaping their livelihoods.

Data Management

The increasing use of digital agricultural platforms raises critical concerns regarding data ownership and privacy (Jakku et al., 2019; Newell & Taylor, 2018). While these platforms offer numerous benefits, such as improved decision-making and access to markets (Aker & Blumenstock, 2015; Fabregas et al., 2019), they also pose potential risks to farmers' personal information.

Maru et al., (2018) argue that the collection and analysis of farm-specific data, including crop yields, input usage, and financial information, raise questions about who owns this data and how it is used. The potential for misuse of this data, such as unauthorized access, discriminatory pricing, or surveillance, is a major concern for farmers (Maru et al., 2018).

Customization and Relevance

Digital tools have the potential to revolutionize agricultural advisory services by facilitating the delivery of personalized and context-specific advice. Unlike traditional methods that often rely on generic recommendations, digital platforms can leverage data analytics and machine learning to tailor advice to individual farmer needs and local conditions (Steinke et al., 2019). By collecting and analyzing data on factors such as soil type, weather patterns, crop varieties, and pest prevalence, digital tools can provide farmers with precise and actionable recommendations that are relevant to their specific circumstances (Carmona et al., 2015; 2018).

Furthermore, digital tools can adapt and learn over time based on farmers' feedback and outcomes can continuously improve the accuracy and relevance of agricultural advice, leading to more effective and sustainable farming practices (Steinke et al., 2022). However, it is crucial to note that the successful implementation of such tools requires addressing challenges related to data collection, privacy, and the digital literacy of farmers (Biemba et al., 2017).

Related work

While specific case studies from Northern Uganda are limited in the provided literature, successful digital agricultural advisory initiatives in similar contexts offer valuable insights. In Ghana, the "Esoko" service has effectively used SMS to provide market price alerts to farmers, enhancing their bargaining power and income (Courtois & Subervie, 2015). In Malawi, Uganda, and Tanzania, ICTs have been pivotal in improving access to knowledge related to post-harvest handling, pest and disease control, market dynamics, weather updates, and fertilizer application, thereby contributing to increased productivity and food security in vulnerable communities (Oyelami et al., 2022).

These initiatives highlight the importance of several key factors in ensuring the success of digital agricultural advisory services. Community engagement plays a crucial role, as understanding the specific needs and challenges of farmers is essential for designing relevant and user-friendly tools (Steinke et al., 2019). User-centered design, which involves farmers in the development and testing of digital tools, can ensure that these tools are intuitive and meet their specific requirements (Biemba et al., 2017). Partnerships between government agencies, NGOs, and private sector actors can leverage resources and expertise to reach a wider audience and provide comprehensive support to farmers.

Challenges and Opportunities

The adoption and implementation of digital agricultural advisory services in Northern Uganda, like in many other developing regions, face multiple challenges.

Limited digital literacy and access to technology are major hurdles, as many farmers lack the skills and resources to utilize digital platforms effectively (Akpabio, Udoh & Edet, 2007; Dillon, 2012; Saidu et al., 2017). Infrastructure constraints, such as unreliable internet

connectivity and lack of electricity, further hinder the reach and effectiveness of digital services. Additionally, language barriers and cultural inappropriateness of content can alienate farmers, making it difficult for them to understand and apply the information provided (Biemba et al., 2017).

The sustainability and long-term funding of digital advisory services also pose significant challenges. Many initiatives rely on external funding, which may not be available in the long run. Developing sustainable business models that can generate revenue and cover operational costs is crucial for the continued provision of these services (Qiang et al., 2012).

Despite these challenges, there are significant opportunities for future research and development in this area. Research should focus on understanding the specific needs and preferences of farmers in Northern Uganda to develop tailored digital solutions that address their unique challenges. This includes designing user interfaces that are intuitive and easy to use, providing content in local languages, and incorporating cultural considerations (Biemba et al., 2017). Furthermore, research should explore innovative approaches to overcome infrastructure constraints, such as offline-accessible content or the use of low-bandwidth technologies.

Methodology

In framing my research inquiry, I utilise Qualitative approach involves gathering data in a natural setting that is attentive to the individuals and locations being studied (Cresswell, 2021). Others argue that in this context, the aim is to understand the meaning of a phenomenon based on the perspectives of the participants (Creswell, 2021). Njie & Asimiran (2014) argue that the qualitative approach provides in-depth, context-rich insights.

Examining the different trustworthy sources of information for extension workers to disseminate to farmers, their impact on using digital tools for farm advisory services could only be undertaken through a qualitative approach. The exploratory approach aimed to identify and examine the importance of digital agro- advisory services for farmer groups in the value chain. Looking at the specific case of Northern Uganda with a broader context to make generalisations, and establish relationships between the stakeholders from the interviews.

Case studies are a common framework for qualitative research (Stake, 2000). Therefore this research is accomplished through a case study design (Creswell, 2021). Some argue that case studies are more appropriate for pilot studies rather than for comprehensive research projects which is “misleading” (Flyvbjerg, 2006). I chose farmer cooperatives within the Northern Uganda because of the established contacts. Also, the region has the highest farmer group membership in the country (Adong et al., 2012) yet suffers severe agricultural productivity issues even in the digital era.

This research project drew its insights primarily from both existing literature and the results of the study's investigations. The literature review in the previous chapter provided a theoretical foundation for understanding the phenomenon under investigation. To complement this, I gathered practical insights through interviews from agricultural actors and farmers within a farmer group, which offered a real-world perspective on the subject. The data collection was based on in-depth qualitative semi structured interviews and focus group discussions with actors of the farmer cooperatives to reveal their roles, pains or frustrations with utilising digital technologies for agro-advisory services. By combining and analysing these sources of information, I have developed ideas and questions that can contribute to further discussions and advancements in this field.

Sampling & Recruitment

Non-probability sampling is often employed in qualitative research because its goal isn't to achieve generalizability. The most prevalent form of non-probability sampling is purposive sampling (Adeoye-Olatunde & Olenik, 2021). Purposive sampling will be utilised to deliberately select participants with specific characteristics or qualities pertinent to the research objectives. Participants were recruited through local networks and contacts (Krueger, 1994). However, using local contacts has been criticized due to its reliance on the availability, willingness, and accessibility of these contacts, which can lead to a loss of control for the researcher during the recruitment process. This method may result in convenience sampling, where participants are selected based on their accessibility, potentially leading to "volunteer bias" (Krueger, 1960; Krueger, 1963). I contend that the recruited participants were chosen for their valuable insights, experiences, or perspectives related to the research questions regardless of availability and accessibility. The local contact moved to their locations and three participants did not show up. Purposive sampling is widely recommended because focus group discussions depend on participants' ability to provide relevant information (Morgan, 1988).

Another important consideration is the number of participants to invite for the Focus Group discussion, generally accepted that six to eight participants are sufficient (Krueger & Casey, 2000). Some studies have reported as few as four and as many as fifteen participants (Mendes de Almeida, 1980; Fern, 1982;). One potential drawback of focus group discussions is the uncertainty that all recruited participants will attend. To address this, Rabiee (2004) suggests over-recruiting by 10–25%. In this study, for most of the groups, I over-recruited about 8-10 members and on average 5 members showed up for the discussion.

The identified twenty (20) interview subjects are farmers who are members of the farmer organisations, service providers for farmer organisations including commercial service provider, agro-input suppliers and extension workers, in the Lango sub region of Northern Uganda. Most of the interviewees fall between the age group of 30-39 but most of the ladies are aged 28 whether they use digital tools or not. Table 1 below shows the categories of the participants, their unique IDs, gender and age. Also, it was important to capture their roles within the agricultural network and whether they use digital tools or not.

Method	**ID**	**Participants**	**Role**	**Tools for gro-advisory services**
Interviews	CS	Commercial Service Provider, M,	Capacity building, marketing of farmer cooperatives	*Digital*
	I1	Spinsky, F	Input dealer/Extension	*Digital*
	I2	Tony, M	Input dealer/Extension but interviewed as an input dealer	*Digital*
	E1	Moro, M	Extension worker	*Digital*
	E2	Prisca, F	Extension worker	*Digital*
	P	Dorcas	Farmer, Farmer cooperative non-participating	*Traditional*
Focus Group Discussion, FGD1	F1 F2 F3 F4	Pakweli, *M, 31* Dennis, *M, 37* Isaac, *M, 32* Winny, *F, 25-30 yrs*	Marketing Secretary Accountant Loan officer	*Digital*
FGD2	F5 F6 F7 F8	Leonard, *M, 30-39* Bonny, *M, 25-30* Betty, *F, 25-30* Semmy, *F, 25-30*	Extension worker Extension worker Accountant Loan officer and agro-input shop dealer	*Transitioning to digital*
FGD3	F9 F10	Aceng, *F, 30* Apio Evaline, *F, 28*		*Purely traditional*

	F11 F12 F13 F14	Oceng Peter, *M, 56* Odongo Benson, *M, 35* Alwedo Santa, *F, 28* Okae Geoffrey, *M, 35*		

Table 1: Breakdown of the interview participants for the study

Ethical Considerations

Besides attending courses on research methods, I listened to recordings from a series of workshops organised by the program to ensure a smooth research process. I followed the study protocol that was issued, reviewed and approved by the institutional review board of Austria before data collection. The study adhered to ethical guidelines for research involving human participants, including obtaining informed consent from all participants. Participants had the liberty to ask questions regarding the interview, and the consent form to have the interview recorded. Participants could opt-out in case they were not comfortable with proceeding with the interview. To ensure confidentiality and anonymity during the data analysis process, I pseudonymised the interviewees and kept the codebook safe on a drive on the cloud. A document with the findings was shared with the research participants for validation.

Data Collection Methods

The primary methods of data collection during a focus group discussion include audio and video recording, note-taking, and participant observation (Stewart, Shamdasani, & Rook, 2007). To observe the outcomes of the activities that point to the extra value that digital advisory solutions for farmer groups in Northern Uganda, I used qualitative data collection methods that is key informant semi-structured interviews and focus group discussions. Focus group discussions and one-on-one semi-structured interviews, are sometimes viewed as being quite similar (Parker & Tritter, 2006). They both reveal participant's values and perceptions (Skeggs, 1997)

Semi-structured interviews

Semi-structured interviews will be conducted with a purposive sample of extension workers to better understand their experiences and perspectives on using digital tools to provide advisory services. The interviews would explore factors such as the challenges faced in using digital tools, and autonomy in using digital tools for advisory services for their ability to reach and engage with farmers. The interviews lasted between 25-60 minutes. An hour is generally considered the maximum duration for the interviews to minimize fatigue for both the interviewer and the respondent (Adams, 2015).

In the key informant interviews, I explored in-depth topics based on the interviewee's responses to their individual experiences and perspectives while still maintaining some structure. According to Krueger and Casey (2000), self-disclosure tends to be natural and comfortable for individuals, though for some it requires trust and effort (Nyumba, Wilson, Derrick & Mukherjee, 2018). These interviews provide a private setting, encouraging openness and honesty compared to the focus group discussions.

Focus Group Discussions

Online focus group discussions (FGDs) are a popular method for gathering qualitative data (O'Connor & Madge, 2003; Schneider et al., 2002; Stewart & Williams, 2005; Synnot et al., 2014; Wilkerson et al., 2014). This is evidenced by the growing popularity of the internet allowing individuals to be flexible in their familiar environments (Woodyatt, Finneran & Stephenson, 2016). Focus group discussions (FGDs) now include online chat rooms and video calls, enabling researchers to connect with populations that may be hard to reach in-person, such as remote communities (O'Connor & Madge, 2003).

The focus group discussions involve multiple participants interacting with each other and group dynamics plus managing group relations generate a variety of viewpoints and ideas (Finneran & Stephenson, 2016) However, to manage the discussion and ensure all voices are heard, there is a need for moderators comprising a skilled facilitator and an assistant (Burrows & Kendall, 1997; Krueger, 1994). The facilitator plays a crucial role in the discussion, not only by managing existing relationships but also by establishing a relaxed and comfortable environment for unacquainted participants (Nyumba et al., 2018). I co-moderated the conversation with a local contact point which made them feel safe to share

their ideas but also made open pledges for intervention towards their farmer cooperatives. Similarly, the co-moderators role involves observing non-verbal interactions and the effects of group dynamics, as well as documenting the general content of the discussion, thus enhancing the data (Kitzinger, 1994, 1995). I contend that the occurrences from the online group discussions were noted during data collection and analysis like “variations in volume, pitch and quality of the voices”, “hesitations, gaps and silence” (Gorden, 1980 cited in Nyumba et al. 2018). However, the online format also limited the ability to directly observe participants' non-verbal cues, relying primarily on verbal responses and perceived pauses or hesitations.

Full engagement in group discussions is crucial for generating valuable data and is more easily achieved within a homogeneous group (Krueger, 1994). Therefore, Krueger (1994) recommends that participants share similar characteristics such as gender, age range, and ethnic and social class backgrounds. Most of the participants especially the farmer group leaders are within the same age bracket, 30-39, hailing from the same villages or the region. However, this homogeneity is contested by some researchers who argue that unfamiliar participants can offer honest and spontaneous views and can break existing relationships and leadership patterns within the group (Thomas et al., 1995). In this study, I stressed the need to have all the genders represented so this was a guarantee although there were fewer women. Evidence indicates that mixed-gender groups can enhance the quality of discussions and their outcomes (Freitas, Oliveira, Jenkins, & Popjoy, 1998).

Due to the limited number of participants in a focus group discussion and its typical design as a single encounter, it is not possible to thoroughly explore a topic with just one session. Therefore, some authors suggest conducting at least three to four group meetings for even straightforward research topics (Burrows & Kendall, 1997). Three focus group discussions were arranged comprising 4-5 members with cooperatives who use digital applications and those who do not use digital applications for managing their information.

Interview Guide

The interviews will be audio-recorded, transcribed verbatim, and analysed using thematic analysis. The interview guide in *Appendix A* was constantly adapted depending on the level of difficulty in which the participants understood the interview questions. The different

stakeholders for example extension workers, leaders of the farmer cooperatives, and farmers impact the format of the interview guide which will be reflected therein.

The interviews were conducted in the order of CS, I1, I2, FGD1, FGD2, E1, E2, FGD3, P depending on their availability. The conversations also revealed the different stakeholders that farmer cooperatives deal with. With these results, I drew stakeholder relationships within the agricultural value chain.

Interviews were conducted online with a telecommunications software Whatsapp. Internet-based calls as costly, although this perception may be influenced by the challenges of unreliable network infrastructure in the region. Despite this, during one of the interviews, the participants requested for a video call to ensure that a human was conducting the research.

Recorded interviews are stored on the cloud as well as the interview transcripts will be deleted after 6 months from conducting this research. The recordings were then transcribed using TurboScribe software later used for data analysis for this research providing insights into the communication preferences and the impact of agro-advisory services.

Data Analysis

The qualitative interview data will be analysed using thematic analysis to identify emerging themes related to the experiences and perspectives of people (Braun and Clarke, 2013, p. 175; Herzog, Handke & Hitters, 2019). With the help of computerized software, NVivo which is the most dominantly used in qualitative interviews (Zamawe, 2015). I generated codes from the interviews and later emerging themes linked to these codes. *Table 2 in Appendix B* shows the table with the themes and codes from the interview data. In this study, we used codes to represent different people involved in agriculture. These codes helped us understand their roles and how they work together.

Findings and Discussion

The research questions will be addressed, and the core concepts explored in the research will be thoroughly discussed.

Findings

This section covers findings from interviews conducted with 20 agricultural stakeholders, 6 of which were semi-structured key informant interviews and 14 were focus group discussions with the farmers or staff of the farmer cooperatives.

I stands for Input dealers, E stands for Extension worker, CS stands for Commercial Service Provider, P for the participating farmer not part of an agricultural cooperative, and FG stands for a farmer within a focus group discussion labeled FGD.

Communication Preferences for Stakeholders

Across the agricultural value chain, stakeholders use a variety of communication methods, both traditional and digital, to share information. In rural settings, face-to-face interactions with extension workers, social networks, and radio broadcasts remain prevalent, while digital technologies,such as websites, social media platforms, and so forth, are increasingly gaining traction. This section presents findings that reveal the preferred communication channels for each stakeholder group.

Farmer Cooperatives

Farmer organizations, or cooperatives, consist of members who are primarily farmers (E1) and are registered with the Ministry of Trade, Industry, and Cooperatives of Uganda (CS). So, the more members a cooperative has, the stronger it becomes (E1). The three cooperatives in this study, established between 2018 and 2019, serve over 1000 farmers (FGD1, FGD2, FGD3).

Extension and commercial service providers focus on training the board members, who are the leaders of the smaller groups within the cooperative (I1, I2, E1, E2, CS). They teach them effective leadership skills and lobbying (E1, CS). By strengthening the leadership, they strengthen the entire cooperative. These cooperatives fall into two distinct categories:

1. Agricultural Cooperatives: These cooperatives engage in the production, aggregation, processing, and marketing of members' agricultural products. This approach enables farmers to consolidate their resources and enhance their market power and profitability (F5, FGD1).

2. Financial Cooperatives (Savings and Credit Cooperatives - SACCOs): Members pool their money together, saving it for themselves and lending it to each other (FGD1, FGD3). It is a hectic process to fill in the physical forms at the bank and some of these banks are in the town areas which require paying public transport and lunch fees associated with travel.

Cooperatives serve their members by pooling resources and working collaboratively, and help the farmers achieve several advantages:

Farmers can aggregate their produce for bulk sale, which improves their bargaining power and guarantees higher prices (FGD1, CS). Cooperative structures simplify business operations for farmers, reducing individual burdens such as packaging and transportation, access to larger markets, and negotiating better terms with buyers. has a factory and hopes to receive a supply of cassava, maize, and rice from the farmers to run the factory, thereby improving their market and sales (FGD1).

When individual farmers cultivate specialized crops or products, cooperatives facilitate direct connections between these farmers and potential buyers (CS). This approach eliminates intermediaries, allowing efficient transactions and potentially higher farmer profits. Usually, intermediaries transact with the potential buyers of farm produce and cut off further engagement with the farmer and buyer (P).

Cooperatives create jobs for young, educated people who can handle administrative tasks (FGD1, FGD3, E1). This is a big deal because it means cooperatives can afford to hire their extension workers to support farmers, rather than relying solely on government services (F10).

Radio is the most effective and reaches a broad audience, but mention that it is expensive (FGD3). In the remote region, they still rely on traditional methods for communication and outreach (F14). They often get marketing information from colleagues, cooperatives, particularly buyers they frequently connect with, or those who physically visit different stores in town to compare the prices of our products (FGD1, FGD2, F1, P, FGD3). This involves regular communication through phone calls to negotiate with buyers and gather insights on market conditions, price fluctuations, and demand (FGD1, FGD2, FGD3). They have

received leads from various sources, including the District Commercial Officer. One contact was a trader operating in South Sudan and some unknown sources (F3). They have a network of extension workers, both from within the cooperative and from the district agricultural office (F12), who visit them in the village to share information and advice on farming practices (FGD3, F14). Cooperatives organise training sessions where farmers can learn new techniques and share ideas. it is a two-way street: even extension workers and agro-input dealers learn from farmers during these exchanges (E1, I1). They invite organisations like the Uganda Cooperative Alliance (UCA) to provide training to their board members on how effective leadership and management of the cooperative (E1).

Face-to-face interactions include physical events designed for farmers and farmer cooperatives to showcase their products (FGD1, FGD2, P). They often participate in marketing events organised by companies that connect them with buyers. Their contacts are sometimes shared during these meetings.

These events bring together many sellers and buyers, providing opportunities for networking and sharing contact information. Additionally, they hold an annual Farmers Field Day where farmers involved in various agricultural activities, including crop and livestock production, come together which attracts potential buyers (F2). Another successful initiative was our Cooperative Day, which significantly boosted their sales. They invited farmers from different regions like the Western and Northern regions, fostering connections and expanding their market reach (F3).

Farmer cooperatives in Uganda empower farmers by giving them a collective voice, expanding their market reach, easing their workload, providing financial access, and fostering a mutual learning environment.

The different stakeholder interactions with the farmers and farmer groups shape the flow of knowledge, resources, and influence within the Agricultural Knowledge and Information System (AKIS) framework. At the core are the farmers who may or may not be organized in farmer groups. Cooperatives interact with many stakeholders, including farmers, model farmers, commercial service providers, agro-input suppliers, buyers, extension workers, financial institutions, development partners, government agencies, transporters, consumers, and opinion leaders.

Extension Workers

Extension workers are like teachers and advisors for both cooperatives and farmers. However, some extension workers might act in the same role as agro-input dealers to supply agricultural inputs like seeds, spray pumps, pesticides, and fumigation of indoor and outdoor pests and insects (E2, I1, I2). They know a lot about farming and share this knowledge with farmers in rural areas who might not be aware of, for example, how to properly use fertilizers or weed killers (E1, E2). They understand how to effectively communicate with and educate these farmers, ensuring they grasp the information clearly and efficiently (E1, E2, I2).

Extension service providers may be hired by the cooperatives or government and allocated to districts or regions by the government (CS, FGD1, FGD2, FGD3). When hired by the cooperative, this extension worker mobilizes the public to buy shares from the cooperatives besides sharing new agronomic practices. While independent extension worker E2 may be less personally invested in the cooperative's overall mission, extension worker E1, being employed by the cooperative, is fully committed to its primary goals.

Extension workers are obligated to invent ideas to support the disadvantaged community, for example, assisting in setting up permaculture home gardens for the disabled and HIV-positive people (E1). Permaculture emphasizes the use of renewable natural resources for the local ecosystem. The crops this community grows are not just for nutrition but also a way to make money. When farmers have more than they need for themselves, they can sell the extra to their neighbors, which brings in some extra cash to help with other expenses at home (E2).

In addition to their teaching role, some cooperatives also mentioned that extension workers help gather data from farmers about their crops and farming methods (FGD1, FGD2, FGD3). This later culminates in the digital data entry role (FGD1, FGD2). Since these extension workers are tech-savvy, they can use the digital tools that the cooperative has invested in, making the whole process even more efficient. In other words, extension workers are gatekeepers of knowledge on novel agricultural practices for rural farmers who are not connected to digital technology.

Extension workers often become the go-to source for advice on good-quality supplies like seeds, fertilizers, and pesticides (E2). This is important because farmers in remote areas might not have easy access to farm advice, and good quality supplies are key to growing

good crops (E2). Farmers might have challenges and need answers to their queries which the extension workers try to solve (E1). Extension worker, E1 adapts information to local contexts and shares it with farmers, sometimes responding to their immediate needs based on prior discussions. These advisory services are usually given to small groups of farmers or to the entire cooperative, which can include many smaller groups. Imagine one cooperative having 35 small groups of farmers.

> *An extension worker, [...] I am that person who extends the services down to the farmer[...] some of these farmers[...] may not be aware of [...] the management practices, the agronomic practices~E2*

E1 mentions that they regularly broadcast on the local radio station to reach a wide audience, including both members and non-members of the organisation, with important information (E1, E2). Radio broadcasts might be expensive but they have partnerships for example Permaculture Denmark which covers their fees for capacity-building over the radio (E1). Even though it can be difficult for some farmers to listen to the radio, it is still the most common way for them to get information because they share what they hear with each other (E1).

On a scale of 1-5, in-person interactions rank highest with a 5 since they allow for direct and two-way communication and relationship-building as compared to radio (E1, E2). It could also be physically visiting the leaders of farmer groups (E2, I1). Phone calls are a convenient way to mobilise individuals for physical interactions.

The extensionists are usually young and energetic, which makes them fit to help older and unfit farmers with the commercial application of fertilisers on the farms (E2). They can travel to different farms, meet with farmers, and share their knowledge (E2, I2). This hands-on approach helps farmers learn and grow, leading to better harvests and a stronger agricultural community.

While farmers appreciate face-to-face interactions with extension workers, their busy schedules and limited numbers make it challenging to meet the demand for their services. To address this challenge from one of the cooperatives has adopted a "Training of Trainers" (ToTs) approach, where select individuals are trained as trainers themselves (E1). This allows for broader dissemination of knowledge and skills, as the TOTs can then conduct training

sessions for various groups within the cooperative, especially since the extension worker alone cannot reach everyone in a single quarter.

Both radio (announcements) and social media are somewhat effective for E2 but he serves farmers in the peri-urban regions yet acknowledges that most farmers do not have smartphones. E2 uses posters to reach his audience but it is the least effective.

Input Suppliers/Agro-Input Dealers

Suppliers provide seeds, fertilizers, and other inputs to the cooperative impacting costs and product quality. Agroinput dealers also take on the role of extension workers to train the farmers on how to use agro-inputs. I1 and I2 use radio adverts to advertise their business. As a result of the adverts, they frequently exchange phone calls to reach out to the leaders of the farmer cooperatives who move into their neighbourhoods to pass the information regarding future training.

I1, I2 finds radio a valuable communication tool for reaching farmers because most have access to radios and listen regularly. They carry the radios to their farms especially if they have interesting programs to listen to. Sometimes they spend the whole day on the farm so the best tool of entertainment is the radio. For the region, the radio adverts are broadcast in the local language, Ngakaramojong (I2). Radio is the best because the radio staff invite an expert like him who can share agricultural knowledge on air. On his terms, he would not pay for the radio programs, he prefers the perks of free radio invitations. The input dealer, I2 is also an extension worker. Radio allows the input dealer to reach a wide audience, including those who have not yet transitioned to digital platforms (I2). Input dealer, I2 is mindful of his communication channels to both the literate and illiterate population who need to access his products. Visual aids are also important (I1, I2), for both literate and illiterate (I2). This is important because they want everyone to have access to information about their products, regardless of their technological capabilities (I2).

> *Likewise, to the local people who are yet to actually transfer to the digital world. Because they also have the money, so I also don't need to leave them out, I need whatever can make them get information about my product. Yes, at all costs actually~ I2*

The second most effective method is organising trainings by having a representative visit the market in person so that farmers can become familiar with their products, delivery schedules, and the salesperson (I1, I2). The illiterates have “button” or feature phones with limited visual capabilities which might not be the best way to showcase the products to them. “Then they are automatically missing relevant information”. The illiterate rely on demonstrations to understand and appreciate the product.

The demonstrations take the form of setting up tables or tents during events and for example, demonstrating the application of some of these products to the masses. These demonstrations happen in the marketplace as one-on-one interactions with potential buyers.

Third, the NGO forum is valuable because it consistently leads to bulk orders of their products (I2). Lastly, digital forums for example WhatsApp, emails and Google groups for the region help him find suitable bulk suppliers but also a market for his products. The literate may view these products on the catalogue on WhatsApp Business or Google Groups or the website. While WhatsApp is a useful tool, it is less effective than the other methods because not all of their target customers have access to smartphones.

Cooperative negotiates prices, quality, and delivery terms with suppliers.

Model Farmers/Agents & Farmers

Model farmers act as examples for other farmers by offering their farms as demonstration gardens for experiments on input supplies by the extension farmers. They become agents of the extension workers and in exchange, they receive discounts on agro-input supplies from the extension workers who double as input dealers. Model farmers may provide guidance and advice to the other farmers and farmers may adopt practices demonstrated by model farmers. Farmers primarily consult agri-extensionists and their peers, they do not normally follow the timings of the radio programs because of the heavy workload ((F9, F14, E1, P).

Opinion Leaders

Opinion leaders influence farmers' decisions and perceptions through advice and recommendations. For example, in 2020, farmers in Northern Uganda were cutting down their pawpaw trees due to a misconception that it was a consequence of COVID-19 (E1). This

misinformation was even spread by some opinion leaders and local leaders. However, the real cause of the problem was an invasive species from Kenya.

> *[...] When you go to Northern Uganda, you realize that [...] in 2020, most farmers were cutting down their pawpaw. And they were saying, it was COVID-19 [...] Even some other opinion leaders and local leaders were advising farmers to do the cutting that it was COVID-19. But, you know, that was an invasive species [mealy bug] which came from this side of Kenya in 2019~Extension worker, E2*

Farmers may follow or reject the advice based on their trust in the leader.

Commercial Service Providers

Commercial service providers help cooperatives establish solid policies and internal rules. They also guide them in creating a business plan that aligns with their goals while ensuring a structured and organized approach. This role involves helping them gather and manage resources from within the cooperative and outside sources. This ensures they have the necessary tools and funding to succeed. These are business experts who help cooperatives run smoothly and make good decisions. They help farmers find the best places to sell their products and get the best market prices (CS, FGD1, FGD3).

Offtakers/Buyers & Cooperatives:

Offtakers purchase produce from the cooperative but also influence prices and market access.

Cooperative negotiates prices, volumes, and delivery terms with buyers.

Financial Institutions & Cooperatives:

Institutions provide loans, credit, financial literacy, and services to the cooperative and its members. These organizations or cooperatives send representatives or bank agents to rural areas to educate people about the benefits of loans, the necessary paperwork, and responsible repayment strategies. The members of the cooperatives then acquire and repay loans for operations and growth through their cooperatives.

Development Partners (NGOs, GIZ) & Cooperatives:

Partners provide funding, projects, and capacity-building support to the cooperative (E1, I2). These organizations might have their own goals to achieve. For example, a group that

develops a mobile app might want to see their product completed yet it might compromise farmers' or cooperatives' data (FGD1).

Cooperative implements projects and initiatives aligned with the partner's goals.

Government Institutions & Cooperatives:

The government sets regulations, and policies, and provides subsidies to the cooperative but they might not be directly involved in day-to-day operations. Some government officials connect the cooperatives to large markets and extension. Additionally, the government assigns extension workers to support with farming advice (FGD3).

Cooperative complies with regulations and utilises the services of the government for its operations.

Transporters & Cooperatives/Offtakers:

Transporters move produce from the cooperative to buyers and markets (I2). Cooperatives and buyers negotiate transportation costs and logistics.

Consumers & Offtakers/Buyers:

Consumers purchase products from off-takers/bulk buyers but they have limited direct influence over the cooperative (CS). The consumers can be other cooperatives, institutions, or individuals and also farmers within the same cooperative.

Consumer demand influences the types and quantity of products purchased by buyers.

The data from Ugandan farmer cooperatives reveals a complex AKIS landscape with stakeholders of all levels. The diagram below highlights the main characters that are the Cooperatives that comprise their members who are farmers. Cooperatives are divided into two categories: agricultural and financial but some also offer both services. The farmers can also be model farmers who test out certain agricultural products on their farms for the rest of the farmers to emulate. Cooperatives implement improved practices based on the advice of extension staff. Opinion leaders have a say on the agricultural practices but farmers decide whether to listen to them or not likewise the government and development partners. That defines the weak relationship between opinion leaders, model farmers and farmers then government institutions, development partners and cooperatives.

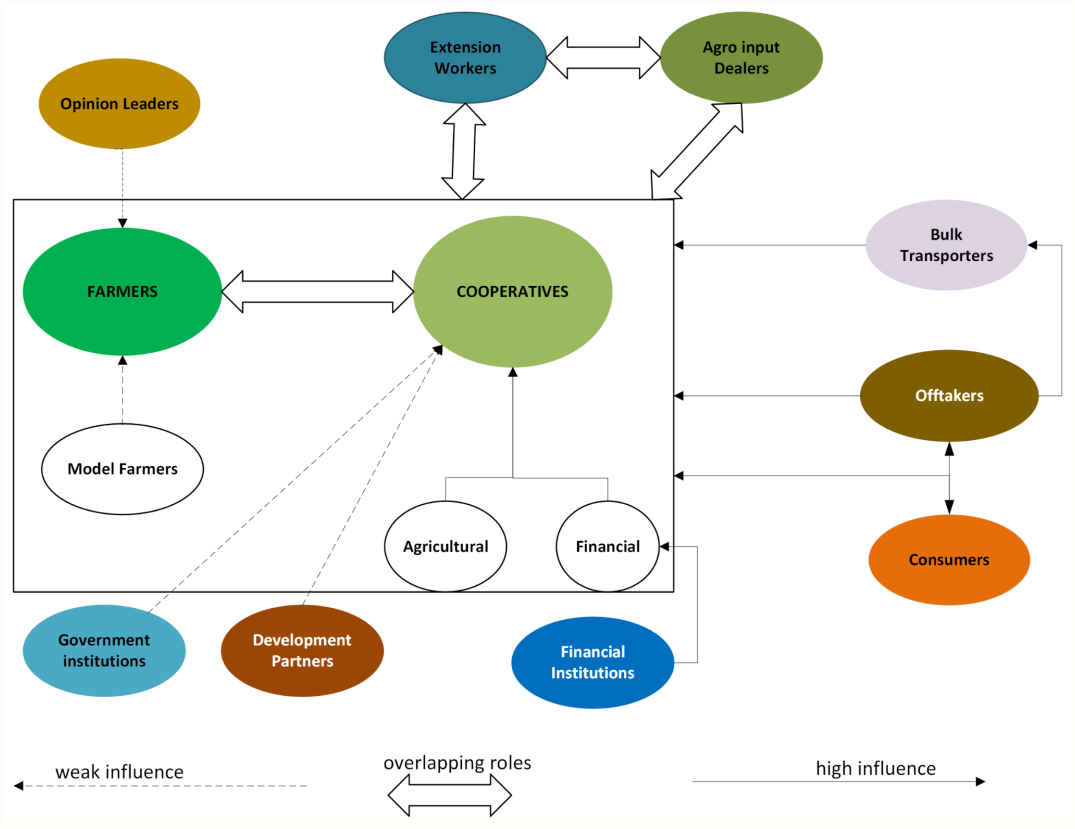

Fig 4: Diagram showing the key players in the agricultural value chain

The diagram above is split into two: the left shows weak influence with dotted arrows and the right the high influence. The two-dimensional arrow shows the overlapping roles of the players. Farmers are members of the cooperatives and may also be the board members in these cooperatives overseeing fellow farmers. Cooperatives have or employ extension workers who are their members/farmers. Extension workers also take on the role of agro-input dealers and vice versa. Cooperatives also supply their farmers with agro-inputs.

Consumers buy directly from cooperatives or off-takers or bulk buyers. Consumers can be other cooperatives or farmers within or without the cooperative. Depending on the quality of the produce, consumers can influence the price and demand of the agricultural produce.

Agro-advisory challenges

Untrustworthy and inaccurate information

Trustworthiness and accuracy of information are major concerns, with farmers often verifying information from multiple sources. Farmers trust the information and agro products

when input dealers or extension workers visit them face to face and practically carry out some experiments.

Extension worker, E2 confirms that the information she shares is accurate by providing information tailored to the farmers' specific situations and challenges, leading to successful implementation.

Farmers trust information and products more when delivered through face-to-face interactions and practical demonstrations by input dealers or extension workers (E1, E2, I1, I2). This in-person connection builds trust and credibility. For example one of the interviewees says that the time it takes for loan and credit approvals can also be a problem as physical meetings and verification processes can cause delays in agricultural activities. The board members wait for the loan requests to pile up before they can arrange for seatings to be approved.

Members of the cooperatives trust the information from the extension workers when they physically visit (FGD1, FGD2, FGD3) with a backup of a technical person employed by the government from the district (E1).

Access and availability challenges

Farmers struggle to get timely information on market prices, weather forecasts, and new farming technologies. They often rely on traditional media and community or opinion leaders for updates on topics like climate change, pests and diseases.

The absence of extension workers hinders the flow of information (F11). Despite one of the cooperatives having a dedicated extension worker, the cooperative's operational area spans four districts, making it difficult to provide adequate coverage. The limited number of extension workers at both district and sub-county levels, along with their various responsibilities further strains their ability to provide consistent support to all cooperatives.

Sometimes the radio station has other programs scheduled that the agricultural stakeholders cannot interrupt their programming.

Farmers currently seek markets by physically interacting with local buyers, but this approach has limitations. They have expressed interest in online platforms where they could advertise their products and connect with a wider range of buyers (CS).

Infrastructural challenges related to user capacities

For farmer cooperatives, agro-input dealers, and extension workers who are less familiar with digital communication, radio programs and face-to-face interactions are the preferred methods. However, radio advertising can be costly, posing a financial challenge for all the interviewees except the E1 whose organisation has designated funding for it.

All the interviewees agree that the cost of radio programs is a significant barrier, as highlighted by all the input dealers, two farmer cooperatives and extension workers. Many rural farmers do not own radios, limiting their access to information broadcast on radio programs (E1, F9). Additionally, radio talk shows or programs are not free; one ought to pay a significant amount for an hour-long program. Without sufficient funds, access to radio as a communication tool is restricted. Many farmers may miss the radio announcements because they are brief and depending on the payment, they may be scheduled at unknown times (E2).

Some communities don't even have access to a radio and even those who have radios, may not be able to listen to the program every day because of other engagements (F9, F14, E1, P).

Input dealers frequently face linguistic barriers when operating in diverse regions. During their travels to provide services, they may encounter farmers who speak local dialects unfamiliar to them and inaccurate conveyance of their intended message due to comprehension difficulties (I2).

Depending on the region, some farmer cooperatives face problems with the phone network and cannot make or receive phone calls (FGD3, F14). Some farmers do not have phones, making it difficult to communicate with them (E2). The farmers argue that they cannot afford even feature phones because they are currently focused on other financial responsibilities like paying school fees for their children (F14, F9, P). Purchasing a smartphone to access digital communication is even harder because the cost of a smartphone is equivalent to the cost of tuition fees. These are dedicated farmers, but low crop prices prevent them from affording smartphones.

> *We do the farming but get very little profit from it, we take back the money into the farm produce for seedlings~P*

Their small profits go towards tuition fees and reinvesting in the next harvest, leaving little for other expenses (FGD3, P).

Digital Transformation and digitalisation

Two farmer cooperatives who have not used any form of mobile application software share their opinions on their current methods of record keeping.

Right now, one of the farmer groups uses spreadsheets to keep track of farmer information. However, farmers and stakeholders in the agricultural sector are increasingly recognising the limitations of manual data management. One of the farmers from the cooperative points out the difficulty of maintaining accurate records manually. One of the staff highlights the security advantages of digitalisation saying that they lose some of the physical records. And that digitalisation will inform their decisions as a cooperative for example in making early preparations for the farmers to counter unpredictable rains.

Digital tools can help find and verify information from farmers (F2). There are notable benefits of using digital tools for farmer profiling and communication with her peers, but she needs more information on how to use the tools (E2).

Instead of writing receipts by hand and transferring them to another book of records, it will be easier to use a computer system to keep track of sales at the input shop. This saves time and helps with quick customer deliveries. Besides assisting with agricultural research, advanced mobile gadgets make it easier to send bulk messages to the farmer group members, unlike the feature phone where they have to send multiple messages to farmers one by one.

Using computers for record-keeping would be much easier, but right now they have to use paper because their office doesn't have electricity. With computers, they could just store the information, search and find information without wasting time manually looking for the files.

The only cooperative using mobile application software for data collection responds that digital systems provide a more comprehensive picture of individual farmers, their crops, and their needs. This deeper understanding enables better-targeted interventions and support, ultimately benefiting the entire agricultural ecosystem.

Commercial Service Providers know that digitalisation will enhance traceability of data and information about a farmer and their produce. The current system of manually keeping record files often has incomplete or untraceable data of farmers hindering effective decision-making (CS). The system has mandatory fields marked with stars, and you can't move forward unless

you fill them all in (F7). This gives us time to double-check the information and compare it with our existing records in Excel before adding farmers to the system (F7).

The transition to digital agriculture, however, is not without its challenges. Commercial Service Provider acknowledges varying adoption rates, with some users embracing the technology fully while others remain hesitant. The key to driving adoption lies in demonstrating the tangible value of digital tools. When farmers see concrete benefits, such as access to new markets or improved yields, they are more willing to invest in these digital solutions.

While digital tools might not be a complete replacement for communication, digital tools can be integrated into existing business processes (I2).

> *In as much as this [moving totally to digital] is not where we are, but it's something that could be helpful [...] even if it is not the same means that you use to reach out to people, but it is maybe something you could incorporate into your business processes~I2*

Data bundles for internet access are cheaper and more useful than call or SMS bundles, and getting smartphones for farmer cooperatives could solve communication challenges (F9).

The experiences shared by these stakeholders portray the transformative potential of digital technologies in agriculture. While challenges remain, the benefits are undeniable, and the movement towards a more digital, data-driven agricultural sector is gaining momentum.

Impact of the digital tools on agricultural processes

The digital tools provided below were the tools that farmer cooperatives have utilised for aggro-advisory services. Most farmer cooperatives are embracing the Symos tool for many reasons indicated in each sub category of tools. Only two input dealers use iProcure for managing and tracking their sales.

YoPay Agric (FGD1)

YOPAY Agric is a digital tool that helps find the farmers and aggregate the demands, market information, prices, and even payments. The first Focus Group admitted that though they

used it for some time, they did not properly own it in regards to having the tool fully developed and handed over to them.

They say that the development partners partnering with the farmer cooperative on a project using that tool was quite confusing and ended quickly. They did not fully understand the details of the tools because it was not their application. The company shared basic information, but not a deep understanding of how the application worked.

The company set up everything and was supposed to train the members of the cooperative on how to use the tool, but there was confusion due to staff changes and the person responsible for training did not show up. The only thing that went smoothly was collecting information about the farmers.

The cooperative still has not been able to use the application and do not know how to proceed with other parts of it. They cannot evaluate the success or failure of the implementation of the application because that was in the hands of the person who was supposed to train them on its usage.

After that experience, another tool, Akello Banker was introduced.

Quest Digital or Akello Banker (FGD1)

This company created a digital tool to help farmers easily access loans and agricultural products. Their technology makes it simple for farmers to buy supplies, get advice on farming practices, and share their information with banks to get loans faster. It also uses mobile money and text messages to make payments and repayments easier, which helps farmers with lower incomes access the resources they need to improve their farming.

One of the farmer cooperatives requested tools from the company and provided their data but also underlying terms and conditions, but they disappeared after that. Due to a previous negative experience with Yopay Agric, the cooperative wanted a partnership with a new provider under specific terms.

The company seemed to disagree with the terms and conditions laid by the cooperative and left before the project could be launched. The cooperatives wanted to manage their data and have control over the application, so they asked them to train them on how to use the tool.

The approach of the tool implementers is more short-term and contractual, while they prefer a long-term partnership or atleast have an ownership of their data. This way, the farmer cooperatives requested for a tool owned by the governing authorities and that was how Symos tool was birthed.

Symos (FGD1, FGD2)

Symos, an agricultural application, fosters connections between farmers and buyers, while strengthening the capabilities of aggregators, agroprocessors, and member-based organizations. This is achieved by enabling these stakeholders to monitor and manage their operations throughout the entire agricultural process, from the initial planting stage to the final harvest and marketing phase. *Fig 5 in Appendix C* shows the various user interfaces of the tool.

As long as there are farmer institutions, aggregators, or input dealers interested in using the tool, the commercial service provider promotes the Symos tool, shows them how it works, helps them get started, and encourages them to use it regularly.

Unlike most foreign-developed tools that are expensive and hard to manage, Symos is a locally developed, affordable, and user-friendly tool customized to the specific needs of local farmers.

Symos empowers farmers with financial insights to make informed decisions about their businesses, provides access to a wider range of buyers offering better prices, and helps establish trust by ensuring product quality and traceability.

Symos streamlines production monitoring by enabling regular updates and information sharing between extension service providers and farmers, ensuring timely interventions and accurate projections.

The digital system ensures accountability throughout the supply chain by assigning serial batches to each farmer's produce. This traceability feature encourages farmers to maintain high quality standards, particularly for organic products, as any quality issues can be directly linked back to them. The system fosters trust between farmers and buyers by ensuring transparency and accountability, leading to increased confidence in the quality of produce.

> *when you have taken your produce to the store [of the farmer cooperative], your bags are serially batched. So you actually have the responsibility over that produce until they reach the final destination. So now they're able to, you know, have some bit of discipline to produce the right quality that is expected of them. And even some buyers of organic products are now having confidence in some of these institutions because they know if they have said produce it organically, they know if you put anything, it will come back to you. So there's a bit of which is being built by this system [...]*
> ~Commercial Service Provider, CS

The contribution of farmers in the three focus Group Discussions reveals that the Symos tool is portable, making it easy to use in the field, and eliminating the need for some physical processes.

Symos significantly reduces costs associated with data collection, such as expenses for printing paperwork and hiring extension workers for profiling. They believe that the extension workers will be hired at the beginning to help with farmer profiling and that will phase out when all the information of the farmers is entered on the tool.

Most of the farmers were relieved that they could finally use the tool offline and sync the information into the cloud whenever they were back in the regions with a good network connection. Previously, the applications like YoPay Agric did not have this feature.

The GPS feature in Symos has been mentioned by the farmers as the most important tool that enables accurate tracking of farmer locations and agent activities, simplifying follow-ups, reducing paperwork, and saving costs of physically visiting to verify farmer location information.

I1 expresses that her supervisor uses the Symos tool to monitor sales even when he is out of the office. This reduces instances of missing products compared to before they had the application which makes the workers accountable in his absence. It is important to exercise caution and understand how to use the system properly to avoid issues.

F2 says that they are currently using the app for free for a year, and the future cost is still unclear. CS mentions that the price of the system hasn't been set yet because it is still under development. But confident that it will be affordable for farmer institutions and farmers. Based on the cooperative's current situation, F7 believe the system will be affordable for them to manage. F3 also affirms that the farmers may not fully understand the importance of

this tool yet, but the cooperative management recognizes its value. Therefore they will negotiate for a price that is affordable for everyone.

iProcure+

The i-Procure Phone Ordering App is a user-friendly mobile application created exclusively for wholesale suppliers. This comprehensive ordering system simplifies and streamlines the order placement process. Customers can conveniently place orders through the app, receive confirmation, and obtain an email record of their transactions. The tool comes as a package on a ticketing machine, desktop and mobile application sold as a package. The interface is shown in *Fig 6 in the Appendix D*.

I realised that only the input dealers are actively using the iprocure+ software to monitor their sales. The machine is linked to a mobile application on their phones, so they can keep an eye on the business and sales activity from anywhere.

One of the dealers mentioned that the machine gives him detailed records of everything, like daily sales, stock levels, and even monthly and yearly reports. It also prints receipts, so they do not have to buy as many notebooks for record-keeping, even though they still write things down as a backup.

All the two input dealers anticipate that the system can connect multiple branches. This would be great for both I1 and *I2* who were planning to open new branches soon. They were advised by the company that they would be able to track how both shops are doing every day. One of the input dealers after careful consideration, chose the iProcure machine over a surveillance camera for managing sales at the shop due to its superior features.

The high cost of the iprocure+ device and the potential future cost of the data management system pose financial challenges for input dealers. The initial price of around 1 million Ugandan Shillings for the machine (approximately USD 267) is considered high. Additional annual maintenance fees of 13,000 Shillings (approximately USD 3.50) further increase the financial burden. Both I2 and E2 emphasise that the machine is not affordable for many people, especially those in rural areas, because of the hefty fees not to talk about the maintenance fees and the internet costs. E2 suggests lowering the price to make it more accessible.

There is a critical need for training on how to use the system. E2 was trained initially, but there's no follow-up training when new features are added. Without hands-on practice, it is hard to master the system. Users need to be educated to a certain level to use this tool, which can be a challenge (E2).

I2 has only ever spoken to the company on the phone, except for the person who delivered and installed the machine. He is skeptical about their physical presence in Northern Uganda and relates that to being a ghost.

> *I only speak to them. I think the only person I saw was the one who brought the machine [and] trained my operator and installed it for me in my system. Ever since then, we have not met [...] I don't know whether they are ghosts or what, but we just speak on the phone. No, I don't think they are ghosts because if they came and did the training, they are not ghosts. I believe they are humans ~I2*

Data Management

Farmers and agricultural professionals value control over their data and information, including ownership, access, and privacy.

Symos tool users share their ideas of data ownership and control over the tool. Commercial Service Providers create access to the tool, which puts them in control to manage farmer cooperative information and deciding who gets to use the system.

Some farmers are hesitant to share information, especially about their land. But if you explain how the information will benefit them and assure them of confidentiality, they are more likely to cooperate (F1, CS, F2).

iProcure users (I2, E2) pride in some actions, like authorizing sales that are immediate only if they have a good internet connection. The extension worker can retrieve a forgotten password and add or delete information without consulting anybody, which gives him a sense of control over the machine. However, it is not easy to identify and fix errors on your own, so you have to call the company for help, but they do not always answer (I2).

Input dealer, I2 likes the feature of iprocure to choose the product codes that work best for him and his staff. But he is aware that while you might ultimately be in control of this aspect of arranging information, he feels like he might not be in full control.

Yeah, I have a feeling that I'm in control, but I'm not in full control [...] people are at the control center of the iProcure, can access your information ~I2

Another problem is that the system sometimes has preconfigured information that can be confusing. For example, when adding a product, you might find a similar one already in the system. I'm not sure if it automatically includes products from other shops, even those that aren't in your inventory (I2).

Empowering farmers and agricultural professionals with data managemetnt over their data can lead to more informed decision-making and greater autonomy.

Trade-offs for Digital Advisory services

While digital tools are helpful, the information they provide still needs verification. Even within cooperatives, staff members like E2 conduct research offline and cross-check information to ensure accuracy, as mentioned by F14.

Input dealer, I2 expresses confidence in the accuracy of digital tools when used correctly. They believe that inputting accurate information will yield reliable results, highlighting the importance of user diligence. However, input dealers, I1 and I2 acknowledge the potential for errors with digital tools, comparing them to the "garbage in, garbage out" principle.

Once you actually enter the right information, you will get the right thing. And the moment you mess it up, that is only the disadvantage part of it [iProcure]~Interviewee I2, iProcure user

While digital applications may be 80% accurate, human error and careful operation contribute to reliable results as mentioned by Interviewee E1, iProcure user.

With the increasing use of digital tools, farmers can check the information they get from extension workers against what's available online (FGD3). They want to make sure they're getting accurate information, so they compare it to other sources if they have access to devices like smartphones or computers.

Digitalisation could be a problem for extension workers because if farmers can find information online, they might not need the extension worker as much. This could potentially put their jobs at risk. However, F14 believes that farmers can use digital tools to research while extension workers can focus on the technical side of things, like how to apply the

information on the farm. This way, both farmers and extension workers can work together, using technology to their advantage.

E1 believes that farmer cooperatives need standardised products with accurate weights to fully benefit from digital tools. The tool can handle variations in weights, but it might be difficult to be precise when using a weighing scale. it is hard to measure exact amounts, especially when customers bargain or when there are small errors in weighing. This discrepancy between the recorded weight and the actual weight could raise suspicions.

Inclusive Digital Advisory Services

Cost and Affordability

The high cost of digital tools and devices is a significant barrier to adoption. Farmers and cooperatives express concerns about the affordability of these tools, especially after the initial free period. One participant mentioned, "We are not sure how much we are going to pay in the future. Since the app is still free, I think the amount is still not clear" (FG2).

Connectivity Issues

Network connectivity challenges, especially in rural areas, hinder the effective use of digital tools. A participant highlighted this issue: "But the issue is with the network. It's really selective. You need to take a spot that you're able to access internet" (FG14).

Training and Support

There is a critical need for training and ongoing support to help farmers effectively use digital tools. One participant emphasized, "Because without the training, there is no way you can really operate the system. So I really recommend there is a critical need to have that kind of capacity development" (E1).

Data Security and Privacy

Concerns about data security and privacy need to be addressed to build trust in digital platforms. Farmers value control over their data and information. A participant shared their perspective: "*Yes, with the information, actually, there are those particulars like some farmers tend to hide, but it depends on how you actually present to that farmer*" (FG5).

Future Considerations

To overcome challenges in digital agriculture, investments in training (E, E2, I1, I2) in the use of and the acquisition of devices like tablets for extension workers (F7) and smartphones for farmers (F9) may be necessary, with potential cost recovery strategies like charging fees (CS, I2).

Farmer cooperatives will be utilising solar-powered charging units the same way they charge for regular phone use (F9). Providing extension workers with tablets would be beneficial for their work, as some of them need better-quality phones. The farmer cooperatives could include this in the budget for the next financial year or seek support from the developers of the Symos tool (F7).

Additionally, ensuring digital platforms are accessible to all farmers, regardless of their phone type (I2), and providing training on both the systems and data analysis (E1, I2) are crucial.

The current system does not allow for digital analysis of expenses. The system doesn't currently show which products are selling the most, which is important information for businesses. It requires manual recording and uploading pictures of receipts, making analysis difficult (I2). The system needs to be simplified so that both operators and input dealers can easily analyze and interpret complex information without relying on external tools like Excel. I2 would like to see his cash flow analyzed within the system itself, without needing to export the data to Excel for calculations. Otherwise, I2 and staff might need training on how to use Excel to analyze information effectively, as well as training on how to use the iprocure system's features, like uploading pictures and entering information.

Finding cost-effective solutions for capacity building and communication is crucial to ensure farmers can access the resources and information they need. Partnerships with organizations like Permaculture Denmark, which focus on capacity building through various training programs, are a valuable resource (E1).

Commercial service providers act as helpers for farmer cooperatives when it comes to selling their products. They give farmers information about the market, like what's popular and where to sell for the best price. They also help with the actual selling process, making it easier for the farmers to get their products to the buyers. Farmers require immediate assistance when they encounter problems, but the current system makes it difficult to provide prompt support (CS). While online support is attempted, it is not always successful because

the farmer cooperatives require physical availability to use digital tools whereas financially costly (CS).

It is difficult to provide immediate support to all the farmer institutions in large service areas due to limited staff (CS). Travelling between institutions is costly and inefficient, especially when issues arise that require prompt attention. They try to offer online support, but some users still struggle. To address this, they are considering centralized training sessions to bring users together and provide comprehensive instruction. This way, they can return to their institutions with the necessary knowledge and skills to use the system effectively.

(E1, I2, E2) expressed a preference for a more effective digital tool for agro-advisory services, even if it meant switching from a familiar one. They emphasized the importance of familiarity over functionality, using the term "proximity" to describe the tendency to stick with what is known. If a superior system capable of performing the same tasks were available, they would readily adopt it.

Summary of findings

The agricultural value chain in Uganda involves a complex network of actors. Farmer cooperatives play a central role, organizing farmers and facilitating access to resources and markets. Extension workers provide crucial knowledge and support to farmers, while input suppliers ensure access to essential agricultural inputs. Other actors include commercial service providers, buyers, financial institutions, development partners, government agencies, transporters, consumers, and opinion leaders. Each actor plays a distinct role in the flow of knowledge, resources, and influence within the agricultural ecosystem.

Communication among stakeholders occurs through a mix of traditional and digital channels. While radio broadcasts and face-to-face interactions remain prevalent, digital technologies like websites and social media are gaining traction. Farmer cooperatives rely heavily on radio broadcasts and in-person events for outreach. Extension workers utilize radio, social media, and in-person visits to disseminate information. Input suppliers primarily rely on radio advertising and in-person demonstrations to reach farmers. The preference for radio broadcasts stems from its wide reach and accessibility, even in remote areas. But in reality, radio cannot work in isolation and so accompanied by phone calls or physical invites.

Digital transformation is gradually reshaping the agricultural sector in Uganda. Digital tools like YoPay Agric, Akello Banker, Symos, and iProcure+ are being used to streamline processes, improve access to information and financial services, and enhance efficiency. Symos, in particular, has gained traction due to its user-friendly interface, affordability, and offline functionality. However, challenges remain, including the high cost of digital tools, limited connectivity in rural areas, the need for training and support, and concerns about data security and privacy.

Discussion

This section will analyze interview data using relevant theories and existing literature.

Agricultural Stakeholder Interactions within AKIS

The Agricultural Knowledge and Information System (AKIS) is a complex network of actors and institutions that collaborate to generate, share, and utilize agricultural knowledge and information (Röling, 1990; Rivera & Schram, 2022). This network, as described by Rivera and Schram (2022), is more than the sum of its parts, forming a cohesive system when its elements are interconnected and work together towards shared objectives. The dynamics between different stakeholders in AKIS are crucial for understanding the flow of information and its impact on farmers (Klerkx & Proctor, 2013; Röling, 1990). Farmer cooperatives, extension workers, input dealers, commercial service providers, and government institutions all play distinct roles in this system. Effective communication and collaboration among these actors are essential for the successful adoption and utilization of both traditional and digital advisory services (Klerkx et al., 2012).

The AKIS framework encompasses various actors and institutions, including:

Farmers and Farmer Cooperatives: The primary producers and end-users of agricultural knowledge and information (Röling, 1990). The interviews highlighted the role of farmer cooperatives in Uganda, which serve as central nodes for knowledge sharing, resource pooling, and market access (FGD1, FGD2, FGD3).

Research Institutions and Universities: These entities generate new knowledge (E1) and technologies through research and development (FAO, 2000; Rivera et al., 2005).

Extension Services: They bridge the gap between research and practice by disseminating information and providing training to farmers (E1, E2).

Other Actors: The AKIS network also includes input suppliers, model farmers, opinion leaders, commercial service providers, buyers, financial institutions, development partners, government institutions, transporters, and consumers (Klerkx et al., 2012; Spielman et al., 2011). Each of these actors plays a crucial role in the flow of knowledge, resources, and influence within the system.

Knowledge exchange is a fundamental process within AKIS, involving both explicit (codified) and tacit (experiential) knowledge (Röling, 1990). The interviews revealed various channels for knowledge exchange in Uganda, including extension services, farmer-to-farmer learning, and digital platforms (E1, E2, FGD1, FGD2).

The findings from the interviews in Uganda directly reflect the evolution of the AKIS concept from a "hard systems" to a "soft systems" perspective. The early focus on formal structures like farmer cooperatives and government extension services aligns with the initial "hard systems" view of AKIS (Leeuwis et al., 1990). These entities were seen as the primary channels for knowledge dissemination, with a top-down approach often prevalent. For instance, the extension workers were primarily tasked with delivering predefined information to farmers (E1, E2). However, the findings also highlight the emergence of a "soft systems" perspective, where the emphasis is on the diverse actors and their interactions within a flexible system (Checkland, 1999). This is evident in the various roles played by different stakeholders. Model farmers (E2) acting as informal knowledge sources and demonstrating practical solutions. Opinion leaders influencing farmers' decisions through their social networks (E2). Commercial service providers offering business advice and market linkages (CS). Farmer cooperatives providing loans and financial literacy to their fellow farmers (FGD1, FGD3). Development partners supporting capacity building and project implementation through extension workers (CS, E1).

The farmer cooperatives themselves can be seen as a miniature of the AKIS, with their internal structures reflecting both formal and informal knowledge exchange processes. They not only interact with external stakeholders, E1, E2,I1, I2, CS but also facilitate learning and knowledge sharing among their members (FGD1, FGD2, FGD3).

The interviews also reveal the limitations of a purely "hard systems" approach. For instance, the over-reliance on formal extension services was sometimes seen as inadequate to meet farmers' diverse needs (P). This emphasises the importance of recognizing and incorporating the informal knowledge networks and the diverse actors that contribute to agricultural innovation.

Innovation is another key aspect of AKIS, with actors constantly seeking new ways to improve agricultural practices and productivity. The interviews highlighted the role of model farmers, extension workers and cooperatives in promoting innovation through demonstration and experimentation (E2, FGD1). This is also evidenced by an extension worker, E1 who

infuses innovation through demonstration farms on permaculture for the vulnerable community to engage in the agri-food systems.

The AKIS framework, while comprehensive, has its limitations where it neglects the broader context in which agricultural knowledge is generated and used, including social, economic, and political factors (Hall et al., 2003).

While AKIS theories provide a comprehensive framework for understanding knowledge and innovation systems, they often lack guidance on practical implementation strategies, especially in resource-constrained settings like the Ugandan farmer cooperatives. The theories do not adequately address the challenges of technology adoption, financial constraints, and digital literacy that were prominent in the findings.

While AKIS theories acknowledge the role of both formal and informal institutions, they tend to focus more on formal structures like research institutes and extension services. The findings suggest that informal networks and social learning play a crucial role in knowledge exchange and innovation adoption among farmers.

By leveraging digital tools and platforms, researchers and innovators can engage with stakeholders, gather feedback, and address ethical, social, and economic concerns related to agricultural technologies (Bronson, 2018; Jirotka et al., 2017; Rose & Chilvers, 2018; Eastwood et al., 2019).

Integrating Digital and Traditional Knowledge Systems

The digital transformation of AKIS requires a careful integration of digital knowledge systems with farmers' existing knowledge systems (Tsouvalis et al., 2000; Lundström & Lindblom, 2018; Bechtet, 2019). This involves not only providing access to digital tools and platforms but also ensuring that the information is relevant, understandable, and applicable to the local context.

The role of extension workers and other intermediaries becomes even more critical in this process (). They need to act as facilitators, helping farmers to navigate the digital landscape, interpret information, and apply it to their specific farming practices (E1, E2).

Digitalization is reshaping the AKIS landscape, creating new pathways for knowledge generation, dissemination, and utilization. However, this transformation also poses

challenges, such as the digital divide and the need for capacity building among farmers and extension workers.

To address these challenges, future research and practice should focus on:

The power dynamics within the AKIS network can lead to marginalized voices, such as those of smallholder farmers, being overlooked (Röling, 2007). Though organised farmer groups give farmers a collective representation of their voices ensuring that all actors, including marginalized groups forexample independent farmers, have a voice in the AKIS network. This can be achieved through inclusive communication approaches. Additionally, developing digital infrastructure in rural areas to bridge the digital divide.

Fostering trust between farmers and extension workers through transparent communication and participatory approaches. This would eliminate the doubts where a private extension worker needs validation from the government extension worker to fortify the trust from farmers about agricultural knowledge. Promoting farmer-to-farmer learning to encourage knowledge sharing among farmers through various platforms.

Farmers have accessed loans through village savings and loan associations (VSLA) or SACCOS however, leveraging digital services to enhance farmers' access to credit, savings, and insurance services.

By addressing these challenges and embracing a more inclusive and dynamic approach, the AKIS framework can continue to play a vital role in promoting sustainable agricultural development and food security.

Communication Preferences for stakeholders using RCS Framework

The Rural Communication Services (RCS) framework, grounded in Communication for Development (ComDev) principles, emphasises the importance of two-way communication and active participation in rural development (FAO, 2017). This approach acknowledges the existing knowledge and experience within rural communities (), fostering inclusive decision-making processes and sustainable development (FAO, 2014). The RCS framework is guided by five key principles:

Right to Information: Recognizing all citizens' entitlement to accurate, timely, and relevant information, as exemplified by radio broadcasts in local languages (Ngakaramojong and

Lango) by extension workers (E1, E2) and agro-input dealers (I1, I2) to reach farmers with limited literacy.

Demand-Driven: Designing communication programs and services that respond to the specific needs identified by the rural community. The "Training of Trainers" (ToTs) approach adopted by one cooperative (E1) is a direct response to the demand for more extension services.

Gender Equitable: Promoting equal participation and empowerment for both men and women in accessing and using information and technology. While not explicitly mentioned in the study, ensuring gender equity could involve tailoring training sessions and radio programs to the specific needs and interests of both female and male farmers.

Fostering Social Inclusion: Ensuring that communication services reach all members of the community, regardless of social status, health, or other factors. The use of visual aids and demonstrations by agro-input dealers (I1, I2) caters to both literate and illiterate farmers, ensuring inclusivity.

Local Context-Driven: Adapting communication strategies and tools to the specific cultural, social, and economic context of the target community. Extension worker E1 exemplifies this by tailoring information to local contexts and addressing immediate needs based on prior discussions.

The research highlights various communication channels used in rural settings, each with different levels of effectiveness:

In-person interactions are considered the most effective due to their direct, personal nature, and ability to foster trust. They include physical events, training sessions, and visits from officials (FGD1, FGD2, P, E1, E2, F12, I1). Training of Trainers (ToTs) is an effective strategy to address the shortage of extension workers and expand the reach of services (E1). Visual Aids & Demonstrations are essential tools for conveying complex information to both literate and illiterate audiences (I1, I2).

Radio remains a popular and widely accessible medium, particularly in remote areas (E1, I1, I2). However, cost constraints (FGD3) pose a challenge, often addressed through partnerships (E1). Phone Calls are primarily used for mobilization, negotiation, and coordination of physical interactions (FGD1, FGD2, FGD3).

Although social media & digital platforms are growing in relevance (E2), access to smartphones and internet connectivity remains limited in some areas. Platforms like WhatsApp are used strategically (I2).

Several challenges hinder the effective implementation of RCS. Financial constraints limit the use of expensive channels like radio broadcasts and in-person interactions. Limited access to smartphones and the internet in some areas restricts the use of digital platforms. The prevalence of illiteracy necessitates the use of traditional visual aids and physical demonstrations which might be costly for service providers if done repeatedly. Lastly, the shortage of extension workers necessitates alternative approaches like ToTs but also a disruption in the flow of information.

Criticisms of the Findings

Limited Geographic Scope: The findings are primarily focused on a specific region and may not be generalizable to other rural contexts with different socio-economic and cultural characteristics.

Selection Bias: The interviewees (E1, E2, I1, I2) represent specific roles (extension workers, agro-input dealers) and may not fully capture the diverse perspectives of farmers and other stakeholders in the Northern region of Uganda.

The findings rely heavily on qualitative interviews and observations, lacking comprehensive quantitative data that could provide a more comprehensive picture of communication channel effectiveness.

Potential overemphasis on radio by the stakeholders without its direct impact on the farmers on the receiving end. While radio is highlighted as a crucial tool, the findings may not fully account for the growing influence of digital platforms and mobile technology in some rural areas.

Criticisms of the RCS Framework

While the framework provides valuable principles, the actual implementation of RCS can be complex and resource-intensive. Ensuring that communication programs are truly demand-driven, gender-equitable, and socially inclusive requires significant effort and coordination.

The RCS framework emphasises participation and inclusion, but it may not fully address underlying power imbalances within communities or the potential for communication to reinforce existing inequalities.

Assessing the long-term impact of RCS initiatives can be challenging, as changes in knowledge, attitudes, and behaviors may take time to manifest and are influenced by a variety of factors beyond communication alone. It may focus on changing individual behaviors, but the findings highlight the importance of collective action and social networks in driving innovation adoption. Communication strategies should therefore aim to foster collective learning and empowerment within farmer cooperatives.

Communication theories often focus on verbal communication, neglecting the importance of non-verbal cues, social norms, and cultural context in knowledge exchange. The findings suggest that face-to-face interactions and trust-building are crucial for effective communication among farmers and other stakeholders.

Ensuring the sustainability of RCS programs, especially in terms of funding and local capacity building, remains a significant concern.

The rapid evolution of technology poses challenges for the RCS framework, as new platforms and tools emerge that may not be fully addressed by existing principles and strategies.

The RCS framework provides a valuable starting point, it's essential to acknowledge its limitations and potential criticisms. Ongoing research, evaluation, and adaptation of the framework are necessary to ensure its relevance and effectiveness in addressing the evolving communication needs of rural communities.

Digital Transformation and Digitalization through AKIS and RCS

The agricultural landscape is undergoing a profound transformation, driven by the rapid advancement and integration of digital technologies. The experiences of farmers and stakeholders in the Northern region of Uganda, offer valuable insights into the interplay between digital tools, and the broader AKIS framework.

According to Klerkx, Jakku, and Labarthe (2019), digitalization has fueled the development of AKIS, with evidence emerging at macro, meso, and micro levels. From a macro perspective, research has examined how innovation support structures enable and are altered

by digitalization, including the integration of big data analysis (Kamilaris et al., 2017). New actors, such as service industries, multinational corporations, and high-tech firms, are also shaping AKIS for digital agriculture (Eastwood et al., 2017).

While some farmer groups still rely on manual spreadsheets for record-keeping, the limitations of this approach are becoming increasingly apparent. Inaccurate records, loss of physical documents, and the inability to quickly access and analyze data hinder decision-making and preparedness for challenges like unpredictable weather patterns (FGD1). This highlights the critical role of digitalization in improving data management within the Agricultural Knowledge and Information System (AKIS).

Digital tools like Symos offer promise in this regard, providing a comprehensive view of individual farmers, their crops, and their needs (FGD1, FGD2). This enables targeted interventions and a more efficient flow of information within the AKIS network, as outlined in the Rural Communication Services (RCS) framework (FAO, 2017). However, successful implementation hinges on factors like data ownership, user-friendliness, and affordability.

The experience with YoPay Agric and Akello Banker (FGD1) stresses the importance of equitable partnerships between farmers and technology providers. Farmers' desire for control over their data and long-term collaboration aligns with the RCS principles of demand-driven and locally context-driven solutions. The emergence of Symos, a locally developed and affordable tool, suggests a potential solution to these concerns.

At the meso level, learning networks and social media platforms are facilitating information sharing and peer learning (Eastwood et al., 2012; Kelly et al., 2017). This aligns with the RCS principle of fostering social inclusion and promoting two-way communication in rural development. Digital platforms like WhatsApp, though not universally accessible, are being used strategically to connect farmers and stakeholders (I2).

However, challenges remain in bridging the gap between "digital knowledge systems" and "farmers' knowledge systems" (Tsouvalis et al., 2000). The need for capacity building and training (E1, E2, I1, I2) highlighted in the case studies emphasizes the importance of AKIS actors facilitating this knowledge transfer effectively.

Impact of Digital Tools on Agricultural Processes

The interviews reveal both the potential and challenges of digital tools in agricultural processes. The experiences with YoPay Agric and Akello Banker (FGD1) exemplify the difficulties in implementing new technologies, particularly when there is a lack of understanding, training, and control over data. This highlights the need for AKIS to prioritize user-centered design, capacity building, and equitable partnerships in the development and deployment of digital tools.

On the other hand, the success of Symos, a locally developed and affordable tool (FGD1, FGD2), demonstrates the importance of tailoring digital solutions to the specific needs and contexts of local farmers. The tool's features, such as production monitoring, traceability, and GPS tracking, align with AKIS goals of improving efficiency, transparency, and market access. The positive feedback from farmers on the offline functionality and user-friendliness of Symos impress the importance of designing tools that are accessible and relevant to their daily practices.

iProcure+, a tool primarily used by agro-input dealers (I1, I2), showcases the potential of digital tools in streamlining business operations and enhancing financial management. However, the high cost and limited training opportunities (E2, I2) pose barriers to wider adoption. This aligns with the AKIS challenge of ensuring affordability and capacity building to maximize the benefits of digital tools.

Data Management

The interviews show the importance of data ownership and control in the digital era. Farmers' concerns about data privacy and the desire for long-term partnerships with technology providers (FGD1) resonate with the RCS principle of demand-driven solutions. The AKIS framework must consider these concerns and promote ethical data practices that empower farmers and ensure their ownership over their information.

Inclusive Digital Advisory Services

The digital divide remains a significant challenge, with limited access to smartphones and internet connectivity in some rural areas (E2). This necessitates investments in infrastructure and training to ensure equitable access to digital advisory services. The RCS framework

emphasizes the importance of fostering social inclusion, which aligns with the AKIS goal of reaching all farmers, regardless of their technological capabilities.

Furthermore, the varying adoption rates of digital tools (CS) reveal the need for AKIS to focus on user-centered design, capacity building, and demonstrating tangible benefits to encourage wider adoption.

The digital transformation of agriculture is a complex and ongoing process, shaped by the interplay of technological advancements, social dynamics, and economic realities. The AKIS and RCS frameworks offer valuable insights into the challenges and opportunities presented by digital tools in agriculture. By integrating these frameworks, stakeholders can develop a more holistic and sustainable approach to digital transformation, ensuring that digital tools are not only accessible and affordable but also relevant, trustworthy, and empowering for rural communities.

Continued research, evaluation, and adaptation of these frameworks are essential to address the evolving needs of farmers and ensure that digital tools truly contribute to a more equitable and prosperous agricultural sector.

Technological Determinism, these theories tend to overemphasize the transformative power of technology, neglecting the social, cultural, and economic factors that influence technology adoption. The findings raise concerns about data management, and the potential for digital tools to reinforce existing inequalities if not implemented carefully (FGD1). During one of the discussions with FGD3, they requested for a video call to confirm that a human was conducting the interview. This aligns with the findings from I2 about doubting the existence of the digital service providers for continous improvement.

> *“I don't know whether they are ghosts or what, but we just speak on phone.*
>
> *No, I don't think they are ghosts because if they came and did the training, they are not ghosts. I believe they are humans”~I2*

The findings reveal that cost, connectivity, digital literacy, and trust issues are significant barriers to the adoption of digital tools in farmer cooperatives.

Digitalization theories often lack contextualization for specific agricultural settings, especially in developing countries. The findings highlight the need for locally relevant digital solutions that cater to the specific needs and constraints of farmer cooperatives in Uganda.

Revised Conceptual Framework

AKIS is a network of actors and institutions collaborating to generate, share, and use knowledge/innovation with the help of communication services (RCS)for agricultural development. This framework is enhanced with data on Ugandan farmer cooperatives, highlighting their role and interactions within the AKIS.

The diagram illustrates the revised conceptual framework for Agricultural Knowledge and Innovation Systems (AKIS), incorporating findings from the study on Ugandan farmer cooperatives. At the core of the framework are three interconnected elements:

Actors: This includes farmers, cooperatives, and other stakeholders such as government agencies, extension workers, input suppliers, buyers, and development partners. These actors play different roles in the generation, dissemination, and utilization of agricultural knowledge and innovation.

Institutions: These are both formal (research institutes, universities, extension services) and informal (social networks, farmer groups, communities of practice) structures that shape the flow of knowledge and resources within the AKIS. The addition of cooperatives as institutions highlights their central role in connecting farmers to other stakeholders and facilitating access to information, services, and markets.

Knowledge: This encompasses both explicit knowledge (codified and transferable information) and tacit knowledge (implicit knowledge gained through experience and practice). The addition of "digital knowledge" reflects the increasing importance of digital tools and platforms in agricultural knowledge and innovation processes.

These three core elements are interconnected through a continuous process of knowledge exchange and innovation. Rural Communication Services (RCS) play a crucial role in facilitating this process by providing channels for communication and information sharing. The revised framework acknowledges the importance of both traditional (face-to-face, radio) and digital (mobile apps, online forums) communication channels in reaching diverse farmers and stakeholders.

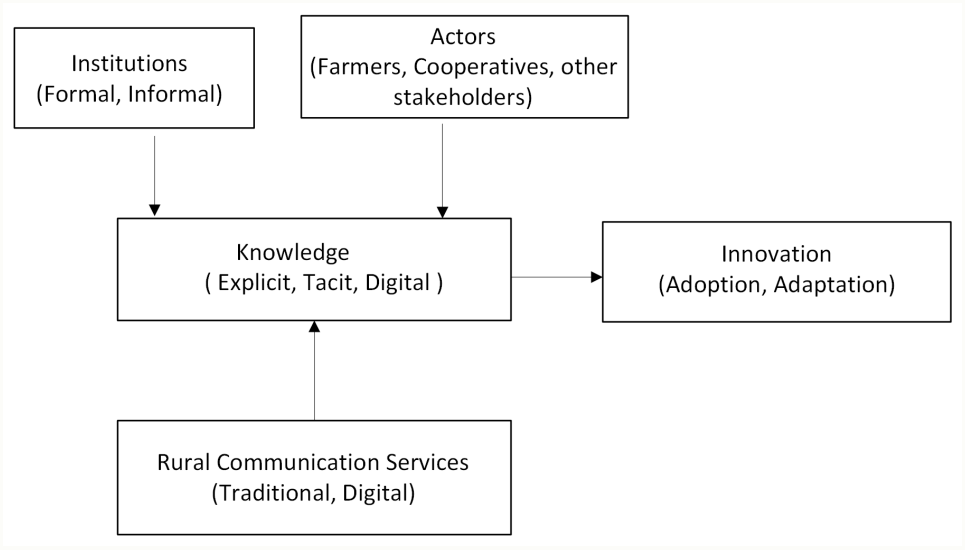

Fig 7: Revised conceptual framework with application of interview data

The arrows between the elements indicate the dynamic and interactive nature of AKIS. Knowledge is not simply transferred from one actor to another but is co-created and exchanged through dialogue, learning, and collaboration. This process leads to innovation, which can be in the form of new technologies, practices, or organizational models that contribute to agricultural development.

The revised framework also acknowledges the challenges and limitations of AKIS, particularly in the context of Ugandan farmer cooperatives. These challenges include limited access to digital tools, concerns about data ownership and privacy, and the need for more effective communication strategies that cater to the diverse needs of farmers and other stakeholders.

Traditional communication theories often assume a linear model where information flows from sender to receiver. This model does not adequately capture the complex, interactive nature of communication in AKIS, where knowledge is co-created and exchanged through dialogue and social learning.

Conclusion

This section will address the research questions, the limitations of this study, and offer recommendations for future research.

RQ1: What are the main sources of agricultural advisory information?

The main sources of agricultural advisory information, as highlighted in the interviews and supported by existing literature, are a combination of traditional and digital channels, each with its own strengths and limitations.

Traditional Extension Services: These services, often delivered through government agencies or NGOs with face-to-face interactions, remain a primary source of information for many farmers mirroring the findings by Norton et al. (2020) and Van Campenhout (2021). Extension workers provide face-to-face advice, training, and demonstrations, which are highly valued for their personalized nature and ability to build trust (E1, E2). This echoes findings by Feder et al. (2010) and Taylor & Bhasme (2018) on the importance of extension services in knowledge dissemination. Studies by Feder et al. (2010) on public and the private extension services by Feder, Birner & Anderson (2011) and Zhou & Babu (2015) may be accessed through non participating or participating in farmer groups. The number of rural farmers accessing extension services are low which is consistent with the findings of Atube et al. (2021). However, the reach and effectiveness of these services are often limited by resource constraints and a lack of coordination between research and practice (Hocde et al., 2008).

Farmer-to-Farmer Networks: Farmers often rely on their peers and social networks for information and advice (FGD1, FGD2, FGD3). This informal knowledge sharing is particularly important for localized knowledge and practices emphasized by findings from Beaman & Dillon (2018) and Zeltzer (2020). Despite this it can also be a source of misinformation if not complemented with accurate and up-to-date information from other sources (FGD3, E1, E2).

Radio remains a widely accessible medium for agricultural information dissemination, especially in remote areas with limited internet connectivity (E1, I1, I2). Yet its effectiveness is constrained by factors such as cost, scheduling conflicts, and the generic nature of the

information provided (Aker, 2011; Mwombe et al., 2014). A mentioned, "*sometimes you also find that a radio does not work independently. It is supported using other media like the telephone[...] to get more information because you have put the contact on the radio. I think it is prudent not to consider that one method fits all,"*~I2.

Therefore, a follow up with a phone call or SMS or physical invites complements communication from radios.

ICTs and Digital Platforms: The emergence of digital tools like mobile applications and SMS services is transforming the way farmers access information as stipulated by Steinke et al., (2019) aligning with global trends towards digital extension (Gow et al., 2020; Klerkx et al., 2022). ICTs have been shown to increase awareness and adoption of suitable agricultural technologies, leading to increased yields (Cole & Fernando, 2012; Nakasone et al., 2014). These platforms offer more personalized, interactive, and on-demand access to information, potentially overcoming some limitations of traditional channels. However, challenges such as inadequate infrastructure, high costs, and lack of digital literacy hinder wider adoption consistent with findings by Mendes, Paz, & Callado (2018), Saidu, Gana & Mohammed (2017), Jain et al. (2015), Dillon, (2012) and Akpabio et al., (2007).

The findings also highlight the importance of a multi-channel approach to agricultural advisory services echoing findings by Birner, Davis, Pender, Nkonya, Anandajayasekeram, Ekboir & Cohen, (2009) and Davis & Sulaiman (2014). Combining traditional and digital channels can leverage the strengths of each actor and provide farmers with a more comprehensive and accessible source of information. For example, radio programs can be used to raise awareness and provide basic information, while digital platforms can offer more in-depth and personalized advice. Additionally, extension workers can play a crucial role in facilitating the use of digital tools and bridging the gap between research and practice.

RQ2: How do digital tools impact the delivery and uptake of agro-advisory services?

In alignment with the findings of Steinke et al. (2022) and Birner et al. (2021), stakeholders across various levels within the agricultural sector expressed a widespread optimistic outlook towards the potential of digital technologies. This suggests a general belief in the

transformative power of digital tools to enhance agricultural practices and outcomes negating the downside of technologies including farmer's data (Biemba et al., 2017).

For farmers, digital tools empower farmers by providing them with direct access to information and decision-support systems, reducing their reliance on traditional extension services aligning with research on the potential of digital tools to improve efficiency and reach (Casaburi et al., 2014; Spielman et al., 2021). For instance, Symos enables farmers to connect directly with buyers, eliminating intermediaries and potentially increasing profits. Additionally, iProcure+ simplifies inventory management for input dealers, allowing them to track sales and stock levels more efficiently. Despite this the digital divide and unequal access to technology can exacerbate existing inequalities (Aker et al., 2016; Blumenstock & Eagle, 2012).

Researchers use digital platforms can facilitate better communication and collaboration between researchers and farmers, enabling researchers to tailor their work to the needs of farmers (Anderson & Feder, 2004). However, challenges in data sharing and integration across different platforms may persist. The role of extension workers may evolve as digital tools become more prevalent (Norton et al., 2020). While some fear that technology may replace them, others see it as an opportunity to enhance their services and reach a wider audience (E1, FGD3). The successful integration of digital tools requires training and support for extension workers to effectively utilize these tools (Mendes et al., 2018).

Digital platforms are recognized for bridging the information gap between farmers and markets. The use of digital tools for data collection and analysis enables more personalized and targeted advice, consistent with the literature on data-driven agriculture (Steinke et al., 2019; Carmona et al., 2015; 2018). For example, Symos collects data on farmers' crops and production practices, which can be used to provide tailored recommendations. Aker's research (2011) demonstrates that access to real-time market information via mobile phones significantly improved prices for farmers in Niger. Similarly, Ugandan cooperatives are leveraging digital tools to expand their market reach beyond local constraints, aligning with Mittal, Gandhi & Tripathi (2018) findings on the power of digital platforms to reduce information asymmetry and empower farmers in price negotiations.

Digital tools provide farmers with the means to track expenses, analyze production data, and make informed decisions. Research by Nakasone et al. (2020) found a positive correlation

between digital record-keeping and improved financial management among smallholder farmers in Tanzania. This resonates with the experiences of Ugandan cooperatives, where digital tools are enabling farmers to assess the profitability of different activities and optimize resource allocation.

Digital traceability systems are enhancing transparency and trust across agricultural value chains. Wolfert et al. (2017) explore the potential of blockchain technology to trace the origin and quality of agricultural products. The interviews with Ugandan cooperatives' use of digital traceability systems mirrors this trend, showcasing how these tools increase consumer confidence, particularly for organic products, and encourage farmers to uphold stringent quality standards. Symos, for instance, assigns serial batches to each farmer's produce, allowing for traceability and quality control.

Additionally, a study focused on mobile phones by Nakasone et al. (2014) highlighted the early stage of many ICT-enabled agricultural programs, the present study found that while the farmer profiling modules of the Symos tool are operational, the core modules directly impacting agricultural processes, such as brokerage and production, remain under development (CS, FGD1, FGD2).

While digital tools hold potential, their reach is limited by the digital divide (Aker et al., 2016), necessitating investments in infrastructure and digital literacy. As highlighted in Zantvoort, van Haastrecht & van Dijk (2020), the centralized control of data in platforms like SYMOS raises questions about data management like ownership and privacy, requiring robust data governance mechanisms. The affordability and long-term sustainability of digital tools remain challenges, as indicated by concerns over the future cost of the data management system by the farmer cooperatives, E1, I2, FGD1 and FGD2.

Therefore, it is possible to affirm that although the introduction of digital tools poses the question on privacy, honesty and transparency, it has the potential to shift the dynamics of delivery of agricultural advisory services in agreement with the findings of Norton et al. (2020). This aligns with the interview setting with FGD3 who preferred a video call to confirm participation of human despite high internet costs. Also, I2 doubts the existence of service providers who do not continuously visit physically and hesitantly calling them “ghosts”.

Future Recommendations

Based on the research findings and the AKIS and RCS frameworks, the following recommendations are proposed for designing effective and inclusive digital agro-advisory services:

- Utilise user-centric Design to prioritize the needs and preferences of farmers and other stakeholders in the design and development of digital tools. Conduct user research to understand their challenges, information needs, and technology preferences. Involve them in the design process to ensure that the tools are user-friendly, relevant, and culturally appropriate. Forexample the development team of the Symos tool constantly reviews the application with the farmer groups unlike iProcure.
- Utilize a combination of traditional and digital channels to reach diverse audiences and maximize impact. Recognize that not all farmers have access to smartphones or the internet, and continue to utilize radio broadcasts, face-to-face interactions, and other traditional channels alongside digital platforms.
- Ensure that digital tools and services are affordable and accessible to all farmers, regardless of their income level or technological literacy. Explore options such as subsidized access, community-based ownership models, and partnerships with mobile network operators to reduce costs and expand access. The approach of symos tool to have the application launched for free for a year and offered at a subsidised price might be a viable business model for rural farmers.
- Invest in training and capacity building programs to equip farmers and extension workers with the necessary skills to effectively use digital tools. Offer ongoing support and mentorship to ensure that users can maximize the benefits of these tools.
- Develop and disseminate agricultural information in local languages and formats that are easily understandable and relevant to the local context. Radios have effectively delivered this service and so would digital platforms. Utilize visual aids, audio recordings, and interactive tools to cater to diverse learning styles and literacy levels.
- Ensure that farmers have ownership and control over their data, and that their privacy is protected. Implement transparent data governance mechanisms and obtain informed consent for data collection and use.
- Foster collaboration and partnerships between different stakeholders, including government agencies, research institutions, extension services, farmer organizations,

and private sector actors. Promote knowledge sharing and co-creation of digital solutions to address the diverse needs and challenges of the agricultural sector.

- Implement robust monitoring and evaluation mechanisms to assess the effectiveness and impact of digital agro-advisory services. Collect data on user adoption, satisfaction, and agricultural outcomes to inform continuous improvement and refinement of the services.

By adopting these recommendations, digital agro-advisory services can be designed to empower farmers, enhance agricultural productivity, and contribute to sustainable development in Uganda.

Summary

In the last 4 decades, farming advice has changed from being mainly about new technology and run by the government to a wider service offered by both public and private groups (Steinke et al., 2022). Farmers themselves are using more digital tools (Norton et al., 2020; Birner et al., 2021). Data and information are essentials in the agricultural sector, intertwined with the flow of produce and financial transactions (Maru et al., 2018). However, in Northern Uganda, smallholder farmers still struggle to access digital opportunities to larger markets. Ferrari et al. (2022) highlight that infrastructure development in many African countries remains inadequate, coupled with ineffective agricultural policies.

Farmer cooperatives play a pivotal role in consolidating resources and facilitating access to markets and agricultural advice for smallholder farmers, thereby enhancing their agricultural productivity (Spielman et al., 2021). In as much as the target for development in Uganda are the farmer groups (Adong et al., 2012), they rely on extension services for new agricultural knowledge (Feder et al. 2011, Zhou & Babu 2015) through in-person interactions (Norton & Alwang, 2020; Van Campenhout, 2021). Traditional extension support has been criticized for its narrow focus on delivering information, neglecting integrated advice and the importance of intermediaries in knowledge exchange (Leeuwis and Aarts 2011; Munthali et al. 2022). Additionally, its inability to effectively engage with value chain actors to address challenges and provide relevant market and credit information (Karpouzoglou et al., 2016; Klerkx and Rose, 2020).

Based on this research gap, a question is posed, *what additional value does digital technology bring to agricultural advisory services for stakeholders in Northern Uganda?*

This study employed qualitative interviews with 20 agricultural stakeholders to examine the interacting agents and their current mode of agricultural information dissemination in Northern Uganda. Then also how digital technologies can enhance advisory services and improve outcomes for farmers.

The findings expose an interconnected web of key actors in the dissemination of agricultural knowledge within the AKIS framework and their communication preferences. Digital tools in Northern Uganda's agricultural advisory services improve information access, communication, and data management through a user-oriented design approach. However, challenges like cost, connectivity, and training hinder adoption of the digital tools.

More detailed findings show:

- The critical role of communication in facilitating knowledge exchange, innovation adoption, and agricultural development within the AKIS framework. Forexample a model farmer demonstrating knowledge and also influencing other farmers.
- Extension workers serve the cooperatives best by physical visits for demonstration and interactive communication. Traditional channels like radio and in-person meetings remain crucial, especially in areas with limited internet. However, the rise of digital tools like mobile apps is transforming how farmers get personalized, and interactive agricultural advice. Therefore, pluralistic communication enhances the ability of stakeholders to access valuable farming advice.
- The promise that digital tools like Symos offer benefits such as improved market access, traceability, and streamlined production monitoring, but their adoption is hindered by early stage development, cost, connectivity issues, and the need for training and support. Concerns about data ownership, privacy, and the potential for digital tools to reinforce existing inequalities necessitate a careful and ethical approach to their implementation.
- The limited availability of digital tools and a preference for familiar or locally accessible options may hinder the adoption of potentially more effective solutions.
- Iterative development of solutions that could enhance daily agricultural operations may alter work processes.

From the above research, future research could explore the adoption of fully designed modules both externally and locally developed tools and the long-term impact on agricultural income, and sustainability. Exploring effective strategies for building digital literacy and capacity among farmers and extension workers. Lastly, investigating ethical and responsible data practices in digital agriculture, including data privacy, and transparency, to ensure that farmers are empowered and their rights are protected. The research insights produced further questions which can be explored in the near future.

Limitations of the Study

This study focused on Northern Uganda, but the data collection was limited to three districts within the Lango sub-region (Lira, Kwania, and Dokolo), which may not fully represent the diversity of the entire Northern region. However, I contend that the experiences of these respondents are likely to resonate with those in other sub-regions, given the common challenges faced by farmer cooperatives in the area. The selection of interviewees was influenced by existing contacts and regional considerations, with all participants being affiliated with a single governing body of farmer cooperatives in the region.

During focus group discussions, despite efforts to ensure gender balance, fewer women participated compared to men. However, the women who did participate were notably active in their contributions. The group dynamic may have influenced the participation of some individuals, particularly those who may have been overshadowed by more vocal participants or leaders. I mitigated this by encouraging quieter participants to contribute and allowed time for response preparation. However, it is acknowledged that this intervention may have affected the natural flow of discussions. Additionally, the reliance on verbal data in focus group discussions may not fully capture the nuances of non-verbal communication, which can provide valuable insights into participants' attitudes and experiences.

Furthermore, conducting interviews online, particularly with participants from rural settings, led to delays and technical difficulties due to network issues. This aligns with the study's findings on the challenges of connectivity faced by farmers in the region.

Bibliography

Abras, C., Maloney-Krichmar, D., & Preece, J. (2004). User-centered design. Bainbridge, W. Encyclopedia of Human-Computer Interaction. Thousand Oaks: Sage Publications, 37(4), 445-456.

Acunzo, M., Pafumi, M., Torres, C., & Tirol, M. S. (2014). Communication for Rural Development Sourcebook | FAO. https://www.fao.org/family-farming/detail/en/c/449432/

Adams, W. C. (2015). Conducting Semi-Structured Interviews. In Handbook of Practical Program Evaluation (pp. 492–505). John Wiley & Sons, Ltd. https://doi.org/10.1002/9781119171386.ch19

Adeoye-Olatunde, O. A., & Olenik, N. L. (2021). Research and scholarly methods: Semi-structured interviews. JACCP: JOURNAL OF THE AMERICAN COLLEGE OF CLINICAL PHARMACY, 4(10), 1358–1367. https://doi.org/10.1002/jac5.1441

Adolwa, I. S., Schwarze, S., Bellwood-Howard, I., Schareika, N., & Buerkert, A. (2017). A comparative analysis of agricultural knowledge and innovation systems in Kenya and Ghana: sustainable agricultural intensification in the rural–urban interface. Agriculture and human values, 34, 453-472.

Adong, A., Mwaura, F., & Okoboi, G. (2012). What determines membership to farmer groups in Uganda? Evidence from the Uganda Census of Agriculture 2008/09.

Aker, J. C. (2011). Does Digital Divide or Provide? The Impact of Cell Phones on Grain Markets in Niger. American Economic Journal: Applied Economics, 3(4), 1-35.

Aker, J. C., & Blumenstock, J. E. (2015). The economic impacts of mobile phones in developing countries: Evidence from randomized experiments. Annual Review of Economics, 7, 191-215.

Akpabio, E. M., Udoh, A. E., & Edet, A. E. (2007). Problems Associated with the Use of Information and Communication Technologies (ICTs) in Agricultural Extension Delivery in Akwa Ibom State, Nigeria. Journal of Agricultural Extension, 11(1), 42-51.

Amoussohoui, R., Arouna, A., Bavorova, M., Verner, V., Yergo, W., & Banout, J. (2024). Analysis of the factors influencing the adoption of digital extension services: Evidence from the RiceAdvice application in Nigeria. The Journal of Agricultural Education and Extension, 30(3), 387–416. https://doi.org/10.1080/1389224X.2023.2222109

Anderson, J. R., & Feder, G. (2007). Agricultural extension. Handbook of agricultural economics, 3, 2343-2378.

Anderson, J. R., Feder, G., & Ganguly, S. (2006). The rise and fall oftraining and visit extension: An Asian mini-drama with anAfrican epilogue. World Bank Policy Research Working PaperNo. 3928.

Anderson, J.R. & Feder, G. (2004). Agricultural extension: Good intentions and hard realities. The World Bank Research Observer, 19(1), 41–60.

Arinloye, J., Oyeyinka, R., Olorunfemi, T., & Ogunmodede, A. (2015). Farmers' Information Needs and Search Behaviour in Nigeria: A Case Study of Kwara State. Information Development, 31(2), 182-198.

Atube, F., Malinga, G. M., Nyeko, M., Okello, D. M., Alarakol, S. P., & Okello-Uma, I. (2021). Determinants of smallholder farmers' adaptation strategies to the effects of climate change: Evidence from northern Uganda. Agriculture & Food Security, 10(1), 1-14.

Baumüller, H. (2018). Mobile Phone-Based Agricultural Extension: A Review of the Literature and Implications for Future Research and Implementation. World Development Perspectives, 11, 1-11.

Beaman, L., & Dillon, A. (2018). Diffusion of agricultural information within social networks: Evidence on gender inequalities from Mali. Journal of Development Economics, 133, 147-161.

beginners. London: Sage.

Belay, K. (2002). Constraints to agricultural technology adoption and dissemination in Ethiopia: A case study of three selected districts. Journal of Social Development in Africa, 17(1), 71-90.

Bell, D. (1979). Communications technology-for better or for worse. Harvard Business Review, 57(3), 20.

Berdegué, J. A., & Escobar, G. (2003). Rural innovation systems and poverty reduction: The cases of Chile and Colombia. International Food Policy Research Institute (IFPRI).

Biemba, G., Daum, T., & Birner, R. (2017). Collecting Agricultural Data with Mobile Phones: Can Smallholders Do It Themselves? The Journal of Development Studies, 53(10), 1676-1692.

Bingen, J., Serrano, R., & Howard, J. (2003). Linking Farmers to Markets: Different Approaches to Human Capital Development. International Food Policy Research Institute (IFPRI) Discussion Paper 00404. Washington, D.C.: IFPRI.

Birner, R., Daum, T., & Pray, C. (2021). Who drives the digital revolution in agriculture? A review of supply‐side trends, players and challenges. Applied economic perspectives and policy, 43(4), 1260-1285.

Birner, R., Davis, K., Pender, J., & Nkonya, E. (2009). From Best Practice to Best Fit: A Framework for Designing and Analyzing Pluralistic Agricultural Advisory Services Worldwide. Journal of Agricultural Education and Extension, 15(4), 341-355.

Björgvinsson, E., Ehn, P., & Hillgren, P. A. (2012). Agonistic participatory design: working with marginalised social movements. CoDesign, 8(2-3), 127-144.

Blumenstock, J., & Eagle, N. (2012). Dialling for Development: The Impact of Mobile Phone Coverage on Farmer Welfare in Rural India. Information Technologies & International Development, 8(3), 7-15.

Braun, J. von, & Webb, P. (1989). The impact of new crop technology on the agricultural division of labour in a West African setting. Economic Development and Cultural Change, 37(3), 513-534.

Braun, V., & Clarke, V. (2013). Successful qualitative research: A practical guide for

Broadbent, G., & Ward, A., 1969, Design Methods in Architecture (AA Papers), Lund Humphries, London.

Broadbent, G., 1979, "The Development of Design Methods," Des. Methods Theor., 13(1), pp. 41–45.

Bronson, K. (2018). The role of information and communication technologies in agricultural knowledge and innovation systems. FAO.

Brown, T. (2005). Strategy by design. Fast company, 95, 52-54. Röling, N. 1990. The agricultural research-technology transfer interface: A knowledge systems perspective. In Making the link: Agricultural research and technology transfer in developing countries, ed. D. Kaimowitz, 1–42. Boulder: Westview Press.

Bueno-Delgado, M. V., Gil, E., Ortega, J. A., & Salmerón, J. L. (2016). A Web-Based Information System for Decision Support in Precision Viticulture. Computers and Electronics in Agriculture, 123, 315-324.

Camacho, A., & Conover, E. (2010). Adaptation to Climate Change through Information Technologies. Computers and Electronics in Agriculture, 74(1), 74-83.

Carmona, E., Cortés, A., Llanderal, J., & Balzarini, M. (2015). An Expert System for Decision Support in Pest Control in Soybean. Computers and Electronics in Agriculture, 118, 313-323.

Carmona, E., Cortés, A., Llanderal, J., & Balzarini, M. (2018). AgroDecisor: A Mobile Application for Pest Management Decision Support in Soybean. Computers and Electronics in Agriculture, 147, 192-202.

Casaburi, L., Glennerster, R., & Suri, T. (2014). Rural Roads and Intermediated Trade: Regression Discontinuity Evidence from Sierra Leone. Journal of Development Economics, 107, 202-220.

Casaburi, L., Glennerster, R., & Suri, T. (2014). Rural social networks and agricultural technology adoption: Evidence from Uganda. American Economic Journal: Applied Economics, 6(2), 241-270.

Casson, M., Yeung, B., Basu, A., & Wadeson, N. (2010). The Oxford handbook of entrepreneurship. Oxford University Press.

Chambers, R., Pacey, A., & Thrupp, L. A. (Eds.). (1989). Farmer first: Farmer innovation and agricultural research. Intermediate Technology Publications.

Checkland, P. (1999). Systems thinking, systems practice.

Courtois, P., & Subervie, J. (2015). The Impact of Mobile Phone-Based Agricultural Information Services on Smallholder Farmers' Market Participation: Evidence from Esoko in Ghana. World Development, 76, 27-37.

Creswell, J. W. (2021). A concise introduction to mixed methods research. SAGE publications.

Cristiano, S., & Proietti, P. (2023). Modernisation of Agriculture through more efficient and effective Agricultural Knowledge and Innovation Systems | modernAKIS Project | Fact Sheet | HORIZON. CORDIS | European Commission. https://cordis.europa.eu/project/id/101060527

Daum, T., Biemba, G., & Birner, R. (2018). Can Mobile Phones Be Used to Collect Data from Smallholder Farmers? Evidence from a Survey Experiment in Rural Zambia. World Development, 101, 113-123.

Davis, K. (2008). Extension in Sub-Saharan Africa: Overview and Assessment of Past and Current Models, and Future Prospects. Journal of International Agricultural and Extension Education, 15(3), 15-28.

Davis, K., & Sulaiman V, R. (2014). The New Extensionist: Roles and Cap acities to Strengthen Extension and Advisory Services. Journal of International Agricultural and Extension Education, 21(3), 6-18.

de Janvry, A., & Sadoulet, E. (2001). Access to land and rural poverty: Then and now. World Bank.

Dillon, A. (2012). Open development: Networked innovations in international development. MIT Press.

Dix, A., Finlay, J., Abowd, G. & Beale, R. (1997). Human-Computer Interaction (Second Edition). New York: Prentice Hall.

Dong, A. (2013). Design x Innovation. Proceedings of Consilience and Innovation in Design, 5th IASDR, 0234-0245.

Donner, J. (2008). The rise of the mobile phone in rural East Africa: A new paradigm for development communication? The Journal of Development Communication, 19(3), 205-221.

Eastwood, C., Klerkx, L., & Nettle, R. (2017). Dynamics and distribution of public and private research and extension roles for technological innovation and diffusion: Case studies of the implementation and adaptation of precision farming technologies. Journal of rural studies, 49, 1-12.

Eastwood, C., Klerkx, L., Ayre, M., & Dela Rue, B. (2019). Managing socio-ethical challenges in the development of smart farming: from a fragmented to a comprehensive approach for responsible research and innovation. Journal of agricultural and environmental ethics, 32(5), 741-768.

Eastwood, C., Lipton, M., Newell, R., & Sexton, R. (2012). The impact of mobile phones on agricultural knowledge and innovation in rural India. World Development, 40(11), 2263-2274.

Ehn, P. (1989). Word-oriented design of computer artifacts (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates.

Ehn, P., & Kyng, M. (1991). Cardboard computers: Mocking-it-up or hands-on the future. In J. Grenbaum & M. Kyng (Eds.), Design at work. Hillsdale, NJ: Lawrence Erlbaum Associates.

Ehn, P., Nilsson, E. M., & Topgaard, R. (2014). Making futures: Marginal notes on innovation, design, and democracy (p. 392). The MIT Press.

European Commission. (2021). Agricultural Knowledge and Innovation Systems (AKIS).

Fabregas, R., Kremer, M., & Schilbach, F. (2019). Real-time information and the price of fertilizer. American Economic Review, 109(11), 3793-3832.

FAO. (1994). Communication for rural development. FAO.

FAO. (2000). Agricultural knowledge and information systems for rural development (AKIS/RD): Strategic vision and guiding principles. FAO.

FAO. (2003). Agricultural knowledge and information systems for rural development (AKIS/RD): Conceptual framework and an evolving agenda. FAO.

FAO. (2014b). Farming for the future: Communication efforts to advance family farming. FAO.

FAO. (2017). Rural communication services: A framework for action. FAO.

Feder, G., Anderson, J. R., Birner, R., & Deininger, K. (2010). Promises and realities of community-based agricultural extension. In Community, market and state in development (pp. 187-208). London: Palgrave Macmillan UK.

Feder, G., Anderson, J. R., Birner, R., & Deininger, K. (2010).Promises and realities of community-based agricultural exten-sion. IFPRI Discussion Paper No 959.

Feder, G., Birner, R., & Anderson, J. R. (2011). The private sector's role in agricultural extension systems: potential and limitations. Journal of Agribusiness in Developing and Emerging Economies, 1(1), 31-54.

Flyvbjerg, B. (2006). Five misunderstandings about case-study research. Qualitative inquiry, 12(2), 219-245.

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS (FAO). (2016). Rural Communication Services for Family Farming.

Food and Agriculture Organization of the United Nations (FAO). (2014). Rural communication services for family farming. Contributions, evidence and perspectives | FAO. https://www.fao.org/family-farming/detail/en/c/473025/

Food and Agriculture Organization of the United Nations (FAO). (2019). The state of food and agriculture 2019. Moving forward on food loss and waste reduction.

Food and Agriculture Organization of the United Nations [FAO]. (2022). UNDFF Forum on Inclusive Rural Communication Services for Family Farming. Rome, Italy.

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS THE WORLD BANK Rome, 2000 at DuckDuckGo. (2000).

Funnel, S. C., & Rogers, P. J. (2014). Purposeful program theory: Effective use of theories of change and logic models. John Wiley & Sons.

Gow, G., Chowdhury, A., Ramjattan, J., & Ganpat, W. (2020). Fostering effective use of ICT in agricultural extension: participant responses to an inaugural technology stewardship training program in Trinidad. The journal of agricultural education and extension, 26(4), 335-350.

Gregory, J. (2003). Scandinavian approaches to participatory design. International Journal of Engineering Education, 19(1), 62-74.

Gulliksen, J., & Göransson, B. (2001). Reengineering the Systems Development Process for User Centred Design. In Interact (pp. 359-366).

Gulliksen, J., Göransson, B., Boivie, I., Blomkvist, S., Persson, J., & Cajander, Å. (2003). Key principles for user-centred systems design. Behaviour and Information Technology, 22(6), 397-409.

Hall, A., Sulaiman, V. R., Clark, N., & Yoganand, B. (2003). From measuring impact to learning institutional lessons: an innovation systems perspective on improving the management of international agricultural research. Agricultural systems, 78(2), 213-241.

Harande, Y. I. (2009). The role of information and communication technologies in agricultural and rural development. FAO.

Hargittai, E. (2002). Second-Level Digital Divide: Differences in People's Online Skills. First Monday, 7(4). https://doi.org/10.5210/fm.v7i4.942

Herzog, C., Handke, C., & Hitters, E. (2019). Analyzing talk and text II: Thematic analysis (pp. 385-401). Springer International Publishing.

Hocdé, H., Triomphe, B., Faure, M., & Dulcire, M. (2008). From participation to partnership: a different way for researchers to accompany innovation processes–challenges and difficulties. Innovation Africa: Enriching Farmers Livelihoods, 135-152.

Irpan, M., Summantri, A., Fajar Kurniawati, M., Apriani Sukmana, R., & Shaddiq, S. (2023). DIGITAL COMMUNICATION IN AGRICULTURAL EXTENSION IN THE ERA OF THE INDUSTRIAL REVOLUTION 4.0. Journal of Engineering, Management and Information Technology, 1(4), 177–190. https://doi.org/10.61552/JEMIT.2023.04.003

Jain, R., Arora, A., & Raju, S. S. (2009). A novel adoption index of selected agricultural technologies: Linkages with infrastructure and productivity. Agricultural Economics Research Review, 22(1), 109-120.

Jain, R., Sinha, R., & Singh, R. (2015). ICT in agricultural extension: A review. Agricultural Reviews, 36(4), 290-296.

Jakku, E., Taylor, B., Fleming, A., Mason, C., Fielke, S., Sounness, C., & Thorburn, P. (2019). "If they don't tell us what they do with it, why would we trust them?" Trust, transparency and benefit-sharing in Smart Farming. NJAS-Wageningen Journal of Life Sciences, 90, 100285.

Jokela, T., Iivari, N., Matero, J., & Karukka, M. (2003, August). The standard of user-centered design and the standard definition of usability: analyzing ISO 13407 against ISO 9241-11. In Proceedings of the Latin American conference on Human-computer interaction (pp. 53-60).

Kamilaris, A., Kartakoullis, A., & Prenafeta-Boldú, F. X. (2017). A review on the practice of big data analysis in agriculture. Computers and Electronics in Agriculture, 143, 23-37.

Kansiime, M. K., Mugagga, I., Mugisha, J., & Nakato, V. (2021). The potential of digital tools for agricultural extension and advisory services in Uganda: A review. The Journal of Agricultural Education and Extension, 27(5), 437-452.

Karpouzoglou, T., Zulkafli, Z., Grainger, S., Dewulf, A., Buytaert, W., & Hannah, D. M. (2016). Environmental virtual observatories (EVOs): prospects for knowledge co-creation and resilience in the information age. Current Opinion in Environmental Sustainability, 18, 40-48.

Kelly, T., Leeuwis, C., & Klerkx, L. (2017). The role of communication and learning in agricultural innovation systems. Routledge.

Kimbell, L. (2011). Rethinking design thinking: Part I. Design and culture, 3(3), 285-306.

Klerkx, L., & Proctor, W. (2013). Beyond the knowledge broker: The transformative potential of intermediaries in agricultural innovation. Knowledge Management for Development Journal, 9(2), 142-160.

Klerkx, L., & Rose, D. (2020). Dealing with the game-changing technologies of Agriculture 4.0: How do we manage diversity and responsibility in food system transition pathways?. Global Food Security, 24, 100347.

Klerkx, L., Aarts, N., & Leeuwis, C. (2019). Adaptive management in agricultural innovation systems: The interactions between innovation networks and their environment. Agricultural Systems, 105(1), 65-76.

Klerkx, L., Jakku, E., & Labarthe, P. (2019). A review of social science on digital agriculture, smart farming and agriculture 4.0: New contributions and a future research agenda. NJAS - Wageningen Journal of Life Sciences, 90-91, 100295.

Klerkx, L., Van Mierlo, B., & Leeuwis, C. (2012). Evolution of systems approaches to agricultural innovation: concepts, analysis and interventions. Farming Systems Research into the 21st century: The new dynamic, 457-483.

Klerkx, L., Van Mierlo, B., & Leeuwis, C. (2012). Evolution of systems approaches to agricultural innovation: Concepts, analysis and interventions. In Agricultural innovation systems: An international perspective (pp. 457-483). Routledge.

Knierim, A., Boenning, K., Caggiano, M., Cristóvão, A., Dirimanova, V., Koehnen, T., Labarthe, P., & Prager, K. (2015). The AKIS Concept and its Relevance in Selected EU Member States. Outlook on Agriculture, 44(1), 29-36. https://doi.org/10.5367/oa.2015.0194

Kosec, K., & Wantchekon, L. (2020). Can information improve rural governance and service delivery?. World Development, 125, 104376.

Kunz, W., & Rittel, H. W. (1972). Information science: on the structure of its problems. Information Storage and Retrieval, 8(2), 95-98.

Kwapong, N. A., & Korugyendo, P. L. (2010). Revival of agricultural cooperatives in Uganda. IFPRI USSP Policy Note, 11, 1-7.

Kyazze, F. B., Bold, T., Kakande, M., & Magala, S. (2018). Effectiveness of radio in agricultural extension and advisory services: A case study of Uganda. Journal of Agricultural Extension and Rural Development, 10(7), 101-109.

Lack, R. (2007). The importance of user-centered design: Exploring findings and methods. Journal of Archival Organization, 4(1-2), 69-86.

Leeuwis, C., & Aarts, N. (2011). Rethinking communication in innovation processes: creating space for change in complex systems. Journal of agricultural education and extension, 17(1), 21-36.

Leeuwis, C., & van den Ban, A. W. (2004). Communication for rural innovation: Rethinking agricultural extension. Blackwell Science Ltd.

Leeuwis, C., Röling, N., & van den Ban, A. (1990). The role of communication networks in the process of agricultural innovation. Knowledge: Creation, Diffusion, Utilization, 12(1), 71-90.

Liedtka, J. (2018). Why design thinking works. Harvard Business Review, 96(5), 72-79.

Loevinsohn, M., Sumberg, J., & Okali, C. (1994). Farmer participatory research in Uganda: The role of crop management research. Experimental Agriculture, 30(4), 381-398.

Lowder, S. K., Skoet, J., & Raney, T. (2016). The Number, Size, and Distribution of Farms, Smallholder Farms, and Family Farms Worldwide. World Development, 87, 16-29.

Lundström, C., & Lindblom, J. (2018). Digitalization and knowledge transfer in agriculture: The role of agricultural advisors. NJAS - Wageningen Journal of Life Sciences, 87, 81-89.

Madon, S. (2000). The Internet and socio-economic development: Exploring the interaction. Information Technology for Development, 8(2), 85-101.

Martin, R. L. (2009). The design of business: Why design thinking is the next competitive advantage. Harvard Business Press.

Maru, A., Berne, D., Beer, J. D., Ballantyne, P. G., Pesce, V., Kalyesubula, S., & Chavez, J. (2018). Digital and data-driven agriculture: Harnessing the power of data for smallholders. Global Forum on Agricultural Research and Innovation.

McCampbell, E., Campbell, B. M., Thornton, P. K., & Vermeulen, S. J. (2021). Smallholder farmers and digital agriculture: A review of the evidence on ICT adoption and impact pathways. Global Food Security, 28, 100495.

Meinzen-Dick, R., Quisumbing, A., Behrman, J., Biermayr-Jenzano, P., Wilde, V., Noordeloos, M., ... & Beintema, N. (2011). Engendering agricultural research, development and extension (Vol. 176). Intl Food Policy Res Inst.

Melles, M., Albayrak, A., & Goossens, R. (2021). Innovating health care: Key characteristics of human-centered design. International Journal for Quality in Health Care, 33(Supplement_1), 37–44. https://doi.org/10.1093/intqhc/mzaa127

Mendes, K. D., Paz, J. P. D., & Callado, A. L. C. D. (2018). The role of extension workers in the adoption of information and communication technologies by Brazilian farmers. Journal of Agricultural Education and Extension, 24(1), 79-95.

Mittal, S., Gandhi, R., & Tripathi, G. (2018). Socioeconomic Impact of ICTs on Agriculture: Evidence from India. Information Technology for Development, 24(1), 142-170.

Mwaura, F. (2014). Effect of farmer group membership on agricultural technology adoption and crop productivity in Uganda. African crop science journal, 22, 917-927.

Myovella, G., Karacuka, M., & Haucap, J. (2021). Determinants of digitalisation and digital divide in Sub-Saharan African economies: A spatial Durbin analysis. Telecommunications Policy, 45(10), 102224.

Myovella, G., Nkhoma, M., Gondwe, T., & Khonje, M. (2021). The role of digital technologies in agricultural extension and advisory services: A systematic review. Agronomy, 11(5), 900.

Nakasone, E. (2014). The impact of mobile phone use on rural livelihoods and poverty reduction: A review of the empirical evidence. World Development, 68, 65-84.

Nakasone, E., & Torero, M. (2016). A text message away: ICTs as a tool to improve food security. Agricultural Economics, 47(S1), 49-59.

Namyenya, A., Daum, T., Rwamigisa, P. B., & Birner, R. (2022). E-diary: a digital tool for strengthening accountability in agricultural extension. Information Technology for Development, 28(2), 319-345.

Newell, P., & Taylor, O. (2018). Contested landscapes: the global political economy of climate-smart agriculture. The Journal of Peasant Studies, 45(1), 108-129.

Njie, B., & Asimiran, S. (2014). Case Study as a Choice in Qualitative Methodology. IOSR Journal of Research & Method in Education (IOSRJRME), 4(3), 35–40. https://doi.org/10.9790/7388-04313540

Norman, D. A., & Draper, S. W. (1986). User centered system design; new perspectives on human-computer interaction. L. Erlbaum Associates Inc..

Norton, G. W., & Alwang, J. (2020). Changes in agricultural extension and implications for farmer adoption of new practices. Applied Economic Perspectives and Policy, 42(1), 8-20.

Nussbaum, B. (2004). The power of design. Business week, 17(5), 2004.

Nyumba, T., Wilson, K., Derrick, C. J., & Mukherjee, N. (2018). The use of focus group discussion methodology: Insights from two decades of application in conservation. Methods in Ecology and Evolution, 9(1), 20–32. https://doi.org/10.1111/2041-210X.12860.

O'Connor, H., & Madge, C. (2003). "Focus groups in cyberspace": Using the Internet for qualitative research. Qualitative Market Research: An International Journal, 6, 133–143.

Ostroff, E. (2011). Universal design: an evolving paradigm. Universal design handbook.

Owen, R., Macnaghten, P., & Stilgoe, J. (2012). Responsible research and innovation: From science in society to science for society, with society. Science and Public Policy, 3

Pafumi, M. 2024. Assessing the digital readiness and communication ecosystem of rural youth – Methodological guidelines. Rome, FAO. https://doi.org/10.4060/cc9216en

Parker, A., & Tritter, J. (2006). Focus group method and methodology: current practice and recent debate. International Journal of Research & Method in Education, 29(1), 23-37.

Pascucci, S., & de-Magistris, T. (2011). Agricultural Knowledge and Information Systems (AKIS): A Conceptual Framework for Understanding the Role of Knowledge Processes in the Agricultural Sector. Journal of Agricultural Education and Extension, 17(4), 347-363.

Preece, J. (2000) Online Communities: Designing Usability, Supporting Sociability. John Wiley & Sons, Chichester, UK.

Preece, J., Rogers, Y., Sharp, H., Benyon, D., Holland, S. & Carey, T. (1994) Human-Computer Interaction. Essex, England: Addison-Wesley Longman Limited.

Preece, J.; Rogers, Y., & Sharp, H. (2002) Interaction design: Beyond human-computer interaction. New York: John Wiley & Sons, Inc.

Prell, C., Reed, M., Racin, L., & Hubacek, K. (2010). Competing structure, competing views: the role of formal and informal social structures in shaping stakeholder perceptions. Ecology and society, 15(4).

Rivera, W. M., & Qamar, M. K. (2003). Agricultural extension, rural development and the food security challenge. Food, Agriculture and the Environment Discussion Paper, (25).

Rivera, W. M., & Qamar, M. K. (2008). Agricultural extension, rural development and the food security challenge. FAO Agricultural Bulletin, 96.

Rivera, W. M., & Schram, S. G. (Eds.). (2022). Agricultural extension worldwide: Issues, practices and emerging priorities. Routledge.

Rivera, W. M., Qamar, M. K., & Mwandemere, H. K. (2005). Enhancing coordination among AKIS/RD actors: An analytical and comparative review of country studies on agricultural knowledge and information systems for rural development (AKIS/RD).

Robertson, T., & Simonsen, J. (2012). Challenges and Opportunities in Contemporary Participatory Design. Design Issues, 28(3), 3–9. https://doi.org/10.1162/DESI_a_00157

Röling, N. (2007). Communication for development in research, extension and education. Communication and sustainable development: Selected papers from the 9th UN roundtable on communication for development, 57-78.

Röling, N., & Jiggins, J. (1998). The ecological knowledge system. In Facilitating sustainable agriculture (pp. 283-306). Springer, Dordrecht.

Roztocki, N., & Weistroffer, H. R. (2016). Conceptualizing and researching the adoption of ICT and the impact on socioeconomic development. Information Technology for Development, 22(4), 541-549.

Roztocki, N., Soja, P., & Weistroffer, H. R. (2019). The role of information and communication technologies in socioeconomic development: towards a multi-dimensional framework. Information Technology for Development, 25(2), 171-183.

Ruecker, S., & Radzikowska, M. (2008). The iterative design of a project charter for interdisciplinary research. In Proceedings of the 7th ACM conference on Designing interactive systems (pp. 288-294).

Saidu, O., Gana, U., & Mohammed, I. (2017). Adoption of ICT by extension workers in agricultural development in Borno State, Nigeria. Journal of Agricultural Extension, 21(3), 101-108.

Sangiorgi, D., & Clark, B. (2004, January). Toward a participatory design approach to service design. In PDC (pp. 148-151).

Schneider, S. J., Kerwin, J., Frechtling, J., & Vivari, B. A. (2002). Characteristics of the discussion in online and face-to-face focus groups. Social Science Computer Review, 20, 31–42.

Schuler, D., & Clement, A. (2004). Artful integration and participatory design: Preface to the proceedings of PDC 2004. In Proceedings of the Eighth Conference on Participatory Design (Vol. 1).

Spence, N. (2010). Gender, ICTs, human development, and prosperity. Information Technologies & International Development, 6(SE), pp-69.

Spielman, D. J., Davis, K., Negash, M., & Ayele, G. (2011). Rural innovation systems and networks: findings from a study of Ethiopian smallholders. Agriculture and human values, 28, 195-212.

Spielman, D., Lecoutere, E., Makhija, S., & Van Campenhout, B. (2021). Information and communications technology (ICT) and agricultural extension in developing countries. Annual Review of Resource Economics, 13(1), 177-201.

Stake, R. E. (2000). Case Studies. In Denzin, N. K., & Lincoln, Y. S. (Eds.), Handbook of Qualitative Research (2nd ed., Ch. 16). Sage.

Stevens, C., Winter, K., Shackleton, C., & Shackleton, S. (2016). Digital development for agriculture: What can we learn from the evidence? The Journal of Development Studies, 52(5), 633-649.

Stewart, K., & Williams, M. (2005). Researching online populations: The use of online focus groups for social research. Qualitative Research, 5, 395–416.

Sylla, A. Y., Mahama Al-Hassan, R., Egyir, I. S., & Anim-Somuah, H. (2019). Perceptions about quality of public and private agricultural extension in Africa: Evidence from farmers in Burkina Faso. Cogent Food & Agriculture, 5(1), 1685861.

Synnot, A., Hill, S., Summers, M., & Taylor, M. (2014). Comparing face-to-face and online qualitative research

Thuo, M., Bell, A. A., Bravo-Ureta, B. E., Lachaud, M. A., Okello, D. K., Okoko, E. N., & Puppala, N. (2014). Effects of social network factors on information acquisition and adoption of improved groundnut varieties: the case of Uganda and Kenya. Agriculture and human values, 31, 339-353.

Torero, M., & Von Braun, J. (Eds.). (2006). Information and communication technologies for development and poverty reduction: The potential of telecommunications. Intl Food Policy Res Inst.

Valente, T. W. (1996). Social network thresholds in the diffusion of innovations. Social networks, 18(1), 69-89.

Van De Gevel, J., van Etten, J., & Deterding, S. (2020). Citizen science breathes new life into participatory agricultural research. A review. Agronomy for Sustainable Development, 40, 1-17.

Verganti, R. (2008). Design, meanings, and radical innovation: A metamodel and a research agenda. Journal of Product Innovation Management, 25(5), 436-456.

Walsham, G., & Sahay, S. (2006). Research on information systems in developing countries: Current landscape and future prospects. Information technology for development, 12(1), 7-24.

Wattenberg, T. L. (2005). Online focus groups used as an accessible participatory research method. In Proceedings of the 7th International ACM SIGACCESS Conference on Computers and Accessibility (pp. 180-181).

Waugaman, A. (2016). Implementing the principles for digital development. The Principles for Digital Development Working Group.

Wilkerson, J. M., Iantaffi, A., Grey, J. A., Bockting, W. O., & Rosser, B. R. (2014). Recommendations for Internetbased qualitative health research with hard-to-reach populations. Qualitative Health Research, 24, 561–574. doi:10.1177/1049732314524635

Wilkinson, C. R., & De Angeli, A. (2014). Applying user centred and participatory design approaches to commercial product development. Design Studies, 35(6), 614-631.

with people with multiple sclerosis. Qualitative Health Research, 24, 431–438. doi:10.1177/1049732314523840

Wolf, S., Frisch, J., & Zilberman, D. (2001). Incorporating knowledge into agricultural models: The case of sustainable agriculture. Agricultural Economics, 25(2-3), 237-249.

Woodyatt, C. R., Finneran, C. A., & Stephenson, R. (2016). In-person versus online focus group discussions: A comparative analysis of data quality. Qualitative health research, 26(6), 741-749.

Woodyatt, C. R., Finneran, C. A., & Stephenson, R. (2016). In-person versus online focus group discussions: A comparative analysis of data quality. Qualitative health research, 26(6), 741-749.

Woomer, P. L., Okalebo, J. R., Palm, C. A., & Smyth, T. J. (2004). Fertilizer use and crop productivity in sub-Saharan Africa. Agriculture, Ecosystems & Environment, 107(2-3), 171-184.

Wuepper, D., Roleff, N., & Finger, R. (2021). Does it matter who advises farmers? Pest management choices with public and private extension. Food Policy, 99, 101995.

Yongling, Z., Riggs, M., Hazelman, M., & Weike, L. (2004). Information services in rural China: Field surveys and findings.

Zamawe, F. C. (2015). The implication of using NVivo software in qualitative data analysis: Evidence-based reflections. Malawi Medical Journal, 27(1), 13-15.

Zantvoort, M., van Haastrecht, J., & van Dijk, T. (2020). Data Governance in Smart Farming: A Systematic Literature Review. Computers and Electronics in Agriculture, 179, 105820.

Zeltzer, D. (2020). Gender homophily in referral networks: Consequences for the medicare physician earnings gap. American Economic Journal: Applied Economics, 12(2), 169-197.

Zossou, E., Van Mele, P., Wanvoeke, J., & Lebailly, P. (2012). Participatory impact assessment of rice parboiling videos with women in Benin. Experimental Agriculture, 48(3), 438-447.

Appendix

Appendix A: Interview Guide

Interview Guide for **Inclusive Agro-Advisory Services For Profitable Smallholder Farmer Groups In Northern Uganda**

The purpose is to gather insights on how you access agro-advisory services.

The interview will be conducted via WhatsApp and will take approximately 25-30 minutes.
If you agree, the interview will be recorded for transcription and data analysis.
Disclaimer: Your responses will be kept confidential and anonymous. The information you provide will be used solely for research purposes.

1. Why did you form the farmer cooperative [extension services]? (If applicable)
2. Who are the different stakeholders that you work with?
3. What are your primary trustworthy sources of advisory information?

   Or: How do you share advisory information with farmers?

4. What is your most common means of communication? If there are many, rank top to last/ How do you find [help farmers] a market for your products/manage your sales? Rate them on a scale of 1-5.

5. What are the types of digital tools you have used (e.g., mobile apps, SMS, social media) **or conventional media?**

6. How useful are digital tools [non-digital] in [helping farmers] find markets for inputs and outputs?

   a. Do you think the platform [means] prepare relevant information for you as a user? Does it provide accurate information?

   b. Do you reach a wider audience with this tool [means]? If not, how can that happen?

   c. Is the information prompt? Explain?

   d. Do you trust the information? Why?

   e. Is it affordable to use the tool? What is the cost of access and use of this information?

   f. Do you feel like you own the information or are in control of it? **What are the 3 things that lead you to feel most in control over the tool?**

7. What challenges are faced in using digital tools [not digital] for information?

8. What potential solutions to address these challenges?

9. What training or capacity-building initiatives are related to using digital tools?

Appendix B: Themes and Codes

Name	Description
Information	Primary sources of information (extension workers, radio, colleagues, internet)
Stakeholders	Actors within an interacting environment
Platforms	Digital spaces that facilitate interaction, communication, or service provision
Agency	Control over data and information (ownership, access, privacy)
Accuracy	The degree to which information or data is free from errors or distortions, ensuring its reliability and validity
Trustworthy	Information deemed reliable and accurate, fostering confidence in its use
Digitalization	The process of converting information and processes into a digital format
Technology Adoption	The process of individuals or organizations embracing and integrating new technologies into their practices

Table 2: Themes and codes from the interviews

Appendix C: SYMOS Tool

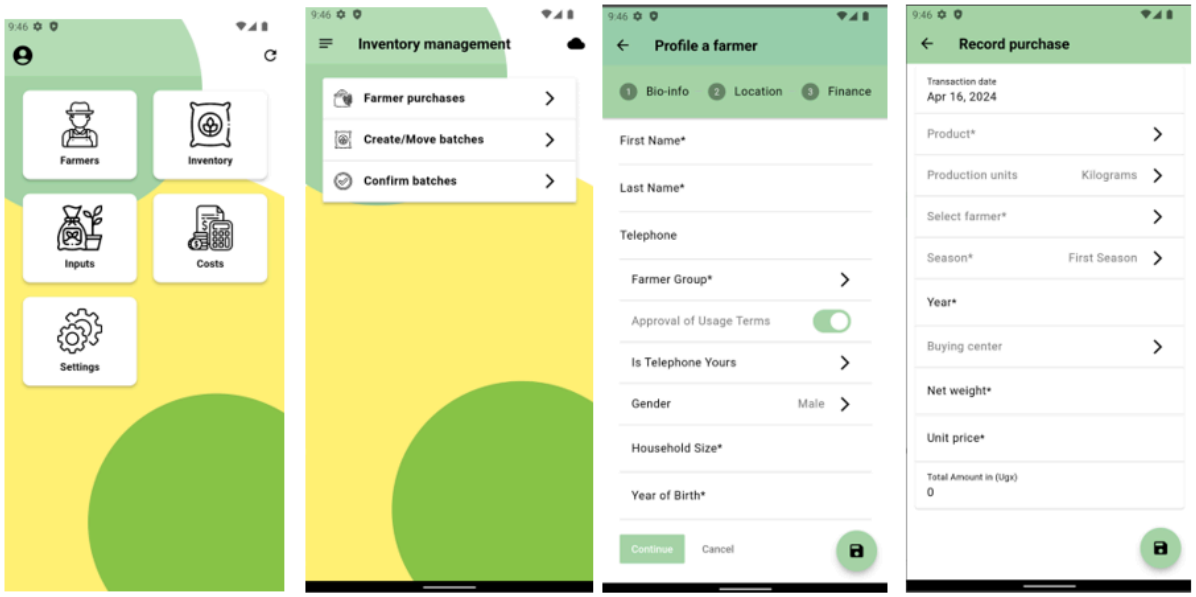

Fig 5: Screenshots of the user interface of the SYMOS tool

Appendix D: iProcure Tool

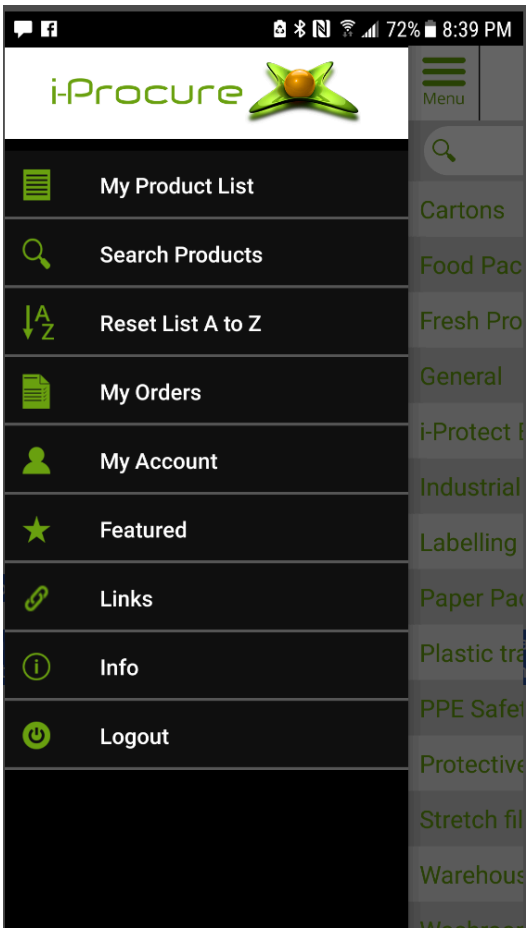

Fig 6: Screenshots of the user interface of the iProcure tool