The Digitalization of Agriculture and the (Un)Changing Dynamics of Rural Smallholder Farming Systems in Ghana, Sub-Sahara Africa

by

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ABSTRACT

THE DIGITALIZATION OF AGRICULTURE AND THE (UN)CHANGING DYNAMICS OF RURAL SMALLHOLDER FARMING SYSTEMS IN GHANA, SUB-SAHARA AFRICA

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University of Guelph, 2022
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This dissertation explores the dynamics of agricultural digitalization in rural smallholder systems in Northern Ghana, Sub-Sahara Africa, with a focus on the 1) anticipated impacts, 2) nature of farmers’ engagement, 3) factors that affect participation, 4) resulting changes to practices, and 5) the elements for successful digital futures. Given the novelties of digitalization, my multidisciplinary scholarly interests and exploratory intentions, I applied political-economy and social practices theoretical and analytical lens, with a mixed-method approach, combining document review, interviews, focus group discussions, observation, and surveys to address the objectives. I found that the digitalization of smallholders is being promoted as transformative by development actors (with potential neoliberal goals) without recourse to the embedded political-economic consequences. Yet, empirical results from Northern Ghana revealed superficial engagement by farmers, as participation and activeness in digital services are structurally hampered by low (digital) literacies and limited access to (digital) resources. Meanwhile, gender, phone ownership, ability to place phone calls, association with farm groups, and access to extension services influence the likelihood of participating and benefiting from digitalization services; however, critical inequities exist across these factors. Nonetheless, digital services may change livelihood practices (everyday routines and space-time rhythms) of farmers as new patterns of actions in season planning, how and when farmers plant, undertake husbandry activities, harvest, market and sell outputs emerge. Hence, I conclude that
smallholder digitalization is uncritical detached from farmers’ lived realities. While prospects for digital innovations to transform livelihoods may exist, the basic building blocks are so lacking that this potential is unlikely to be realized in the near term. Meanwhile, uncritical implementation of these tools is only likely to entrench existing inequities and create newer unfair power distributions. Thus, it is essential to move beyond the holistic propagation of digital innovations and the uncritical claims of transformativeness. Instead, we need a context-based 'digitalization for smallholders' that (re)focus the expectations towards incremental change in everyday social practices embedded in (African) farmers’ socio-political-economic realities. Thus, stakeholders must work towards inclusive digital access in smallholder systems, partly through establishing and integrating required materials, competencies, and meanings that bring digitalization to life across scales.
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PREFACE

Chapter Two and Chapter Five are sole author manuscripts by the Ph.D. student (Abdul-Rahim Abdulai). Chapter Three is a manuscript authored by the student, colleagues from the research group (Phillip Tetteh Quarshie, Emily Duncan), a lab Research Associate (Krishna KC) and the advisor (Evan Fraser). Chapter Four is a manuscript by the student, a research scientist in the lab who offered statistical support (Krishna KC), and the advisor of this dissertation. Chapter Five is a manuscript by the student, a member of the advisory committee (Ryan Gibson,) and the advisor. The student collected the data for all manuscripts and prepared the first drafts. Subsequent drafts of all manuscripts were prepared by the student with inputs and advice from all co-authors.
1.0 Setting up the Research

1.1 Introduction

In this dissertation, I explore the contextual dynamics of agricultural digitalization—the application of digital tools and services, including phones, e-advisories and e-commerce platforms—in smallholder farming systems\(^1\) in Ghana and Sub-Saharan Africa\(^2\). I discuss the nature of digitalization, the potential for farming/rural “re-scripting” (cf Giddens, 1984; Rose & Chilvers, 2018) in smallholder Africa, and the political-economic implications of digital innovations.

Recognizing that every technology is inherently social\(^3\) (cultural and political) (Carolan, 2018), I ask how digital agricultural technologies would manifest and re-model smallholder farming and their implications in Sub-Saharan Africa. Specifically, 1) how is digital agriculture forming and manifesting in smallholder systems? 2) how does digitalization alter farmers' practices and livelihoods?; 3) what are the local political-economic issues arising from digitalization?; and 4) what are the pathways for understanding and directing smallholder digital futures? Through these questions, I investigate and extend a growing but limited literature on the social dimensions of the digital agricultural transformations in rural areas and, more so, the political-economic implications of the phenomenon.

It is by no accident that technology and (rural) change have widespread attention in varied scientific communities, including rural geography (Ruttan, 1996). Technology has in the past and continues to manifest in society through agriculture and food (DeGregori, 2001), which partly explains earlier scholarly attention among rural geographers on technology adoption and diffusion research (see Ilbery, 2014; Rogers, 1983, 1995). Unsurprisingly, agriculture, the orthodoxy at the centre of the technology-driven human civilizations axis (DeGregori, 2001; Rimas & Fraser, 2010), is at the onset of another potential transformation, powered by the same technologies that brought forth the internet and aggressively changed the course of modern society (Weersink et al., 2018).

Digital tools and services, including mobile phones, automated machines, robotics, GPS

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\(^1\) Farming system is conveniently used interchangeable with agriculture systems throughout this dissertation to refer to complex interrelated elements, structures, processes, and activities that underpin crop and animal production. I also use food system to describe the farming system in a more encompassing form that goes beyond production to include consumption processes.

\(^2\) Sub-sahara Africa is used to refer to the sub-continent of Africa that excludes North Africa. I used sub-sahara and Africa interchangeably throughout this dissertation in reference to this geographical sub-continent.

\(^3\) By social I am referring to the consequences of digital technologies in altering “the ways in which people live, work, play, relate to one another, organize to meet their needs and generally cope as members of society. The term also includes cultural impacts involving changes to the norms, values, and beliefs that guide and rationalize their cognition of themselves and their society” (Interorganizational Committee on Principles and Guidelines for Social Impact Assessment, 2003: 231). Research on social impacts on technologies also incorporates economic variables (Fischer et al., 2015). My use of social in this project, therefore, spans socio-cultural and economic dimensions of change.
technologies, drones, and personal digital assistants, are progressively applied in farming systems worldwide. Scholars have described this phenomenon with different terminologies, including Agriculture 4.0, smart farming, and digital agriculture (Rose & Chilvers, 2018; Wolfert, Ge, Verdouw, & Bogaardt, 2017). Elsewhere, I, with colleagues, have referred to the phenomena as digital agriculture or digitalization of agriculture and explained it in much detail (see Duncan et al., 2021 for further discussion). Bronson (2018) notes that this unfolding phenomenon, which others also describe as a revolution (for example, Deichmann, Goyal, & Mishra, 2016; King, 2017; Sundmaeker, Verdouw, Wolfert, & Freire, 2016), promises to change the socio-economic, political, and cultural futures of food and agriculture.

Hence, there have been some bold predictions that digitalization would transform agriculture by yielding economic benefits, ensuring input-use efficiencies, and environmental sustainability (Balafoutis et al., 2017; King, 2017). However, social (particularly embedded political-economic) issues are relegated to the background in such discourses (Bene, 2022). Nevertheless, there has been nascent social science research on the subject in recent years (Bacco et al., 2019; Carolan, 2017, 2018; Klerkx et al., 2019; Rolandi et al., 2021; Rose & Chilvers, 2018; Rotz et al., 2019). This literature focuses on the implications of digitalization on various issues, including agricultural labour, rural communities, data governance, and power dynamics (see Klerkx et al., 2019 for an extensive review). For rural farming dynamics, Carolan (2017: 145) mentions anxieties over potentially mixed impacts of digitalization in rural communities. Likewise, Rose and Chilvers (2018) opine that digitalization may result in social consequences that rescript rural landscapes. Despite the burgeoning attention around digitalization worldwide and among scholars, the realities of digital agriculture in smallholder farming systems, particularly in Africa, is not yet well-understood in the literature. Many actors have thus called for context-specific explorations of the nature and implications of agricultural digitalization in Africa (FAO, 2019; Food and Agriculture Organization of the United Nations & the International Telecommunication Union, 2022; Kim et al., 2020; Tsan et al., 2019). These calls are informed by social concerns from earlier technological experiences, including the Green Revolution innovations (Altieri & Nicholls, 2012; Shiva, 2016) and biotechnology (see Fischer, Ekener-Petersen, Rydhmer, & Björnberg, 2015). Following this line of thought, I also believe that digital technologies would engender practical socio-cultural and political-economic effects as they continue to embed in the African society. Hence, this dissertation offers an exploratory yet nuanced outlook of perceptions and experiences of digital innovations’ embedded contextual social implications for farmers, farm households and communities in Ghana and Africa.

I engage in this critical research endeavour from political economy and social practice theoretical and analytical perspectives, rooted in an underlying rural change/development interest.
Methodologically, I draw experiences from these scholarly fields to use qualitative methods common in these areas, including research-document reviews, interviews, observations, and focus groups discussion (see Sutherland et al., 2014). I complement these methods with quantitative surveys of farmers in Northern Ghana to broaden the reach and capture the diverse realities of smallholders. Through this approach, I advance the literature on digital transformations and provide critical, locally embedded insights needed to understand the unfolding dynamics of these tools in Africa and ask the right contextual questions.

1.2 Contextualising the Research: Digitalization in Sub-Saharan Africa and Ghana

African smallholder agriculture is progressively situated in the digital economy in varied ways. We are seeing the growing discussions on the use and application of phones, tablets, drones, satellites, artificial intelligence, cloud computing, the internet, and big data programs within the space of food and farming in the region (Food and Agriculture Organization of the United Nations & the International Telecommunication Union, 2022; Tsan, et al., 2019). Many documents provide an in-depth description and analysis of digitalization in Africa (see Deutsche Gesellschaft für Internationale Zusammenarbeit et al., 2021; Food and Agriculture Organization of the United Nations & the International Telecommunication Union, 2022; Kim et al., 2020; Technical Centre for Agricultural and Rural Cooperation, 2019). So, I would avoid duplicating efforts and focus on expanding the literature.

A wide array of digital tools and hardware are deployed to aid farming practices and processes in Africa. From receiving weather alerts on mobile phones (see Figure 1.1) to reaching out to call centres to drone use for spreading fertilizers and controlling pests, farmers can use digital-enabled hardware and equipment for various farm tasks (see Chapter Three). Hence, governments, development organizations, and the private sector are leveraging digital innovations to create novel services to aid farmers’ activities (Alabi, 2016; Deichmann, Goyal, & Mishra, 2016; Munyua et al., 2008; Wafula-Kwake & Ocholla, 2007) (see Chapter Two for more discussion). The Technical Centre for Agricultural and Rural Cooperation (2019) has classified these emerging digital agricultural services into five categories (see Table 1).
Figure 1.1 Weather alert SMS to smallholders (Source by student)

Table 1.1 Key Service and Solution Areas of Agricultural Digitalization

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<tbody>
<tr>
<td>Advisory and information services</td>
<td>They provide farmers with information on diverse topics, including agronomic practices, weather, and market information;</td>
<td>• Agronomic/livestock management good practices&lt;br&gt;• Market information systems and services (i.e., agriculture input and crop/livestock price intelligence)&lt;br&gt;• Early warning tools for weather/climate advisory or pest/disease control&lt;br&gt;• Customized (precision) advisory services at the level of the farmer, farm or specific field&lt;br&gt;• Participatory platforms (e.g., peer-to-peer smallholder communities, curated farmer videos)&lt;br&gt;• Livestock and farm management software&lt;br&gt;• Linkage to agri-inputs (e.g., digitally-enabled input distribution, online input marketplaces)&lt;br&gt;• Mechanization linkage platforms (e.g., shared economy for mechanization, pay-as-you-go irrigation)&lt;br&gt;• Linkage to market access (e.g., digitally-enabled associations to wholesale buyers)&lt;br&gt;• End-to-end integrated market linkage models (e.g., digital linkage to both inputs and markets)&lt;br&gt;• Ag buyer-seller digital marketplaces/exchanges</td>
</tr>
<tr>
<td>Market linkages</td>
<td>These are platforms to link smallholder farmers to input and output markets</td>
<td></td>
</tr>
</tbody>
</table>
### Supply chain management services
These are solutions that connect different levels of the agri-food supply chain actors in ways that allow for greater efficiency and transparency

- Traceability solutions (e.g., digital sustainability and organic product certification tracking)
- Enterprise Resource Planning (ERP) platforms for smallholder farmer cooperatives, nucleus farms, agribusiness out-grower schemes
- Digital quality assurance solutions for farm inputs and produce
- Logistics management solutions for post-harvest cold chains, storage and transport

- Smallholder farmer payment solutions (e.g., agribiz to the farmer, government to the farmer, farmer to input supplier)
- Digital agri-wallets and commitment savings systems
- Smallholder credit (e.g., digital credit assessment/delivery/collection platforms and products)
- Smallholder insurance (e.g., digitally-enabled index weather, precipitation, pest insurance)
- Crowdfunding platforms for smallholder farming
- Business-to-business fintech data analytics intermediaries (e.g., digital credit profiles)

### Financial access services,
These services provide digital financial solutions such as payments, savings, and insurance for smallholders

- Government agriculture sector tracking dashboards
- Agriculture extension system management tools
- Agribusiness and agriculture investor national and regional intelligence systems
- Agronomy/R&D agenda setting digital tools
- Weather and climate observatories for agriculture

### Macro agricultural intelligence services
This involves data analytics and digital decision support tools that integrate a variety of data sources to provide valuable country and value-chain level insights and decision tools for government policymakers, extension agencies, agronomists, agribuses, and investors

Source: Technical Centre for Agricultural and Rural Cooperation (2019)

These categories show services with potential for practice-altering for farmers, and they form the basis for my explorations of the subject in this dissertation. The proliferation of these services is partly attributable to Africa being the fastest-growing global telecommunications market, with increasing availability and access to mobile phones and internet technologies (CTA, 2019) (see Chapter Two for further discussion). Likewise, in some areas, like Ghana, a stable political climate breeds a surge in digital activities (Etwire et al., 2017; FAO, 2019).
Though there are different contexts of digitalization in Africa, Ghana may present a good case for understanding the dynamics of the phenomenon in the area due to its peculiar characteristics. Ghana is one of the hubs of digital agriculture on the African continent (Food and Agriculture Organization of the United Nations & the International Telecommunication Union, 2022; Kim et al., 2020). Increasing mobile penetration rates, where mobile network coverage now reaches over 85% of the country and over 65% of rural people using mobile phones (Etwire et al., 2017), allow new digital enterprises to tap into opportunities. According to the GSMA, Ghana’s 2G, 3G, and 4G network coverages were about 96.8 percent, 89 percent and 68 percent, respectively. Broadband coverage is about 90% of the population, and mobile connections are nearly 127% (2020 – GSMA Mobile Connectivity Index, n.d.).

The growing connectivity in the country lays the foundation for the emerging digitalization of agriculture services. The FAO and ITU report about 25 active digital agricultural services in the country (Food and Agriculture Organization of the United Nations & the International Telecommunication Union, 2022). In particular, entities such as Esoko⁴, Farmline⁵ and many others now offer smallholders weather and market information to aid farming practices. Other emerging entities, Ziongate Geospatial and Research Services and Acquamayer, supported mainly by CTA and other international organizations, provide farmers with precision farming services using drones and satellite data. Likewise, the siting of Google’s first artificial intelligence lab in Africa and Twitter African headquarters in Accra (Ghana’s capital town) (see Figure 1.2) corroborates the digitalization drive in the country. The strategic digital agriculture thrust of Ghana, including in the Northern areas, which have the most substantial composition of households in farming (Minister of Food and Agriculture, 2016; 2011), makes a good case for exploring the dynamics of digital agriculture in the setting, with the potential to provide insights of broader relevance.

⁴ “Esoko is powering rural communities through digital transformation and financial inclusion. Our solutions include mobile and web-based tools for data collection coupled with field deployment; an SMS/voice-based communication platform for farmer management; and an electronic extension mobile and web app” (https://oldsite.esoko.com/)

⁵ Farmline is an award-winning venture which works to digitize the agricultural value chains in Ghana through diverse services including mobile and web-based market and weather information delivery to farmers (https://farmerline.co/)
The proliferation of digitalization in Ghana and Africa could change farming experiences, as evident through prior innovations. For example, Nyantakyi-Frimpong & Bezner Kerr (2015) focused on high-input agriculture in Ghana and alluded to how that approach has changed small farmers' day-to-day practices. Similarly, Kansanga et al. (2018) studied the mechanization of agriculture in northern Ghana. They revealed that technology has resulted in a paradox of farms expanding. At the same time, cropping patterns are being shifted from traditional and staple products in the area, altering the cultural dimensions of food security and social life (see Kansanga et al., 2018). With experiences of how earlier technologies have contributed to defining the form and practices of farming, the recent developments may imbue new socio-cultural implications, a phenomenon which early digitalization experiences are already pointing toward (Nikoi et al., 2016).

However, these studies have focused mainly on the older conception of ICTs, which incorporates radio, films, and so on, without engagement with the recent expansion of the scope to encompass digitalization broadly. Much of the research has also been broad, limiting insights into the actual unfolding of these technologies within specific cases. These studies provide a point of
reference, but there is a need for more focused and contemporary research on digital agriculture in the age of ever-advancing digital opportunities across scales in African smallholder systems. This research thus contributes to expanding the scope of knowledge in this field to offer newer insights into agricultural digitalization in Africa through five key objectives that I discuss in more detail below.

1.3 Research Aim and Objectives

This dissertation aims to assess the digital technology-agriculture nexus in the rural smallholder systems in Africa. The overarching goal of my work is to explore how the digitalization of agriculture is unfolding and changing rural smallholder farming systems in Africa. I pursue this goal via five sub-objectives:

1) Identify and discuss the anticipated impacts, motives, and drivers of agricultural digitalization in Africa;

   This objective is addressed primarily in Chapter Two using document analysis. Specifically, I systematically review program reports and other documents by development organizations and technology service providers in the African digital agriculture space to highlight the narratives around impacts carried by the key proponents.

2) Assess the nature of agricultural digitalization in rural smallholder farming systems;

   This objective is addressed in Chapter Three. Mainly, I draw on an extensive survey of farmers in Northern Ghana to show how rural smallholders engage and interact with digital tools and services. I focus primarily on the type of digital tools farmers use, how they interact with digital services offered in their communities, and the perceptions of digitalization.

3) Determine the key factors that influence farmers' participation in digital agricultural services;

   I address this objective in Chapter Four of this dissertation. Similar to Objective Three, I draw on the survey results to assess the effects of specific variables on participation in digital services. The focus of the objective and the chapter is to explore what current characteristics of rural farmers can reveal about the effects different variables may have on the likelihood of participating in services.

4) Evaluate how new digital agricultural technologies change the everyday practices of farming;
This objective is exclusively discussed in Chapter Five. I highlight how farmers perceive and experience changes in their routines through interactions with digital services. A mixed-method approach is adopted to achieve this objective, explicitly drawing on the field survey in Northern Ghana and qualitative interviews and focus group discussions with farmers.

5) Propose novel understandings and scaling of digital technologies in food and farming futures.

This objective is addressed in Chapter Six of this dissertation. This objective exclusively draws on expert interviews with stakeholders in the African digital agriculture ecosystem. Primarily, interview transcripts are analyzed using content and thematic analysis to propose potential directions for the future of digitalization in Africa.

1.4 Theoretical Underpinnings

To address the five research objectives, I employ two theoretical approaches, political-economy and social practices and transitions from an overreaching rural change and development perspective.

This dissertation is broadly situated within rural change and development discussions. Agrarian change and broader restructuring of rural farming have been the centre of much rural research (Cloke et al., 1990; Ilbery, 2014; Woods, 2011). Rural change and restructuring describe the processes and consequences of changes experienced in rural spaces and life (Ilbery, 2014). As Smithers, Joseph, and Armstrong (2005) posit, rural geography has grown in many ways. It has featured "theorizing concerning farm and community change and the local manifestation of broader forms of change related to globalization, restructuring, demography and technological change" (p.45). Whether through rural change, restructuring, or development, research on the complex processes and consequences of change engulfing rural spaces is critical. Hence, a wide range of theoretical lenses, including but not limited to political economy, diverse social theories, livelihoods, and development (Dixon, 2015; Woods, 2009, 2011, 2012), are used to explore this subject. Central in all strands of interest in change lingers the processes and dynamics of how technologies and innovations, including those applied in agriculture, restructure distinctive rural spaces (Maumbe & Okello, 2013; Summers, 2019). The common theme in this discourse, though sometimes contested, is that technologies and innovations of diverse forms transform rural people and life. Therefore, this dissertation draws on my interest in technology and rural social change to inquire about how farmers engage with novel digital agricultural innovations and the consequences on everyday farming and livelihood practices. My engagement with rural development is thus indirect; it serves as the broader
underlying lens I see everything in this dissertation. However, I directly discuss digitalization through a political-economic and social practices lens.

1.4.1 Political economy, Food and Agriculture

Political economy theory and ideas guide my exploration and discussions of digitalization in this dissertation. This section offers a higher-level overview of this critical theoretical approach. Political Economy (PE) is “a branch of social science that studies the relationships between individuals and society and between market and the state, using a diverse set of tools and methods drawn largely from economics, political science, and sociology” (Balaam & Veseth, 2014, para 1). PE is also a distinct strand of Marxist philosophy that critically positions and juxtaposes historical, structural, institutional and power dynamics in the (re)formation of economic behaviours and outcomes (Bates, 1987; Boner, 2018; Friedmann, 1993). Early PE focused on the individuals' behaviours concerning the formation and distribution of wealth. Over time, the concept was heavily developed and applied to understand state behaviours towards markets, market trends, international trade and relations among nations. In the 1980s, Karl Max introduced class-based analysis of PE activities, which has evolved into many strands of contemporary scholarly traditions. Adam Smith's individual-centred PE, Friedrich List's state and national-based PE, and Karl Max's class-based PE have since evolved into discursive and issue-based PE in various scholarly communities (Balaam & Dillman, 2018; Balaam & Veseth, 2014; Boner, 2018).

PE is a field for the holistic study of individuals, estates, markets, and society interactions. The political economy provides ontological and epistemological rubrics to explain changes in societies' constitutions through understanding the nature and dynamics of power distribution. PE emphasizes the implications of political-economic changes on such issues as inequalities, power dynamics, identity (re)negotiation, class formation and differentiation, and access. The contemporary political economy is concerned with how politics and economic decisions affect society's welfare, primarily individuals. In particular, constructivist- and Marxist-influenced approaches to PE explores actors; interests (e.g. profit, security, wellbeing, solidarity, and so forth); sources of power (e.g. economic resources, legal mandate, discursive power); and scales (e.g. local, national, global) involved in shaping structural or system dynamics (Anderson et al., 2019, p. 5).

The tenets of PE, especially power distribution and dynamics, have been applied to understanding food, agriculture, and rural issues. More than a century ago, the original Agrarian Question reflected the peasants' faith considering broader political and economic pressures from states and markets (cf Kautsky, 1899). Following the original agrarian question and the subsequent
interest by rural and agricultural scholars, PE is applied to explain and speculate on diverse issues of changes experienced within the agri-food and rural spaces. Hence, political-economic analysis has often explored how various forces within and outside food and agriculture engender power changes and their resultant inequities and impacts on different groups. Some areas of PE interest and application in food include food regime changes, state interventions in food, agriculture and rural restructuring, and food systems transformations.

One significant engagement of PE in food and agriculture is the food regime analyses (Friedma & Mcmichael, 1989; Friedmann, 1982). The food regime perspective examines agri-food changes with the development of global capitalist structures, and how struggles among social movements, capital and states engender social changes. According to food regime scholars, two main stages have been identified: British hegemony in the world economy between 1870 and 1970, where colonialism and imperialism defined the global food order and the US-dominated post-war economy between 1945 and 1973 (Bernstein, 2016; Friedmann, 2016; McMichael, 2005). However, there are debates on the potential new food regime after the 1970s, as either a “corporate food regime” (McMichael, 2005) or a “green” food regime (Anderson et al., 2019). Central to this analysis is how power is defined by the dominant forces within each food regime and the implications across scales, including communities and farmers. Another essential part of the food and agriculture political economy is the role of policies and state interventions in shaping social dynamics (Bates, 2014; Islam, 2014; Patnaik, 1997). Political economists of food and agriculture consider the impacts of state policies, such as tariffs and export taxes, on societal dynamics across scales. Policies have distributive powers that affect society and people's welfare (Swinnen & Van Der Zee, 1993). Linked to state interventions in food is how governments and civil society (governance) actions affect food system changes. Discussions on this theme focus on how governance can be leveraged to transition food systems towards more efficient and just structures (Anderson et al., 2019). Other political-economic food engagements areas include capitalist neo-liberalization (Alkon, 2014; Moseley et al., 2010) and financialization of food and agriculture (Clapp, 2014), the social and class (re)structuring processes that result from changes in agri-food systems (Bates, 1987; Bernstein, 2010; Johnsen, 2004; Marsden et al., 1996), and in recent times the digitalization of agri-food systems (Béné, 2022; Carolan, 2018; Clapp, 2018; Rotz et al., 2019).

Central to many streams of PE engagement with food and agriculture is a direct or indirect concern about the power implications of technologies and innovations (Herring & Paarlberg, 2016; Kloppenburg, 2005; Pechlaner, 2010). Within such discourse is how technology diffusion and interventions emerge and their consequential influence on diverse social conditions (Nyantakyi-Frimpong & Bezner Kerr, 2015; Shilomboleni, 2020). Critiques, for example, argue that agricultural
technologies are promoted to serve neoliberal economic and political interests without carefully considering their potential adverse impacts (Braimah et al., 2017; Schurman, 2017; Vercillo et al., 2015). Much of the discussions of PE of agriculture technologies are influenced by the humanist turn in social science, driven also partly by critical science and technology studies. This line of inquiry emphasizes a need to assign agency to non-human things, such as technologies, and critically assess their implications for social change, including power distributions.

From the ensuing overview, PE is an extensive scholarly field, and so is PE in food and agriculture. I have synthesized some critical areas of PE of food and agriculture that do no justice to this crucial theoretical framework. However, I have attempted to provide readers with a broader sense of PE and what makes it essential to my dissertation on the digitalization of agriculture. Following this line of analysis, I subject the emerging digitalization of agriculture to political-economic perspectives in this dissertation. My interest in using this to understand the implications of digitalization on society in general and smallholder wellbeing. I am interested in issues of access to digitalization, local PE structures that influence the penetration of the phenomenon, and the implications of digital services on inequalities and power dynamics in rural smallholder systems. While this is apparent in Chapter Two, I implicitly use this frame throughout this dissertation to critically analyze and discuss the implications of digitalization in rural Africa (see Chapter Two for further discussion).

1.4.2 Social practices and transitions

This study is also situated in the broader perspectives of transitions and social practices theory. Innovations such as digitalization have often drawn the attention of researchers. However, some disciplines turn to emphasize the innovations, knowledge creation, and production dynamics of emerging technologies without adequate attention to the realities of the beneficiaries or what Boamah and Rothfuß (2018) referred to as the “user-side” mechanisms (Boamah & Rothfuß, 2018; Breschi & Malerba, 1997; Geels, 2004). Meanwhile, the success or otherwise of any form of innovation or the potential transition, including agri-food digital tools, largely depends on having enough user engagement. One approach that has been extensively used in understanding and describing the change in society is transitions (Geels, 2004, 2006). From demographic transitions to nutritional transitions to technological transitions to sustainability transitions, transitions feature in many social science scholarships to understand the movement from one state to another. Hence, in this dissertation, digital agricultural technologies are viewed as a technological transition in agriculture with their unique unfolding mechanisms and potential to change everyday activities in farming. I
present digitalization as a phenomenon that holds the potential for a “gradual, pervasive shift from one state of agriculture to something different” (Hinrichs, 2014, p.145). Hence, I adopt a fundamental and growing transition theoretical approach: social practice-based theory, where the unit of analysis of transitions rests on everyday practices (Hinrichs, 2014; Shove & Walker, 2007). So, unlike other approaches that study institutions, social structures, human behaviours (Jone & Murphy, 2011) or socio-technical processes (Geels, 2003; 2011; Shove et al., 2012), interest in practices form the “muster station” for practice theorists (McMillan, 2017; Schatzki, 2001).

Social practice is a distinct conceptualization of social activity and order, human behaviour, and change (Schatzki et al., 2005). Practices in this context are open and spatially, temporally dispersed sets of doings and sayings integrated by shared understandings, teleology, and rules (ibid). For Reckwitz (2002), they are the "routinized way in which bodies are moved, objects are handled, subjects are treated, things are described, and the world is understood." [p. 256]. Practices "appear at different locales and at different points of time and are carried out by different body/minds" (Reckwitz, 2002, p. 250). For some practice theorists (Schatzki, 2001; Shove et al., 2012; Shove & Pantzar, 2005), practices come together through integrating elements. Practices are skillfully/consciously carried out by bodies/minds using things/objects, and they make up the structure of our everyday life. Hence, practices are the routine entities that practical conscious practitioners constitute for and within their day-to-day functioning. These practices, therefore, exist whether performed (practice as performance) or not (practice as entities) (Shove et al., 2012). Some common practices in the literature are cooking, playing football, walking, and skateboarding, but almost all activities in society, including farming, are either practices or constituents.

Applying practices in research may vary based on the dimension of the theory and the researcher's focus. In this dissertation, I rely on the descriptions and practice influences of Schatzki and Shove (see Chapter Five and Chapter Six). Schatzki distinguished practice as a coordinating “entity” and practice as “performance.” Practice as an entity refers to the spatial and temporal dispersed saying and doing of everyday life. This notion emphasizes the formation of practices by connecting what people say and do. For Schatzki, sayings and doings are integrated into practice (1) through understandings — for example, of what to say and do; (2) through explicit rules, principles, precepts, and instructions; and (3) through “teleoaffective” structures embracing ends, projects, tasks, purposes, beliefs, emotions, and moods (Schatzki, 1996: 89). Practice as performance describes practically undertaking the doings and sayings, which “actualizes and sustains practices in the sense of nexuses” (Schatzki, 1996: p.90).
Another aspect of social practices understanding relevant in this dissertation is Shove et al. and practice dynamics (Shove et al., 2012; Shove & Pantzar, 2005; Shove & Walker, 2014). Shove et al.’s advancements to practice theory include simplifying elements and understanding change through practices. For Shove et al. (2012, p.8), practices are constituted by three elements: 1) “materials – including things, technologies, tangible physical entities, and the stuff of which objects are made; 2) competences – skill, know-how and technique; and 3) meanings – the symbolic meanings, ideas and aspirations”. Hence, there exist no universal types of elements, “cultural conventions and representations (meanings), material objects and infrastructures (materialities), and normative understandings of competent performance (skills and procedures)” are generally cited as key to the formation of practices (Southerton, 2020; p.58). The three-element model provided the most practical leap to adapting practices to the real-world research context and set a foundation for “practice” understanding of social change, including digital changes. Hence, I apply and propose this approach to understanding and guiding the digitalization process (see Chapters Five and Six for further details).

My use of political economy and social practice in this dissertation is deliberate. This thesis employs these two critical lenses in different sections without a cross-theoretical conversation. Essentially, each theory is used separately as I do not intend to crossover the two theoretical approaches. However, I must appreciate that I could have derived value from bringing these theories into a conversation. Yet, I purposely choose to take separate approaches to engage each lens as it allowed for effective and deep engagement on specific aspects of digitalization. The political economy approach allowed me to probe the institutions, actors, and interests driving African digitalization. Likewise, their political-economic implications explored the potential power dynamics of the phenomenon across scales, including changes to inequalities, uneven benefits and losses across socio-economic groups. While the political economy allowed for structural analysis of digitalization, the continuous distinctive embedding of the phenomenon in smallholder systems informed my choice of complementing the approach with social practices. The social practices lens is used to assess the digitally informed emergence, formation, and resultant changes in farming practices in the smallholder system. Thus, combining the two approaches provides analytical and theoretical depths to my exploratory engagement with the temporary and scalar unfolding of digitalization in smallholder Africa.
1.5 Research Methodology

The following sections outline the research design (mixed method case study), the study subjects, how participants were recruited, and data was collected using quantitative(surveys) and qualitative methods (document review interviews, focus group discussions, and observation).

1.5.1 The case study design

My approach to this research was a mixed-method case study (Adams et al., 2014; Chmiliar, 2010). "A case study is a methodological approach that involves the in-depth exploration of a specific bounded system, utilizing multiple forms of data collection to systemically gather information on how the system operates or functions" (Chmiliar, 2010: p.1). Case study research explores the depths of a social phenomenon to advance deeper understanding (Meyer, 2015; Tight, 2010; Yin, 2011). It involves extensive data collection with diverse methods to unravel the nuances of a case. Hence, using the case-study approach, contextual and relational depths of digitalization were explored (Liepins, 2000) through multiple research methods (Adams et al., 2014; Bartlett et al., 2016; Yin, 2011). The choice of the case study was informed by theoretical, conceptual, and practical considerations. The case-study approach can blend diverse methods to provide in-depth insights into a social phenomenon (Adams et al., 2014; Castree, 2005; Yin, 2011), such as technological changes which varies across spaces and temporalities and are very much socially and culturally imbued in people’s lives (Spaargaren, 2011). Also, case studies have been extensively employed in human geography, including rural geography, especially following the humanist and cultural turn in the sub-discipline (Castree, 2005), to emphasize particulars and provide an in-depth understanding of social phenomena. Hence, the research approach used in this study very much informed the methods and techniques for data collection and how fieldwork was organized. Due to the earlier noted in-depth focus of case studies, I undertook an extensive data collection from multiple sources as stipulated by Chmiliar (2010) and Yin (2011). However, despite the strength of the case-study approach, I acknowledge its limitations to my research, including the potential lack of generalizability as it focuses extensively on the specific context (Bartlett et al., 2016).

1.5.2 Study population, subjects and elements

The study population- the entirety of the members of a defined class of people, objects, places, or events selected because they are relevant to the research question(s) (Clifford et al., 2008; Halcomb, n.d.; Walliman, 2017)- included all actors in the agri-food systems in Ghana and Africa. Specifically, these groups included farmers in Northern Ghana, retailers of technologies, development and government institutions in Ghana and Africa, and other relevant stakeholders who
were directly or indirectly involved with the dissemination efforts of digital agricultural technologies or were engaged in decision capacities. Linked to the institutions are policy and program documents about interventions currently employed to oversee digital technologies, which served as units of inquiry (Clark & Ivankova, 2015; Walliman, 2017). At the same time, specific social practices and everyday activities, structures and forms of rural areas, and policies/interventions they undertake regarding farming and rural life were used as units of analysis.

1.5.3 Methods and participant recruitment

Due to the variety of units of inquiry and sources, I employed multiple techniques to recruit participants and collect relevant data. Before I detail my sourcing of participants, let me clarify issues surrounding the number of participants in my methods. The quantity of participants is always crucial, especially in quantitative studies using mathematical analyses. However, that is not the case for qualitative studies emphasizing saturation and information power. In mixed methods, a balance is constantly stroked between depth and a larger sample (Creswell & Creswell, 2017). Mainly, sample size considerations are dichotomized, with small samples associated with qualitative research and quantitative studies noted for large samples (Bryman, 2017). In cases where the two techniques are mixed, as in this study, there are varied views on the appropriate sample needed to make valid conclusions (Onwuegbuzie & Collins 2007). Having this in mind, I emphasized both information power and representativeness to deeply appreciate the dynamics and implications of digital technologies in farming. Hence, I employed diverse research techniques (document review, surveys, interviews, focus group discussions and observations) in line with the mixed-method case study design (Cousin, 2005; Yin, 2011).
Table 1.2 Summary of research methods and participants

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<tr>
<th>Method</th>
<th>Description</th>
<th>Purpose and focus</th>
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<tr>
<td><strong>Document review and analysis</strong></td>
<td>Review of policy and program documents from international development organizations and technology service providers (see Chapter Two for details)</td>
<td>The document reviews were employed as the bases for literature scan on digitalization. The purpose was to document what digitalization looks like, broader drivers and motives for promoting digitalization, and anticipated effects for farmers. The reviews provided the foundations for developing questions for the field research and exploring narratives in Chapter Two.</td>
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<tr>
<td><strong>Surveys</strong></td>
<td>Surveys were conducted in 28 communities across four districts in the Northern region. 1565 participants (see Chapters Three and Four for details)</td>
<td>The surveys aimed to assess the nature of farmers’ digital tools and services, how they use them, and perceptions of change and challenges. Surveys included only farmer participants.</td>
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<tr>
<td><strong>Focus groups</strong></td>
<td>16 focus group discussions in 12 communities Two agents-focus groups (see Chapter Five for details)</td>
<td>Focus group discussions were undertaken for farmers and agents of service providers who work with farmers. Farmer focus groups included male-only, female-only, and mixed groups. The purpose was to assess community-level experiences with digitalization. Discussions covered what and why farmers use certain technologies, impacts on farming within communities, engagement challenges, and way forward.</td>
</tr>
<tr>
<td><strong>Interviews</strong></td>
<td>22 farmer interviews 32 interviews of officials across Africa 54 participants (see Chapters Five and Six for details)</td>
<td>Interviews covered all respondent groups, including farmers, service providers, and key informants, from local to international actors. Interviews focused on experiences with digital services, motivations, challenges, and the way forward for digitalization.</td>
</tr>
<tr>
<td><strong>Observation</strong></td>
<td>Observation of farmers’ activities in communities See Chapter Five</td>
<td>Observations were applied throughout the research, particularly with farmers and service providers. The aim was to see how farmers use digital tools and services and how farming activities are changed. It also allowed for understanding how service providers engaged with farmers on the ground.</td>
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I conducted a document review and analysis (see Chapter Two) by collecting secondary information about farmers/farm activities in the digital agriculture space, digital agricultural programs and broader level policy discussions on the subject. I used online sources like web pages and in-field requests from organizations to obtain documents. Also related to this method were
reports of various programs systematically reviewed to assess the narratives of digitalization. Likewise, documents were consulted as part of an ongoing literature search process with some application in the analysis stage for triangulation to enhance rigour (Bryman, 2017; Flick, 2018). This method allowed me to understand some of the broad issues underpinning the diffusion of technologies and the current and anticipatory motives (Carolan, 2017) of organizations driving such actions.

Besides the secondary review of documents, primary data were collected through multiple methods, including surveys, interviews, focus group discussions, and observation (see Table 1.2). I must note that the exact forms of collecting primary data were reflective, informed by unfolding events during fieldwork. Participants were recruited mainly through agencies, researcher community immersion, and snowballing. I contacted program directors and retailers who have worked with farmers to implement digital technology programs as a first step toward choosing specific study regions. There were two approaches afterward; first, in some cases, I found communities of operation and used personal networks to access areas to recruit participants for both survey and interviews. Secondly, I used technology service providers to access communities and recruit participants. In each community, I then used different methods to collect data.

Surveys were conducted in Northern Ghana with designed questionnaires (see Appendix VII). Specifically, in-person surveys were undertaken with the help of research assistants (see Chapters Three, Four and Five). The survey is one of the most familiar data collection methods in quantitative social science, geography, and earlier rural geographers (Madsen & Adriansen, 2004), informed mainly by the positivist and quantitative roots (Brunsdon, 2017). Survey techniques are convenient for data collection, including understanding social phenomena (Moser et al., 2017). Therefore, I used the survey to understand specific characteristics of study populations to derive relationships with change. In terms of design, questionnaires included open- and closed-ended questions (Nardi, 2018) to understand the characteristics of respondents, perceptions of the impacts of digital technologies, and social factors that influence adoption and possible effects. Closed questions entailed pre-coded answers from which respondents chose, while open-ended gave respondents the liberty to express their opinions. My choice of the survey was because of its ability to reach out to many participants and capture a broad scope of a phenomenon while enhancing the validity of the study findings (Moser et al., 2017; Nardi, 2018).

Beyond surveys, interviews formed an integral method of my data collection. Specifically, face-to-face interviews were conducted with an interview guide (see Appendix V and Figure 1.3).
Interviews have become an essential geographical research technique, especially in human geography (Clifford et al., 2008; Hay, (ed), 2016) due to the value of conversation in understanding discourses and intentions. The technique is extensively used in rural geography to understand the experiences of the farmers from the perspectives of those who live it (Madsen & Adriansen, 2004; Panelli, 2001; Smithers & Johnson, 2004), a movement centred on principles of lay discourses of rurality (Liepins, 2000). Hence, semi-structured interviews (McIntosh & Morse, 2015; Paine, 2015) were used in this research. Interviews were mainly recorded with audio recorders and later transcribed for analysis. However, respondents who opted out of recording were still interviewed, and notes were taken. Proceeding with interviews off tape was influential in the Ghanaian context when people were sometimes hesitant about being on record. All interviews were scheduled appropriately to ensure that the researcher and participants were not inconvenienced and safe according to COVID-19 protocols and as outlined in the Research Ethics Documents (see Appendix II). The usage of interviews was primarily influenced by the role of spoken language in creating discourses. It provided more detailed data than other methods within a relaxed atmosphere like everyday conversations. Also, interviews helped gain insights about digitalization, allowed participants to express their feelings, and were suitable for generating quotes and stories that create mental pictures of practices and change. However, the intrusiveness on the participants, as some may perceive the technique, and its time consuming and expensiveness (Hay, 2016) impacted the data collection by limiting the number of participants in this study.

Figure 1.3 Student conducting interviews with participants

Another method I employed was focused group discussions (see Chapter Five for details). This method was used with the help of a focus group guide (see Appendix VI and Figure 1.4). Focused group discussion mainly involved interaction between the researcher and a selected group of people, mainly between six to twelve purposefully selected informants (Carey et al., 2016; Krueger,
Focus groups have also been used in geographical research to understand socio-cultural issues within groups following cultural turn in the discipline (Clifford et al., 2008; Hay, (ed), 2016). The technique is generally used to solicit information on issues that requires extensive discussion. This study employed the method to collect community-level information to elucidate current and potential structural changes in farming households and communities resulting from digitalization. Due to the complexity, diversity, and possible collective experiences of new technologies, focused group discussions provided an avenue for conversations about how diverse but closely-knit groups perceive digital social changes. Discussions were set up in communities in the study regions in Ghana. The selection and composition of participants were dictated by each community's social structures and characteristics. For example, mixed groups were conducted in communities where females felt free to speak in the presence of males. At the same time, separate discussions were held in areas with clear gender power imbalances. However, the challenges of having people participate or even speak freely when brought together was still an issue in some areas, especially for women. This challenge was minimized through interviews that allowed participants to speak without the concerns of others. Likewise, including a female research assistant as part of conversations helped break some of the barriers for women in discussions.

Figure 1.4 Student conducting focus group discussions at Kuduhizegu and Paţazaa

Finally, observation formed an essential part of my research. Like the other techniques, observations are commonplace in human geography and among rural geographers, especially those inclined to the humanistic and cultural turns in the discipline (Ilbery, 2014; Munton, 2017). In rural geography, observations have been used, for example, Holloway (2004), to unravel how rurality is practiced and imaged. Also, geographers have often used observation as a powerful tool in ethnographic studies to document everyday activities across spaces (Bear & Holloway, 2015;
Holloway & Hubbard, 2014). Following the early applications of observations in rural research, I used the method to understand the everyday practices of farmers in the context of digital technologies in the study sites. This technique helped create a mental picture of how digital technologies are employed and how they shape everyday practices in farming. Observations were also adopted to complement interviews during fieldwork to understand expressions and behaviours and determine how these technologies are employed and their impact on everyday practices and structures. This method was crucial in analyzing data and information throughout this dissertation.

1.5.4 Data processing and analysis

I used multiple techniques, tools, and mechanisms to process data for further analysis. Data collected from secondary sources and fieldwork were processed through editing, organizing, coding, and deductions.

For quantitative data from surveys, Microsoft Excel, SPSS and R-Statistics were combined to process and create relevant diagrams and charts in specific manuscripts. The data were exported to excel from Kobotoolbox and later exported into SPSS and R-statistics depending on the statistic or graph needed. After entering the data, descriptive and inferential statistics were used to make sense of the information. A simple univariate analysis presented basic descriptive accounts of farmer responses, including frequencies, percentages, averages, and medians. Also, Chi-square analysis was used to determine the relationship between farmers’ characteristics and various digitalization variables, including participation, retention, and farmer interest in future participation. Kramer V was also conducted with the Chi-square to show the strengths of each relationship. I also employed probit modelling to establish the likelihood of farmers participating in digitalization services in the area. These inferential statistics allowed me to delve deeper into the data to ascertain relationships.

For qualitative data collected through interviews and focus group discussions, an approach of recording, transcription, editing, and analysis was followed. Some interviews and focus group discussion recordings were transcribed with Express Script Version 6 with the help of a transcription peddle. Transcripts were then processed for a two-stage coding through editing to correct grammar and spelling errors (only mistakes made by the researcher were fixed). The first entailed a manual approach where I read through the transcripts to identify general patterns while noting key themes. The transcripts' softcopies were then uploaded to Nvivo for a more directed coding informed by the first set of themes derived. However, coding at each stage was informed by predetermined themes from the research objectives and theoretical propositions. After themes were grouped under research objectives, a more inductive approach was used to present ideas aligned with the research objectives. The entire process was built around the thematic analysis. The choice of thematic analysis was informed by its flexibility. Still, the lack of transparency and the absence of clear and concise
guidelines on its application proved difficult and problematic. However, I minimized the impacts of these issues by using some colleagues to check the themes, while I also combined it with content-based analysis. For content analysis, latent and manifest content, a technique of identifying what is said, was mainly used (Hay, 2016). Hence, throughout this work, I describe what was said (latent content) and what that means (manifest content). I, however, did this with care to ensure contents stayed close to respondents' words, a situation that adds more validity to qualitative information (Assarroudi et al., 2018). To achieve this, Nvivo 12 was again very useful. The software was used to do a word search in policy documents and interview transcripts to reveal information clusters and to quickly identify contents around policy, programs, projects, and so on. Also, in some cases, quotations from translated transcripts were used throughout the research to echo respondents' voices (Ritchie, 2003) as used mainly in qualitative human geography (Hay, 2016).

1.6 My positionalities in the research

The researcher's positionality is central in the literature on research processes, especially among qualitative researchers (Bourke, 2014; Corlett & Mavin, 2018). In particular, the reflexive turn in many social science disciplines has made researchers increasingly conscious of how they negotiate identities in their position as either insiders or outsiders in research (Geleta, 2014) and how their personalities interact in the research activities (Dosu, 2021; Moser, 2008). Positionality clarifies how a researcher's personal experiences (re)shape the research process, including the choice of methods, data collection, analysis, and interpretation (Qin, 2016). As I combined qualitative and quantitative methods, I will offer a cursory reflection on my positionalities (as an insider, outsider, and insider from outsider/outsider from inside) was negotiated in the research process and the advantages and disadvantages each provided.

I was born and raised in Tamale, Northern Ghana, until 2016, when I left to pursue postgraduate studies in Canada. I speak Dagbani and other closely-related dialects that are spoken in Northern Ghana. I was born to a farmer and grew up occasionally helping on the farm and experiencing the issues and changes in smallholder systems in the area. Thus, I considered myself an insider from the onset of this research because most of my fieldwork was in Tamale and surrounding districts, where Dagbani is the predominant language of communication by the thousands of rural smallholders in the region. Also, my upbringing in the area made me familiar with the place's culture and social ways of doing things. Likewise, participants considered me an insider as many were quick to point out that I was a native by saying, “Ti niri mbala,” translating as "he is our person." Even in places that spoke different dialects in the Upper East region (Ghana), I was still considered an insider
as they noted that "we are all one people, and tribe," referring to a common ancestry shared by our cultures.

My birthplace and culture were instrumental in my choice of study location(s) (among other factors stated in subsequent chapters in this thesis). They provided me with the right opportunity to study at a place dear to my heart. This position provided both advantages and disadvantages. On the positive, my ability to speak the Dagbani and understand other dialects in the study regions offered an easy way to interact with participants in many areas of Northern Ghana (including those speaking other languages). I remember visiting the community of Nasia in the North-Western region, where I successfully conducted focus group discussions speaking a different language (Dagbani) to my participants (Mumpruli) without using a translator. As many participants considered me an insider, it was easy to build trust and gain credibility with farmers and hold conversations they may only be willing to share with people they trust. Likewise, my ability to organize the field activities, access communities, and talk to local leaders was highly facilitated by my insider knowledge of the setting, which provided me with an extensive social capital to draw upon. This position allowed me to interpret conversations much more profoundly than an outsider could understand. In contrast, my position as an insider, from my assessment, made it challenging to access institutions in the area. As the familiar dictum goes, "Ghanaians like outsiders more than insiders," which I concur with considering my data collection experience. Institutions were reluctant to work with me or offer me information as they probably felt threatened by what I may use the information to do as an insider.

Despite being an insider, I felt like an outsider at certain times- a position that was also not lost to some of my participants. As an educated person with a university degree, who has spent much of his life in what is considered a city by many rural participants’ standards and being considered to come from abroad, I was also part an outsider. Internally, my time away from the region and the culture as I pursued education made me gave me occasional feelings of an outsider. Likewise, some participants always referenced me as “yi Tamale Nimmaa” (you, the Tamale people) or “yi Karachi Nimmaa” (you the educated people), which meant they viewed me as an outsider. This position presented opportunities and challenges for my field activities. The outsider position allowed me to negotiate specific topics quickly. Being considered an outsider meant that participants hoped I could bring some changes to their lives through my connections. Hence, they were open to talking about their concerns more candidly. However, some were still hesitant to speak to me as I was viewed as part of the "many outsiders who come to take their information and never see anything happen." This challenging situation emanated from the research saturation by academics and NGOs in the area.
My insider-outsider status culminated into what I call an insider from outside/outsider from inside. In essence, I viewed my ultimate position in the research process as an insider from the outside or an outsider from the inside. This mixed, entangled and intersectional position emanated from the confusion on the parts of some participants and myself on where I belonged due to the two statuses mentioned above. I felt more like an insider throughout the process, but there was occasional confusion in my head about my position. I typically introduced myself in communities as a student doing research who is also a Dagomba from the area. Also, the nostalgic feeling of collecting data in familiar communities where I grew up, walked and travelled as a child constantly contrasted with the new me and my ambivalent and disconnected feelings of the setting that interplayed at certain moments. Participants also expressed their positional confusion regarding their approach with me by questioning who I am there for (either a part of them trying to create awareness of their concerns or an outsider just interested in self-gratification). This mixed and uncertain position also presented advantages and disadvantages. The position allowed me to seamlessly navigate the field activities and interactions by drawing on whatever identity I found helpful in each case. For example, introducing myself as a native (insider) researcher from outside (Canada) allowed me to draw on the identity needed at each point. On the contrary, this status sometimes heightens participants' confusion, leading some to be hesitant to engage.

Another important position that affected my research was the power dynamics that emanate from gender differences. As a male conducting research in a highly patriarchal society, my position influenced the research process in various ways. Being a male allowed me to access the study communities easily and connect with digital technology users—who were also mainly male. However, women play a crucial role in smallholder agriculture in Africa (Doss, 2001; Doss, 2002; GSM Association, 2019), which meant it was essential to capture their voice. I anticipated that females might be reluctant to open to men on sensitive topics; however, the lack of sensitive issues in the general agriculture focus of my research allowed me to circumvent some of such barriers. Nonetheless, there were instances where the power imbalances influenced the voices captured—a typical example was in focus group discussions. Women were primarily reluctant to talk in mixed-gender focus groups, especially when male figures in the family were present. My decision to conduct separate focus groups for males and females in specific communities helped minimize the effects of such differences. In all, I acknowledge that my position as a male, with its resultant power implications, shaped my research methods and the analysis of the results.

Generally, navigating these positions demanded practical conscious reflectivity throughout the research process. I successfully leveraged these positions, partly through using my personality to create trust, credibility, and acceptance among the research participants and communities (Adu-
Ampong & Adams, 2020; Cousin, 2010; Dosu, 2021). While negotiating my positions, I always acknowledged my roles as an male insider, outsider, and outsider from inside, whose main goal was to generate valuable knowledge to inform theory, policy, and practice. Thus, I acknowledged my "responsibility and indebtedness" to all my research participants for their roles in this process. I also recognize the biases these positions inherently brought to the data collection and interpretations of the texts in the following chapters.

1.7 Structure of Dissertation, Manuscripts, and Contributions

This dissertation is structured as seven chapters, which include five peer-reviewed manuscripts. Chapter One, Setting up the Research, lays the foundation for the dissertation (see Figure 1.5). The Chapter begins with a broad introduction to this dissertation, which outlines the background of the research and the themes covered. The following section in the Chapter is Contextualizing the Research: Digitalization in Africa and Ghana, which introduces the digitalization of agriculture as a concept and sets up an understanding of digital agricultural technologies in Africa. Following the section are the Theoretical and Analytical Underpinnings of this work, where I introduce the two theoretical perspectives: political economy and transitions and social practices theory. I present each theoretical approach as an underpinning pillar to how I think, analyze, and discuss the digitalization of agriculture in this dissertation. Following the theoretical approach, I outline the five objectives of the dissertation. In the next section, I discuss the methodology of this research at the broader level, highlighting the research design, the study subjects, the process of data collection and steps towards analysis. The Chapter ends with the Structure of the dissertation, Manuscripts, and contributions. Beyond this structure, the remaining of the dissertation is as follows:

Chapter Two, "A New Green Revolution (GR) or Neoliberal Entrenchment in Agri-Food Systems? Exploring narratives around digital agriculture (DA), food systems, and development in Sub-Saharan Africa," I discuss the narratives of digitalization as shown by organizations championing efforts in Africa. Using document reviews from international development organizations and technology service providers in Africa, digitalization is promoted by an international development organization and private sector actors. I also use the documents to reveal the seven key anticipated impacts of digital agricultural technologies in Africa as presented by the promoting actors. Ultimately, the narratives in the papers are generally positive and technological optimistic at best. Then, the political economy theory shows that the current descriptions follow and entrench earlier green revolution rhetoric, but such an approach may mask underpinning issues and risks digital technologies may create for specific classes, such as the uneducated and women.
In Chapter Three, I present "Is agricultural digitization a reality among smallholder farmers in Africa? Unpacking farmer's engagement in rural Ghana." This chapter introduces the dynamics of rural farmers' engagement with digital agricultural technologies in Africa and Ghana. The first field-based paper in the dissertation introduces farmer participation in digitalization and discusses the nature of services provided to smallholders in Africa. The Chapter draws on the surveys in Northern Ghana to show the types of digital tools and services available to farmers and the characteristics of farmers who use them.

In Chapter Four, "Gender, access to digital tools and digital competencies affect rural smallholders' participation in digital agricultural services in Northern Ghana," I examine how diverse factors may influence farmers' participation in digital services. Chapters Three and four both utilize the results of the survey. While Chapter Three is inherently descriptive and simply describes the technologies and services different farmers use, Chapter Four picks up where it leaves off and uses a polynomial modelling technique to create a predictive model of farmer engagement with digital agriculture.

In Chapter Five, "Beyond Transformations: Agricultural digitalization and the changing practices of rural farming in Northern Ghana, West Africa," I employ a mixed-method approach to show the change dynamics of mobile-based digital services. First, I draw on the survey of farmers in Ghana used in Chapters Three and Four to show that rural farmers generally perceive digitalization as a potential mechanism for changing farming and rural livelihoods. Furthermore, I use a practice theory to examine and show that farmers' engagement with digital tools leads to change by altering their everyday farming and livelihood activities through the reconstitution of the use of space and time. The paper sheds light on the "how" of the change mechanism of digital agricultural technologies for African rural farmers.

In Chapter Six, "Towards digitalization futures in smallholder farming systems in Sub-Saharan Africa: A social practice proposal" I offer a pathway to think, research and guide the institution of digitalization of agriculture in smallholder Africa. I draw on insights from all the preceding papers and data from key informant interviews with actors in the African digitalization ecosystem to show how Shove et al. (2002) three elements of practices could be critical to digitalization efforts. I emphasize the need for equal attention to digitalization materials, competencies, and meanings if we stand any chance of successful digital futures in Africa.

In Chapter Seven, I present the summary of findings and conclusions from the key results across the preceding five chapters. The Chapter starts with the essential findings and deductions from all the
chapters, presented according to the objectives outlined in Chapter One. The Chapter also discusses the scholarly contributions of this dissertation, limitations, and the study's practical implications.
Main Question: how would digital agricultural technologies manifest and re-model smallholder farming and what implications do they present in Sub-Saharan Africa?

Political economy

Social practices

Mixed method case study

**Quantitative**

- Surveys

**Qualitative methods**

- Document Reviews
- Expert Interviews
- Interviews
- Focus group
- Observation & photography

**Objective 1**

Impacts, motives, and drivers of digitalization

Chapter 2

A New Green Revolution (GR) or Neoliberal Entrenchment in Agri-Food Systems?
Exploring narratives around digital agriculture (DA), food systems, and development in Sub-Saharan Africa

- Development actors drive transformative narratives
- Digitalization is attracting funding and hype
- Political-economic issues are often neglected

**Objective 2**

Nature of agricultural digitalization in smallholder systems

Chapter 3

Is agricultural digitization a reality among smallholder farmers in Africa?
Unpacking farmers engagement in rural Ghana

- Smallholder engagement is low
- There is weak building blocks for smallholders
- Weak building blocks are still limited
- Digitalization is superficial

**Objective 3**

Factors that influence farmers' participation in digital services

Chapter 4

Gender, farmer groups, extension services, digital competence, and mobile phone ownership/access increase the likelihood of farmer participation in digital agricultural services

- Gender, ability to place phone calls, internet access, group association, and extension access influences digital service participation
- However, critical inequalities exist

**Objective 4**

How digital technologies change the everyday practices

Chapter 5

Beyond Transformations:
Agricultural digitalization and the changing practices of rural farming in Northern Ghana, West Africa

- Digital services change farmers' social practices (everyday routines and rhythms)
- Digitalization introduces new patterns of farming activities

**Objective 5**

Guidance towards understanding and scaling of digital technologies

Chapter 6

Towards digitalization futures in smallholder farming systems in Sub-Saharan Africa: A social practice proposal

- Inclusive digital futures require three key elements:
  - Material elements
  - Competencies required
  - Meanings & understandings

**Findings**

1. Current promotion of digital agriculture is disconnected from smallholders lived realities
2. While prospects for digital-enabled change may exist, potential transformations are unlikely in the near term because the basic building blocks is so lacking.
3. Uncritical promotions of digital innovations may only reinforce existing structural power imbalances and inequities, while creating newer inequalities.
4. We need a ‘digitization for smallholders’ where expectations and goals for digital innovations are dialed-down and situated towards incremental changes in every social practices which aim for inclusive access.

**General conclusions**

Figure 1.5 Structure and flow of the dissertation

28
1.8 References


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35


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https://doi.org/10/fxpq7d


https://doi.org/10.1596/26791
2.0 A New Green Revolution (GR) or Neoliberal Entrenchment in Agri-Food Systems? Exploring narratives around digital agriculture (DA), food systems, and development in Sub-Saharan Africa

2.1 Preface to Chapter Two

In this chapter, written as a standalone manuscript, I present some preliminary reviews on digitalization in Africa, as seen through the documents of the key proponents of agricultural digitalization. Chapter One showed that digitalization is a growing phenomenon in Africa and is primarily promoted and supported by and within international development programming (Kim et al., 2020; Rolandi et al., 2021; Tsan et al., 2019). Following the brief pretext, this chapter begins to examine the dynamics of the phenomenon through the narratives of development actors and organizations. Specifically, the chapter is situated within the political economy of rural development by answering the question, considering the growing promotions of digitalization in Africa by development actors, what effects are these technologies anticipated to have on smallholders and rural development?

To answer this, I use systematic document analysis to show that the narratives expect digitalization to transform rural food systems and development through seven key areas: I DA will bridge agricultural information and knowledge gaps; II DA will lead to productivity gains and greater on-farm efficiencies; III DA will lead to food and nutritional security in Africa; IV DA will facilitate Climate change/environmental sustainability and resilience; V DA will create employment opportunities and empower youth; VI DA will promote gender and women empowerment in agriculture, and VII DA will ensure rural livelihood improvements and resilience. These potential impact ways are noted as partly the motivations and justification for development organizations that implement and hype digitalization interventions, ultimately attracting substantial financial support from international donors and cooperations.

To inject a critical perspective to the narratives, I subject the findings to political-economic analysis that shows that development impact pathways presented in the reports are a continuation and entrenchment of older Green Revolution rhetoric of technological saviorism. Hence, digitalization justifies the activities of the proponents as they position the phenomenon as pro-poor development interventions set to transform livelihoods. Through this political-economic analysis, I point out the need to move beyond broader narratives of what digitalization is or could be or do for smallholders and rural communities and instead begin to consider the local implications on power dynamics and class (re)structuring associated with them. This wholesome call in this chapter
becomes the critical block for the field-based empirical articles and the Chapters that follow as they begin to unpack some fundamental structural dynamics of the digital revolution in Ghana and Africa.

2.1.1 Preface references


2.2 Publication Details

2.3 Abstract

This paper adopts a document analysis to describe the expected developmental effects of agricultural digitalization in Africa. Narratives show that digitalization is expected to bridge information and knowledge gaps in agriculture; promote food security; increase climate change/environmental sustainability; provide employment and empower the youth; promote gender and women empowerment, and enhance livelihood resilience in rural areas. With these findings, I argue that, though justifiable, private sector-led digitalization, with its optimistic technocratic narratives, follows, entrenches, and extends the ‘transformational rhetoric’ of earlier Green Revolution efforts to improve smallholder rural lives through technological diffusion. However, without critical considerations of political-economic issues affecting its proliferation and their implications on power structures and class restructuring, these narratives mask potential neoliberal incursions. Thus, issues of connectivity and the digital divide, the slow pace of technological adoption, scaling and sustainability of digital solutions, and the weak enabling environments must be addressed to make benefits inclusive. The political-economic discussions of the narratives inject much-needed critical perspectives into the early conversations by showing that digitalization [among others] may further concentrate power and restructure social classes.

Keywords: Digital agriculture; development agencies; African development; smallholders; rural livelihoods

2.4 Introduction

Developmental organizations promote disruptive digital technologies as tools that lead to new development opportunities in Africa. But what effects on these technologies have on smallholders and development in general? Since the contested successes of the “Green Revolution” (Juma, 2015, Patel, 2013), mechanization, biotechnology, hybrid seeds, irrigation, biotechnology, synthetic fertilizers, and recently Information and Communication Technologies (ICTs) have been promoted to transform livelihoods and reduce poverty in Africa. Under a pretext of a “New Green Revolution” or “African Green Revolution,” these “transformational technologies” have centred development practices and research on rural development, poverty reduction and economic development (see Dawson et al., 2016; Ejeta, 2010; Otsuka & Larson, 2016; Scoones & Thompson, 2011). As a complementary technology to the earlier Green Revolution innovations in Africa, ICT promotion in agriculture continues unabated (Munyua, 2007).
For over a decade now, the ICTs agenda has continued to expand into the digitalization of agriculture (digital agriculture) programming, where ICT in agriculture, e-agriculture, Mobile-Agri, and big data in agriculture is used to describe the application of ICTs in agri-food systems (see Ajani, 2014; Akullo & Mulumba, 2016; Alabi, 2016). Whatever terminology is used, digital agriculture is at the nexus of intelligent machines and data-driven agriculture, where digits [transmitted as 0s and 1s] direct agricultural activities and practices to optimize operations (Zhang, 2002). Digital agriculture in Africa, therefore, includes mobile-enabled technologies that provide information to farmers to sophisticated automated systems where data-informed commands are given to self-controlled and intelligent devices to carry out activities (Emeana et al., 2020; Olaniyi et al., 2018; CTA, 2019).

Specifically, digital agriculture is the increasing application of digital tools such as mobile phones, robotics, drones, blockchains, cloud computing, and artificial intelligence to generate and manage data and the services and solutions (products that utilize digital tools and systems) for agricultural processes. Digitalization's focus moves beyond the direct deployment of novel digital technologies to include creating services and solutions to overcome diverse agri-food challenges. Hence, development agencies increasingly focus on African agricultural digitalization (Kim et al., 2020). And while digitalization may be promising, the literature on the subject is still scanty, fragmented, and lacks cohesive narratives and critical engagements of potential impacts in the African context.

In this paper, I offer a birds-eye view of the narratives of development agencies on what might be the effect of DA being in Africa while also exposing the anticipations to potential political-economic perspectives to explain why identified effects attained relevance. I show that digitalization is anticipated to provide wide-range benefits to transform smallholder practices, rural livelihoods, and stakeholders' activities across the agricultural value chain; however, the connectivity/digital divide, adoption and scalability, and enabling environment must be ensured. To underline this argument, I use the results to present Seven anticipated effects of DA in Africa while the discussions probe why the themes emerge. The discussion explicitly describes digitalization as an emergent (uncritical) pillar of the African agricultural transformation and highlights who and what drives the digitalization and narratives while moving the discussion forward with two political economy issues to start critical conversations. Three Practical considerations for DA's success in Africa are presented before a conclusion reflecting on the future of digitalization and areas for further research.
2.5 Background

2.5.1 Political economy and technology promotion in agriculture in Africa

Scholars of African agriculture have long employed political economy to discuss how the differential composition of power in African society is shaped and how that, in turn, influences the wellbeing of different groups, including smallholders, rural people and marginalized groups (see Bates, 1987; Bates & Block, 2009). It probes how historical, structural, institutional, and power dynamics of economic activities and behaviours reshape societal structures and processes (Bates, 1987; Boner, 2018; Friedmann, 1993). Specifically, the class (re)structuring processes and power dynamics within Africa's agricultural development is of concern. Within such discourse is how technology diffusion and interventions emerge and their consequential influence on diverse peasants and smallholders' socio-economic conditions (Nyantakyi-Frimpong & Bezner Kerr, 2015; Shilomboleni, 2020). Central to the literature are the strong critiques of technology diffusion processes in the region, primarily through the attempts to propel a “Green Revolution for Africa” by prescriptions of biotechnology, fertilizers, and high-yielding seeds. Critiques argue that agricultural technologies are promoted to serve neoliberal agendas' economic and political interests without considering their potential adverse impacts (Braimah et al., 2017; Schurman, 2017; Vercillo et al., 2015). The literature on the political economy of agricultural technologies in Africa is enormous (see, for example, Berhanu & Poulton, 2014; Nyantakyi-Frimpong & Bezner Kerr, 2015; Scoones & Thompson, 2011); any attempt to fully engage such literature would amount to duplications without adding value to this paper. Hence, I focus on why the approach is appropriate for discussing digitalization's early narratives.

First, as already mentioned, political economy is extensively used in understanding agricultural dynamics in agrarian societies, including in Africa (Bates, 1987; Birner & Resnick, 2010). Hence, applying it to digitalization builds on an earlier analysis of agricultural change in the region. Secondly, because of its ability to critically engage processes, political economy offers a more in-depth analysis of why and how interests interact for certain things happen the way they do and their potential impacts on social structures (Boner, 2018). Thus, adopting a political economy lens will allow examining the motives behind narratives identified while contemplating the possible consequences of such descriptions and their supporting interventions. Likewise, it will allow for injecting much-needed critical perspectives into early discussions of agricultural digitalization in Africa.
2.5.2 Context: Overview of digitalization in African agriculture

Digital agricultural tools, described as a part of disruptive Agri-technologies (Kim et al., 2020), are increasingly evident across agriculture in Africa. Though their spread has been uneven, Kenya, South Africa, Nigeria, and Ghana boast the region's highest disruptive digital agricultural services (ibid). Digital agriculture in Africa is characterized and driven mainly by private actors, from small start-ups (e.g. Trotro Tractor in Ghana) to large multinational corporations (e.g., Microsoft’s Farmbeats, Alibaba) that provide multiple solutions within single platforms (Birner et al., 2021)

According to the CTA (2019), one of the leading development agencies for digital agriculture in Africa, there were more than 390 digital agricultural service providers in Africa in 2019, with over 70 percent established in the last decades. By January 2020, the GSMA AgriTech programme tracked 437 digital agricultural services in Sub-Saharan Africa (GSM Association, 2020a). A World Bank scoping of the sector identified four critical drivers of digitalization (among others) in Sub-Saharan Africa: “(1) low-cost and pervasive means of connectivity, (2) adaptable and more affordable tools, (3) advances in data analytics and exchange, and (4) increasing demand for contextualized agricultural solutions”(Kim et al., 2020, p. xiv). However, the increasing availability of mobile phones and internet services are the main drivers, especially in rural Africa. In Sub-Saharan Africa, despite the digital divide and inequalities within and among countries, mobile and internet penetration is growing steadily. According to the GSMA (2020b), in 2019, mobile subscriptions were about 477 million (accounting for 45% of the population), increasing from about 37 million in 2015. This penetration is expected to reach “reach half a billion subscribers in 2021 and 50% subscriber penetration by 2025”. Likewise, smartphone adoption is rising rapidly in the region, and will reach 50% of total connections in 2020 —cheaper devices are expected to double penetration in the next five years (ibid). Hence, by 2019, the various digital services were estimated to have covered more than 33 million smallholders (Technical Centre for Agricultural and Rural Cooperation, 2019). With the wide range of DA services, farmers receive advisory and information services, market linkages, supply chain management services, financial access, and macro agricultural intelligence solutions. The basic unit is leveraging big data to provide information and knowledge to solve some of the long-standing challenges in agriculture in Africa.

2.6 Methodology

This paper is based on document analysis that involves carefully considering a set of documents [printed and electronic] to apply their information to answer specific research questions. It
involves careful reading and interpretation to gain meaning from documents (Bowen, 2009; Wood et al., 2020). I first defined the focus to explore and understand the current narratives on digital agriculture in Africa. I focused this paper on the documents produced by development agencies due to the decisive role and the power of their discourses and activities in shaping the trajectory of digital agriculture in Africa (Babcock, 2015; Emeana et al., 2020; Olaniyi et al., 2018; CTA, 2019). The data were retrieved through a series of steps (see Figure 1) from google, google scholar and other platforms (websites) using specific search terms (see Table 2.1).

**Table 2.1 Search terms**

<table>
<thead>
<tr>
<th>Key terms</th>
<th>+ Africa and/or Sub-sahara Africa</th>
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<tr>
<td>Digital agriculture OR farming</td>
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<td>Digital agriculture OR farming revolution</td>
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<td>Precision farming OR agriculture</td>
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<td>e-agriculture OR farming</td>
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<td>Smart farming</td>
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The search process was targeted and only included documents published by international development organizations or produced through their support; seventy-five documents were retrieved for further consideration through title consideration of search returns. The process was supported by a targeted search for records from websites of known development agencies and NGOs in Africa's digital agricultural ecosystem, including Food and Agricultural Organisation (FAO), CTA, African Green Revolution Forum (AGRF), Alliance for a Green Revolution in Africa (AGRA); World Bank; USAID, DFID, GIZ; and CGIAR. An additional ten documents were added through this process. Of the 85 documents thoroughly read for inclusion, 46 articles met the inclusion criteria of being 1) published from 2010; 2) in English; 3) addressed newer spectrums of digital agriculture conceptions rather than just older ICTs in agriculture rhetoric 4) and 5) directly addressed digital agriculture in Africa or spoke to digital agriculture broadly concerning Africa (see Appendix X). The documents were supplemented with information from websites from identified development agencies driving Africa's digital agriculture ecosystem. All papers included in the review were available online.

However, the limited availability of agency-produced documents from Africa on the web could affect this review. Likewise, the biases of the researcher and the available records online could favour specific types of digital technologies in this analysis. Also, since the researcher seeks to explicitly assess digital technologies broadly (emphasizing the direct usage of newer terminologies of digital, smart, precision, etc.), earlier ICTs interventions that implicitly refer to digital processes could be excluded. Likewise, using only available online documents could exclude certain narratives unavailable in web sources.
Figure 1 The document review process

<table>
<thead>
<tr>
<th>Establishments of research question</th>
<th>Research question created from preliminary knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>what might the effect of DA be in Africa</strong></td>
<td><strong>what might the effect of DA be in Africa</strong></td>
</tr>
<tr>
<td>Google scholar key word search N= 145</td>
<td>Google search N= 86</td>
</tr>
<tr>
<td>Records from other sources N= 23</td>
<td></td>
</tr>
</tbody>
</table>

Total Records n= 254

Title consideration for relevancy and duplicate exclusion N= 76

Reference list search + Relevancy Exclusion & duplicate exclusion n=9

Full text examined for inclusion N= 76+9=85
Retained documents for coding=46

Thematic coding

<table>
<thead>
<tr>
<th>Exclusion criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Published in last decade</td>
</tr>
<tr>
<td>Addresses ICTs with inclusion of newer technologies</td>
</tr>
<tr>
<td>Specific to digitalization in Africa or partly speaks to subject</td>
</tr>
</tbody>
</table>

| Thematic coding of themes emerging |

Figure 2.1 Document review process

Retrieved documents were uploaded to Nvivo 12 for analysis, using content and thematic strategies. Each document was carefully scanned to draw broader themes, as expected in content and thematic analysis (Vaismoradi & Snelgrove, 2019). A detailed reading followed this process to draw sections about “what impact would digital technology in agriculture have on African development?”. The nodes function in Nvivo 12 was used to code sections in documents. The coding provided the needed information to draw segments and quotes from the documents related to specific themes that echo discourses around digital agriculture. Each node was later reviewed and harmonized to remove duplications while combining nodes with similar issues. Two broad themes of anticipatory benefits and practical considerations with many sub-themes under each category emerged from the data review. The approach allowed for emphasis on the contents of the documents and the presentation of what is implicitly or explicitly said about the digital transition (Assarroudi et al., 2018) in Africa. The thematic analysis allowed for drawing out key areas and topics evident in the literature (Nowell et al., 2017; Vaismoradi & Snelgrove, 2019).
2.7 Results

The results present the narratives of the expected effects of digitalization in Africa. The section outlining the seven key impacts of digital agriculture and their pathways to change (See Table 2.2 and Supplementary Table 1 for details) on African development as revealed through the document analysis.

2.7.1 Key expected effects of digitalization in Africa

The seven fundamental thematic areas on how digital agriculture will affect development in Sub-Saharan are presented in Table 2.2.

Table 2.2 Anticipated benefits for digital agriculture transformations

<table>
<thead>
<tr>
<th>Expected effects/impacts</th>
<th>Supporting quotes</th>
</tr>
</thead>
<tbody>
<tr>
<td>I DA will bridge agricultural information and knowledge gaps</td>
<td>“Key benefits of digitalization include greater access to information…..””①</td>
</tr>
<tr>
<td>II DA will lead to productivity gains and greater on-farm efficiencies</td>
<td>“For farmers, they offer access to tailored information and insights that allow individuals to optimize their production…..””⑦ P5</td>
</tr>
<tr>
<td>III DA will lead to food and nutritional security in Africa</td>
<td>“One of the greatest opportunities for increasing agricultural productivity globally is marrying plant science with improvement in farming practices through precision agriculture””⑧ p1</td>
</tr>
<tr>
<td>IV DA will facilitate Climate change/ environmental sustainability and resilience</td>
<td>“Precision farming New digital technologies can also help make farming more sustainable and productive.””③</td>
</tr>
<tr>
<td></td>
<td>“Increased access to and adoption of new technologies can address the challenges of food insecurity from multiple fronts, including increasing access of households to non-farm income and enabling households to better gauge the safety, quality, and nutritional value of their food””④ p135</td>
</tr>
<tr>
<td></td>
<td>“E-agriculture can increase food and nutrition security and food production and processing by managing information flow, data gathering and analysis,””⑤ p5</td>
</tr>
<tr>
<td></td>
<td>“D4Ag has likely already helped reduce some effects of climate change by improving resource use (e.g., soil and water conservation due to advisory services), building resilience (e.g., via digitally-enabled agri-index insurance) ….””⑥ p7</td>
</tr>
</tbody>
</table>

① BYTE BY BYTE-Policy Innovation for Transforming Africa’s Food System with Digital Technologies:


③ Digital and data-driven agriculture: Harnessing the power of data for smallholders: https://hdl.handle.net/10568/92477

④ Digital and data-driven agriculture: Harnessing the power of data for smallholders: https://hdl.handle.net/10568/92477

⑤ Digital and data-driven agriculture: Harnessing the power of data for smallholders: https://hdl.handle.net/10568/92477

⑥ Digital and data-driven agriculture: Harnessing the power of data for smallholders: https://hdl.handle.net/10568/92477

⑥ Digital and data-driven agriculture: Harnessing the power of data for smallholders: https://hdl.handle.net/10568/92477

⑦ Digital and data-driven agriculture: Harnessing the power of data for smallholders: https://hdl.handle.net/10568/92477

⑧ Digital and data-driven agriculture: Harnessing the power of data for smallholders: https://hdl.handle.net/10568/92477

⑨ Digital and data-driven agriculture: Harnessing the power of data for smallholders: https://hdl.handle.net/10568/92477

⑩ Digital and data-driven agriculture: Harnessing the power of data for smallholders: https://hdl.handle.net/10568/92477
“Farming communities and others involved in agriculture have to adapt agriculture to climate change and other challenges. In this context, ICT-driven tools and technologies to enhance decision making through accurate, reliable and timely information have an important role to play.”

“V DA will create employment opportunities and empower youth”

“The Internet offers concrete hopes for innovation and prosperity and when applied to agriculture may free the sector of its stigma - drudgery and poor income prospects and make it more attractive for young people.”

“VI DA will facilitate gender and women empowerment in agriculture”

“Women play a core role in agriculture but underperform in terms of productivity largely because they lack access to resources such as finance, skills training, and information services. Mobile technology could bridge this gap, helping to: … Increase productivity and incomes of rural women and their households • Empower rural women in their households and communities and • Improve livelihoods overall for underserved communities.”

“VII DA will ensure rural livelihood improvements and resilience”

“A growing body of evidence highlights the potential of digital technologies to improve the lives of poor people.”

2.7.1.1 DA will bridge agricultural information and knowledge gaps

One-way digital agriculture is expected to affect development pathways, and processes in Africa is through the provision of “…. accurate, timely, and location-specific price, weather, and agronomic data and information…. “

A cross-cutting issue is bridging the information gaps and increasing access to valuable agricultural knowledge, including the CTA and FAO documents. As digital agriculture produces and relies on quality data to gather information, it is anticipated to improve decision-making, enhance practices, enable innovative services, and enrich communication amongst sector stakeholders. For instance, “mobile-based advisory services can provide much-needed information on agricultural best practices, market prices and weather forecasts.” Specifically, mobile advisory services (e.g., Arifu, Farmline; Zowasei, Usomi, FARMsmall, ESOKO, Lima Links, etc.) provide farmers with agronomic advice and other


11 the gisma women global development alliance is a programme: https://www.gsma.com/mobilefordevelopment/wp-content/uploads/2014/06/Women_in_Agriculture-a_Toolkit_for_Mobile_Services_Practitioners.pdf


information, are central to enhancing practices and overcoming some structural barriers to agriculture in the region\textsuperscript{14}.

However, the mere presence of services and information cannot guarantee access and usage among smallholders, as adoption is equally critical for any impact. Likewise, socio-cultural beliefs may undermine the value of digital information because farmers are likely to be indifferent to new knowledge and practices emanating from digital tools. Smallholders are also likely hindered in accessing digital information due to socio-economic and institutional conditions, for example, lack of access to mobile phones.

2.7.1.2 DA will lead to productivity gains and greater on-farm efficiencies

Stakeholders like CTA, FAO, AGRA and World Bank all consider digital tools, services and solutions as the levers to change farming and agriculture towards more productive practices. For instance, precision farming, a variant of digital agriculture that aims to use the right inputs at the right time, is presented as essential “for smallholder farmers in West Africa to enhance crop productivity.”\textsuperscript{15} by minimizing decision errors. Specifically, all development actors believe that offering farmers tailored agronomic advice and connecting them to inputs through digital tools would propel efficiencies across different farming models.

However, the narratives also contemplate the current shortcomings in achieving the needed productivity change. The inability to prove the benefits of digital tools to farmers hinders their use and potential application of agronomic advice. Likewise, any discussions of productivity must include the ability of smallholders to utilize digital tools and create digital solutions that are sensitive to the specific needs of the diversity of farmers in Africa. The power of digital tools to create such efficiency impacts also depends on providing smallholders the needed structural and capacity supports to appreciate and perform digital farming fully.

2.7.1.3 DA will lead to food and nutritional security in Africa

Digital agriculture is also presented as a pathway to ensuring food and nutritional security in Sub-Saharan Africa by producing more food and increasing people's access to healthy foods. Sub-Saharan has been the most food-insecure region globally in the last decade. One approach where organizations, for example, AGRA, find value in mitigating the situation in the area is through digital


\textsuperscript{15} Highlights From The West African Forum On Precision Agriculture: https://www.apni.net/2020/06/29/highlights-from-the-west-african-forum-on-precision-agriculture/
technologies. The 2019 African Green Revolution Forum annual meeting was themed: “Grow
digital: Leveraging digital transformation to drive sustainable food systems in Africa.”¹⁶ The theme
and conversations that ensued during the program underscore the anticipated role of digital
technologies in promoting food security in Africa. Also evident in this narrative is the impression that
“improved access to health and nutritional information through digital technologies would contribute
to the reduction in the prevalence of hunger amongst the poor”¹⁶, p.135. For example, Nutrition
programs — mobile-based delivery of food and nutrition information to households have been used in
some parts of Ghana and Tanzania to promote food and nutritional behavioural changes (see also
Barnett et al., 2019).

The ability of digitalization to promote food security may have some merit, but such claims
could undermine the different experiences of food insecurity in Africa. The causes of food insecurity
on the continent are far and wide, including poverty, climate change, wars, and policy failures.
Hence, claims of digitalization promoting food security, though partly true, appear reductionist and
may obscure some of the actual drivers of the phenomenon.

2.7.1.4 DA will facilitate Climate change/ environmental sustainability and resilience

Climate change resilience and environmental sustainability are anticipated effects of
digitalization in African agriculture. As the World Bank’s “Scaling Up Disruptive Agricultural
Technologies in Africa” report Error! Bookmark not defined., p.8 puts it; digitalization would “improve
farmers’ decision-making through accurate, timely, and location-specific price, weather, and
agronomic data and information that will become increasingly important in the context of climate
change.” Likewise, the “Data-driven solutions for Africa: Using smart tools to combat climate
change”¹⁷ reports outline the many ways digitalization will respond to climate change, including
digital imaging tools delivering stress-tolerant maize faster and for less, disease tracking and
response, bringing the data revolution to smallholder farmers, and making use of digitized genetic
diversity (p.3). Precision-based technologies like drones, satellite systems, AI, and mobile advisories
are central to the climate and environment narrative.

However, limited coverage of current precision interventions limits any meaningful
judgements of this claim. Also, while digital technologies could help smallholders and rural people

¹⁶ Leveraging Digital Transformation To Drive Sustainable Food Systems In Africa: 2019 Summit report
¹⁷ Data driven solutions for Africa Using smart tools to combat climate change:
https://repository.cimmyt.org/bitstream/handle/10883/20205/60822.pdf?sequence=1&isAllowed=y
adapt to changing climate, discussions must be situated on the local challenges driving unsustainable smallholder practices, such as declining soil fertility and traditional beliefs.

2.7.1.5 DA will create employment opportunities and empower youth

With about 40 percent of Africa’s teeming youth engaged in agriculture (Sakho-Jimbira & Hathie, 2020), digitalization is expected to offer “an opportunity for Africa to leverage its youth bulge” (Error! Bookmark not defined. P. 5); because ”D4Ag solutions bring clear benefits, some of which are particularly relevant to youth” (Error! Bookmark not defined. P. 114).

The many youth-based projects, primarily supported by some development agencies, show the anticipations intersecting youth, agriculture, and ICTs in Africa. For instance, The African Green Revolution Forum and partner organizations established Generation Africa to ”strengthen the ecosystem that supports agripreneurship,” particularly for youth (p.31). Youth digital solution competitions like GoGettaz and Disruptive Agricultural Technology (DAT) Challenge and Conference are further testament to the anticipated youth employment and empowerment effects of digital transformation in Africa.

However, countries may still face challenges attracting the youth into primary agriculture without government support and engagement. Youth interest in agriculture may be rising, partly from the application of technologies, but claims of development actors must not be detached from poor internet access telecommunication networks in much of rural Africa. Likewise, the low education due to decades of inaction in rural areas may also limit the ability of rural youth to avail themselves of the opportunities of digitalization.

2.7.1.6 DA will facilitate gender and women empowerment in agriculture

With women being central to agriculture in Africa, digital technologies are anticipated to empower women and help bridge gender gaps that characterize agriculture in Sub-Saharan Africa. In a recent piece by the Head of Gender and Inclusiveness at AGRA, she noted that “What had previously been a growing but limited shift towards the use of digital tools and technologies for food production and business has become a lifeline in the face of market restrictions, food insecurity and lockdowns. And among the biggest winners have been women” (21). She added that the pandemic had driven the number of African women using digital services, including social media, to about 90%. Therefore, digital agriculture has the potential to ‘level the playing field for women in Africa’ with opportunities

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19 GoGettaz is an agripreneurship program that allow Africa’s brightest youth to present agribusiness ideas that combine ‘technology, innovation and passion’ to food—https://vc4a.com/gogettaz/2020/
for empowerment and inclusively. The sentiment in the piece is evident in the development community, with AGRA and GSMA highly optimistic about the prospects to help overcome some of the gender barriers that limit women's access to productive resources like markets, finance, mechanization, and land.

Nonetheless, the ability of digital tools to empower women will depend on the specific local context in Africa. For most parts, gender gaps are culturally driven, and access to digital services would likely be influenced by similar factors. Hence, the empowerment potential of digital tools must be rooted in cultural conversations rather than treating digital tools as given. Women's access to mobile phones and education (ability to use phones) would be critical in any such discussion.

2.7.1.7 DA will ensure rural livelihood improvements and resilience

The narratives have argued that digitalization could provide an impetus for rural livelihood transformation. The increasing access to digital tools and information for the rural poor is viewed as a step toward opening more livelihood opportunities, including improvements to rural finance schemes through mobile payment systems. Likewise, targeted information could help rural people make effective decisions to cope with economic and environmental changes that affect their livelihoods while also allowing for diversification of rural economic activities. Digitalization may become a pathway to raising rural incomes and reducing poverty by opening opportunities with new services and access to information. Early examples of digital farmer advisory services documented by the “Digital Agriculture in Africa Report” are already making inroads in this regard. However, such effects may vary across regions and classes in rural Africa. The impact of digitalization on rural poverty could be uneven; hence, discussions need to be situated on how such effects will affect different groups, such as women, peasants, illiterates, youth, and other marginalized classes.

2.8 Discussion: Digitalization as an (uncritical) emergent extension of the African Green Revolution?

In agriculture, investments in digitalization could be a game-changer in boosting productivity, profitability, employment, resilience to climate change, and COVID-specific responses. A digitally enabled agricultural transformation could help achieve meaningful livelihood improvements for Africa’s smallholder farmers and pastoralists. It could drive greater engagement in agriculture from women and youth and create employment opportunities along the value chain. All this is driven by the fact that digitalization for agriculture has the potential to enhance efficiency, inclusiveness, and risk reduction in a combined way.23

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23 [https://sav.org/assets/explore/download/Overview%20of%20D4Ag%20Sector.pdf](https://sav.org/assets/explore/download/Overview%20of%20D4Ag%20Sector.pdf)
The extract above encapsulates the anticipated impacts of digitalization revealed in the results. Development stakeholders, irrespective of their area, focus on how digitalization could solve some of the challenges in their areas of interest, such as “the agricultural knowledge gap, lack of access to finance, lack of access to markets and climate change.” (GSM Association, 2020a, p. 14), food insecurity, and empowerment of women. Due to these agencies' change and impact focus, the documents reviewed show commonalities primarily in outlook rather than conversations around diverse effects or local political-economic considerations. Thus, development agencies are convinced that "Nowhere is the potential of disruptive technologies [including digitalization] in agriculture more promising than in Sub-Saharan Africa… " (Kim et al., 2020). In fact, “digital, data-driven and tech-enabled solutions” are thought to have the ability to “trigger a new green revolution for Africa.”

Thus, the potential effects of digitalization, as presented in the narratives, extend and entrench the pro-poor Green Revolution rhetoric of "technology saviourism" in Sub-Sahara, which has earlier resulted in mechanization, biotechnology, hybrid seeds, synthetic fertilizers, and later ICTs promoted to overcome these longstanding challenges under the pretext of a ‘new Green Revolution for Africa’ (Dawson et al., 2016; Nin-Pratt & McBride, 2014; Vercillo et al., 2015). This technocratic outlook by agencies is also evident in the vast literature on ICTs and emerging scholarship on digitalization in Africa. Hence, digitalization in Africa continues the path of the Green Revolution for Africa, at least in rhetoric. However, the potential for digitalization to entrench green revolution outcomes is still debated in the literature. Weersink et al. (2018) suggest that DA is fundamentally different from the Green Revolution in that at some point, it will allow for the management of individual plants/animals in near real-time. Hence, Weersink argues that DA and GR are fundamentally different types of technology in that one scales up and out (GR) while the other (DA) scales down and in. By contrast, Clapp and Ruder (2020) argue that power, money, and politics mean that the same dynamics will play out with the DA revolution, as did the Green Revolution. In the absence of a different policy regime, they think that the negatives of the GR are bound to repeat themselves. Understanding the narratives of digitalization could help extend these debates and provide inroads to engaging and perhaps resolving them.

### 2.8.1 Who and what drives agricultural digitalization and narratives?

The neoliberal incursions into the food system and political-economic perspectives offer a starting point to unpack the drivers of the optimistic technocratic effects surrounding digitalization. The narratives' technological saviorism exhibits neo-liberalization traits that have engulfed agri-food

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systems in the last three decades (Busch, 2010; Carolan, 2018; Moseley et al., 2015). Four emerging features direct to this conclusion: 1) The limited engagement of governments in the African digital agriculture space, 2) allows for enthusiastic interest from multinational corporations, donors, and philanthropies who take lead roles, financially and technically, to 3) support plethora of private technology services providers and new actors to emerge in the agri-food system. Thereby 4) integrating smallholders into neoliberal market structures through digital platforms and services.

As the World Bank noted, “the key institutional investors in Sub-Saharan Africa are a mix of venture capital and development partners and include the International Finance Corporation (IFC), the Meltwater Foundation, Ahl venture partners, the Global System for Mobile communications Association (GSMA), and the US Agency for International Development” (Kim et al., 2020, p. 23). Thus, digital technologies are predominately dominated by private and corporate actors and agribusinesses, supported by international development entities (see Birner et al., 2021 for extensive discussion on this). For example, in 2019, Google established the first AI lab in Ghana, with agriculture analytics a central piece of their work.²⁵ Microsoft cooperation has also entered the space with Microsoft’s Farmbeats in Kenya. Likewise, Chinese e-commerce giant Alibaba is noted as one of the big players to look out for in Africa's digital agriculture ecosystem, and so are IBM and John Deere International (CTA, 2019). These entities extensively shape the said narratives and entrench the set of ‘self-evident truths’ of their neoliberal values that promise transformations and efficiencies to smallholders and rural people. Hence, the emergence of these positive-spin themes is not surprising because development agencies and agribusinesses have worked in these areas (e.g., food security, women empowerment, livelihood resilience, etc.) with support from donors for decades, carrying the same rhetoric of transformations and continually are likely to appropriate innovations in ways that further their interests and activities around the issue areas. More importantly, these issue areas appeal to aid and donors in African development and poverty reduction. Thus, as with the older GR rhetoric, the romanticized framing of digitalization as pro-poor allows it to gain legitimacy in the development circles (Ignatova, 2017). And with legitimacy comes entrenchment of the activities and interests of influential international and local proponent organizations that drive such activities in Africa.

Also, the digitalization of agriculture sits well within older donor-driven (e.g. World Bank) national digital economy interventions in Africa (see African Union Commission & OECD, 2021; Azu et al., 2021; Korovkin, 2019). For most parts, these initiatives, such as the World Bank-supported African Digital Economy Initiative, moved to digitally enable people to ensure access to services (World Bank, 2021) and allow governments to generate revenues. Digitalization of

agriculture sits within such initiatives, showing more similarities than differences to such efforts. For instance, Bill Gates, a lead sponsor of the African Digital Thinking Initiative, expressed that, like other sectors, digitalization “might also bridge the gap between the formal systems of commercial agriculture and urban food markets, and the informal systems surrounding smallholders and rural trade26 p.90.

Agricultural digitalization follows plans to formalize smallholders like earlier digital interventions in finance. The creation of digital identities for the smallholder, mostly the first step to digitalization, could be viewed as an avenue to bring out-of-reach smallholders into formal systems, thereby increasing their access to services. Such identities are presented as pathways to bringing support to smallholders, but they could also be leveraged -maybe in future- as revenue engines. However, the private drive of agricultural digitalization—thus far—also makes this new strand of digital economy different from the older efforts because the goal of such entities is mainly to make a profit through competitive service provision rather than purely taxation purposes. Nonetheless, putting private actors at the centre of digitalization furthers the declining rural agricultural finance and government disinvestment shaped by the shifting interest of crucial actors (Odusola, 2021). Such disinvestments put smallholders at the mercies of agribusinesses, resulting in African states’ declining roles in providing public goods.

2.8.2 Two political-economy areas to start critical conversations?

While the transformations, optimism and saviorism in the narratives are valid, to some extent, as Scoones and Thompson (2011, p. 14) argue, such technological interventions are unsustainable “without addressing the politics of innovation – and with it, the interests, values and choices that drive agricultural technology research and development.” Elsewhere, such optimistic yet tilted narratives surrounding the digitalization of agriculture have birthed a young but growing body of scholarship on the potential social implications of digital technologies -- but primarily focused on the global north (see Carolan, 2018, 2020; Fraser, 2018; Rotz et al., 2019). This work emphasizes the urgency to explore the more significant political, economic, ecological, and material motivations and interests that shape technological interventions, including digital agriculture. Hence, I draw on this scholarship to open discussions in two areas for potential political-economy considerations of digitalization in African agriculture.

First, it is essential to question the power dynamics that may emanate from digitalization in agriculture. As already mentioned, agricultural digitalization in Africa is driven by private entities (see Birner et al., 2021), with support from external actors. While the narratives position these neoliberal incursions positively—as opportunities for investments1,2—critical questions on their impacts on smallholders and rural economies’ survival must be asked. As corporate entities take the lead in app creation and knowledge generation, the digital space may impose external knowledge that could potentially threaten local knowledge structures and the power they engender. As earlier technologies (seeds, agro-chemicals) have shown, a lack of critical examination could entrench corporations’ power and expose smallholders to the rigours of the neoliberal market system (Amanor, 2009; Moseley et al., 2015). Hence, market-oriented digitalization, as evident now, could deepen the neoliberal markets induced agrarian crises in Africa as farmers’ dependencies on external actors for knowledge and resources expand. Hence, it is critical to ask questions on how the digitalization of agriculture will re-shape knowledge-defined power structures in rural smallholder systems.

Secondly, digitalization may also raise concerns about the potential for class (re)structuring associated with technology diffusion. As Bernstein (2010) noted about class formation, introducing new resources (e.g. inputs) into agrarian systems is primarily influenced by the power of access regarding rights of ownership, distribution, utilization, and control. Hence, as with earlier GR technological diffusion, uneven impacts of DA on farming models, rural/urban areas, cropping systems and genders groups would potentially create new layers/classes of “haves” and “have-nots.” The adoption, scaling, and sustainability of services in the region are still limited by many barriers, including resistance to change (see Duncombe, 2018; Emeana et al., 2020; Hidrobo et al., 2020). Part of the problem emanates from socio-economic, political, institutional, and cultural barriers that limit certain groups’ ability to benefit from technologies (Juma, 2015). For instance, the GSMA (2019) estimates that Sub-Saharan African women are 15% less likely to use mobile phones than men and 41% less access to and use mobile internet. With mobile phones and the internet at the centre of the digital transformation in Africa, inequalities in access (e.g., across geographies and genders) would undermine the anticipated impacts. Without sensitivities to class differences in rural Africa in the design and implementation of digitalization, benefits risk being exclusionary, a concern already manifesting in this innovation space. For example, although women make up nearly 50% of agricultural producers in Sub-Saharan Africa, early statistics show they constitute only about 25% of the user base of digital solutions in Africa (CTA, 2019). With the high cost and uneven access, digitalization could entrench older classes and add newer classes as people with access enjoy certain exclusionary benefits. The uneven access to technologies, services, and connectivity necessary for an
inclusive future of digitalization in Africa may create unfair disadvantages for specific groups and open class differentiation spaces for some farmer groups.

2.8.3 Three Practical Considerations for the Success of DA in Africa

Despite the strong emphasis on prospects and anticipated benefits, the narratives also clarify that some practical considerations are needed to facilitate the digitalization process. These considerations, when carefully enacted, could help address the political-economic challenges of early digitalization.

First, the digital divide inequitable access to digitalization—must be bridged for digitalization in Sub-Saharan Africa to thrive. The “African Agriculture Progress Report” 2019 emphasized connectivity and the digital divide as one of the three constraints to the continent's digital agriculture future. Many organizations in the digital agriculture ecosystem share the document’s rhetoric, including The Digitalisation in African Agriculture Report, 2018-2019. For example, of the 25 worst-connected nations globally, 20 are in Africa, where only about 22 percent of households in these regions have access to the internet — with scarcity partly accounting for high prices. With such barriers to access, digitalization could disproportionally affect different classes, with the rural population, women, and landless poor likely to be excluded. Hence, efforts to increase access to other groups would be needed to ensure equity of impacts. Bridging the digital divide could make the effects anticipated inclusive to disadvantaged classes. However, some progress is being made: "…Today, more than 1.2 million kilometres of Internet cables run across the oceans' floors, but just 20 years ago, Africa was completely disconnected"p.130. There is a huge potential to leverage the growing internet and the ubiquity of mobile phone penetration mentioned earlier to develop digital solutions to reduce the digital divide and ensure digitalization does not create undesirable class re-structuring.

Secondly, the adoption, scalability, and sustainability of digital solutions are critical to the success of agricultural digitalization in Africa and to making inclusive impacts. In this case, scalable describes the ability of solutions to expand their reach and serve a broader clientele, while sustainability is how services can maintain operations on a long-term basis. Despite the high penetration of digital agriculture in the last decades, the sector is still primarily driven by isolated donor-supported solutions that become hard to sustain after project funds run out. Part of the issue is attributable to challenges in obtaining farmers’ willingness to adopt and pay for digital solutions — after donor-support subsidizations run out. As the CTA reports, "while D4Ag’s reach figures are impressive given the relative nascence of the space, use remains low"p.20. Local
political-economic factors are at the centre of the adoption and scalability challenges. For example, poor network, limited phone usage, illiteracy, and poverty, coupled with skepticism of innovations, continue to undermine the adoption and use of digital tools among many rural smallholders (Etwire et al., 2017; Kim et al., 2020). Hence, tackling this would require addressing local political-economic factors that undermine sufficient proliferation. Specifically, governments and private actors must work together to provide rural education and create opportunities to improve livelihood activities. Such efforts would go a long way to creating classes of people ready to take advantage of digitalization.

Thirdly, and more importantly, an enabling environment that provides the foundation on which digital agriculture will thrive in Africa must be consciously pursued by all stakeholders. The CTA’s Digitalization in Africa report comprehensively describes the essence of this practical consideration:

"The speed and effectiveness at which an agricultural system transforms to become more data- and technology-driven is largely dependent on an enabling institutional environment that allows and encourages data and information to be managed, used, shared and exchanged effectively, equitably and fairly. This environment spans governments, farmers' associations, financial and research institutions, and training centers, policies, regulatory frameworks as well as information and communications-related infrastructure. Crucially, enabling policies are required that allow, and in fact, catalyze investment in the backbone infrastructure that will permit rural populations to overcome their geographic, social and economic isolation" [Error! Bookmark not defined., p.25].

The extract alludes that the enabling environment is needed to cushion the digitalization agenda across scales while maximizing the impacts on rural classes. Identifying the current constraints to enabling digital solutions, policy regulations necessary for digitalization, and structural changes needed for successful digital agricultural solutions is crucial for targeting. Yet, digital solutions and services may find it difficult to sustain operations without an enabling environment in policies, infrastructure, capabilities, and business culture. At the same time, farmers also struggle to avail themselves of services.

The three practical considerations highlighted in the narratives show that the anticipation of crosscutting benefits – which the narratives are heavy on—are not given. Achieving the full potential of digitalization and minimizing the political-economic challenges would require further measures to overcome barriers currently evident in the region.

2.10 Conclusions and Ways Forward

While digital technologies may transform African agricultural and rural areas, introducing these novel innovations entails challenges, limitations, and risks. Hence, through political-economic perspectives, I argue that though the narratives are justifiably optimistic, they uncritically entrench and extend the pillars of the earlier Green Revolution efforts to transform and modernize smallholders without considering the potential power and class re-structuring. Yet, digitalization's
full potential would be unattainable without carefully considering the political-economic implications. Digital agriculture in Africa is at a nascent stage, but it opens a research space in desperate need of critical engagements that explore the dynamics between these novel digital tools and African societal elements, such as smallholder systems, farming life, rural structures, livelihoods, power relations, and economic conditions. Only through such considerations can we unequivocally understand the actual effects of digitalization in the region.

Also, creating an inclusive, enabling environment is critical to reaping digitalization benefits while minimizing the potential risk and inequality concerns. While governments are just beginning to realize the potential for digital agriculture and following that with efforts, their role in the digital transition is almost non-existent (Kim et al., 2020). Without the needed policy and regulations, connectivity infrastructure, and supporting infrastructures like transportation, the potential unequal consequences on underserved groups, such as women, youth, and rural smallholders, cannot be minimized. Such an enabling environment would also help the private sector fully take advantage of the emerging opportunities. Likewise, it could reduce the current fragmentation and limited scalability and sustainability in the industry characterized by infant start-ups whose desperation to survive make them susceptible to corporate control and half-baked solutions insensitive to user needs. Smallholders, who form most African farmers, must be actively centred on creating the enabling environment and the solutions and services across the scale.
2.11 References


Berkeley, California, United States


https://doi.org/10.4324/9781351316446


http://www.wphna.org/htdocs/downloadsmay2012/Harriet%20Friedman%20The%20Political%20Economy%20of%20Food%20pdf.pdf


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3.0 Is agricultural digitization a reality among smallholder farmers in Africa? Unpacking farmers' engagement in rural Ghana

3.1 Preface to Chapter Three

This chapter, a standalone manuscript, addresses Objective 2 by presenting empirical insights on how rural farmers engage with digitalization in Ghana. In Chapter Two, I highlighted the narratives of development actors, who I argue are the main drivers of agricultural digitalization in Africa. My political-economic analysis of the narratives resulted in my call for critical attention to structural issues associated with digitalization. To attain this goal, I further emphasized the need to understand digitalization dynamics at the local level to provide a foundation assessment for political-economic considerations. Hence, this paper answers Chapter Two's call by exploring the digital tools and services different farmers are likely to access and engage within their contextual realities.

With a focus on digitalization within the rural African context, Chapter Three empirically assesses the nature of smallholder digitalization and how farmers engage with the phenomenon. The Chapter provides a practical assessment of what digitalization is like for rural farmers and how farmers interact with the phenomenon through their services. I used the empirical data of 1565 smallholder farmers surveys in Northern Ghana to ask if digitalization was a reality among rural farmers. To answer this question, I propose a simple framework for understanding smallholder engagement with digitalization by assessing how farmers I) use digital tools and II) how farmers participate in available digital services

The results presented in this chapter reveals that farmers' use of digital tools and services is limited. Despite the hype and relatively positive perceptions about digitalization services, many farmers are not engaged with the phenomenon. Farmers' engagement with digital services is limited as the results show low participation and continuous use of services(activness of usage). Notably, farmers turn to discontinue usage of digital services when free or discounted offerings by development NGOs elapse (Hidrobo et al., 2021; Palloni et al., 2018). Likewise, The results show that farmers cannot fully participate in digitalization due to their limited competencies, low education, digital illiteracies, and lack of access to essential digital resources. Hence, scaling or sustaining digital services for long periods is a daunting task within the smallholder system (Emeana et al., 2020; Kim et al., 2020).
Ultimately, the paper concludes that digitalization in its broadest sense is not a current reality; instead, the transformative digitalization promoted by key organizations is a distant goal within African smallholder systems due to existing weak foundations. Hence, it is critical to circumvent our expectations regarding smallholder digitalization's supposed ‘transformativeness’ and disruptiveness. Notably, the chapter calls for consideration of the contextual realities of digitalization within diverse contexts related to local socio-political-economic structures.

3.1.1 Preface references


3.2 Publication Details

Expected Authorship: Abdul-Rahim Abdulai; Emily Rose Duncan; Phillip Tetteh Quashie; Krishna Bahadur KC, and Evan Fraser. Journal not decided at the time of submission.
3.2 Abstract

Despite the transformational anticipations on agricultural digitalization in Africa, smallholders' engagement with digitalization is underexplored. We surveyed 1,565 rural farmers in Northern Ghana to explore how farmers interact with digital tools and services. Despite the growing array of digital opportunities, smallholder farmers are mainly confined to simple devices (mobile phones, radio and TV) as internet access remains low. NGOs and private-sector projects provide farmers access to digital services delivered through SMS, IVR, radio, or field agents. However, participation remains unimpressive and often fades when projects end. (Low) Participation is affected by the weak building blocks evident in a lack of digital competencies and limited access to resources. Thus, full-scale digitalization remains a distant goal, and transformation claims are disconnected from smallholders' lived realities. However, opportunities exist to create a ‘digitalization for smallholders’ that is sensitive to the structural limitations, including low literacy and limited access to digital tools.

Keywords: Digitalization; rural; smallholders; digital services; digital agriculture; Africa

3.3 Introduction

Digitalization of agriculture is a growing phenomenon worldwide and among diverse scales of farmers (Duncan et al., 2021). In Sub-Saharan Africa, digitalization is proclaimed as a “game-changer” pathway to transformation for farmers and communities (Agyekumhene et al., 2018; Atanga, 2020; Etwire et al., 2017). Hence, rural farmers across the region are being inundated with digital tools and services, including mobile-enabled advisories, precision agriculture services, and big data-enabled services (Kim et al., 2020; Tsan et al., 2019). At the end of 2019, there were about 390 digital agricultural solutions (products and services that use digital systems to aid any form of farming activities) in Africa (Tsan et al., 2019), and over 437 tracked by the GSMA AgriTech by January 2020 (GSMA Association, 2020a). Meanwhile, the ubiquity of mobile phones and growing access to the internet in Sub-Saharan Africa continue to create opportunities for farmers to engage with digital services. Mobile subscriptions in Africa reached 477 million (about 45% of the population) in 2019, rising from 37 million in 2015. And the reach is expected to cover half a billion in 2021 or 50% penetration by 2025. Likewise, smartphone adoption reached 50% of total connections in 2020 (GSM Association, 2020b). This access to digital technologies across the continent lends itself to growing digital opportunities for farmers. Although we have evidence of
mobile and internet technologies penetrating rural Africa, amid farmers’ use of digital services (GSM Association, 2020b; Tsan et al., 2019), the full extent of digital penetration and engagements, specifically regarding food and farming is unknown.

This paper offers insight into rural farmers’ experiences and attitudes toward digital tools and services in Ghana. Specifically, we ask the following questions? 1) what are the characteristics of farmers who use digital agricultural services in Northern Ghana? 2) how do these farmers interact with digital agricultural services? 3) what digital hardware/tools are the smallholder farmers using? 4) what are the characteristics of the farmers who use these tools? 5) how do smallholder farmers perceive digitalization in Ghana? Through these questions, we show that farmer engagements with digitalization are minimal and driven mainly by NGOs rather than the deliberate drive of farmers. Our research sheds light on the realities of farmers’ interactions with digital tools and services, which will allow policymakers to situate digitalization discourses and interventions within the context of smallholders. In what follows, we first provide a background to the digitalization of agriculture in Africa. The following section then describes our study context and survey method. The results highlight how farmers use digital tools and interact with services. The discussion then describes digitalization as a nascent yet distant phenomenon in Sub-Saharan Africa. The conclusion reflects on the results – and calls for the sensitivity of digitalization efforts to the realities of rural farmers and African people.

3.4 Background

3.4.1 Digitalization for agriculture in Africa

Digitalization of agriculture encompasses applying digital tools and systems to aid agriculture practices and processes (Duncan et al., 2021; Green et al., 2021; Tsan et al., 2019). The increasing availability of mobile phones, the internet, and emerging technologies such as big data analytics, blockchain, drones, satellite imagery, AI, machine learning, and remote sensing mean that new tools are being integrated into farming systems (Bergvinson, 2017; Wolfert et al., 2017). In practice, these innovations are applied directly to farm production systems (for example, the use of drones for spraying chemicals) or leveraged to create services to solve farming challenges (for example, blockchain-driven traceability solutions or mobile weather advisories) (Deutsche Gesellschaft für Internationale Zusammenarbeit et al., 2021). This work thus uses digitalization, digital services, and digital solutions to refer to the broad spectrum of direct and indirect applications of any form of digital technology (hardware, software, or data) to agricultural processes across scales.
In smallholder systems in Africa, digitalization manifests in farmers’ access and use of the various digital hardware/tool, software and services for farming activities. Digitalization may include direct or indirect use of *simple digital devices* (e.g., phones, computers, radios, tablets, etc.) and more *advanced digital hardware* (drone, satellite/GIS, field sensors, machinery sensors, portable soil/crop/input diagnostics precision systems). It also includes leveraging the simple and more advanced digital hardware and software (e.g., data capture tools, field agent management tools, data analytics tools, and blockchain platforms). Likewise, it involves using data (e.g., farmer registries, farmer transactions, soil maps, weather, pest & disease surveillance) to create solutions/services that enhance agri-food processes (Babcock, 2015; Deutsche Gesellschaft für Internationale Zusammenarbeit et al., 2021; GSM Association, 2020a; Tsan et al., 2019). The services and solutions are mainly in two areas: *information or advisories* and *connection/linkages to resources* (input and outputs) (see Figure 3.1).

![Diagram of Farmer’s engagement in digitalization]

**Figure 3.1 Framework for farmers’ engagement with digitalization in smallholder systems**
From Figure 3.1, the mechanisms for farmers’ engagement with digitalization may be extensive and expansive. The penetration and growth of these services vary from large-scale coverage, such as Ethiopia 101 call center with over a million users, to isolated pilot projects implemented in a few communities within countries. And the trend is only expected to grow as access to the internet, and mobile technologies continue to develop (GSM Association, 2020a). Our interest is in understanding the type of digital tools diverse farmers access/use and how they interact with the services offered in the digital space. Previous research revealed that mobile phone usage remains one of the commonest forms of smallholders' engagement in the digital area. However, the exact ways farmers use their phones in farming activities are not well-understood. Likewise, while we know the existence of various digital agricultural services, little is known about the specific ways farmers use and interact with such services when provided with the opportunity. Thus, it is also critical to understand the true extent of engagement, what they use, how they use them and why they use different tools and services. Hence, we explore farmers’ access and use of basic digital tools as a foundation for smallholder digitalization and how they broadly interact with digital agriculture services.

3.5 Research Setting and Methods

This study is situated in the Northern Savannah of Ghana. Ghana lies within latitude 4° 44'N and 11° 11'N and 3° 11'W and 1° 11'E longitude. Covering approximately 238,500 km², Ghana is bordered by La Cote D'Ivoire to the west, Togo to the east, and extends inland from the southern coast along the Gulf of Guinea to the border of Burkino Faso. Due to the agricultural potential in the area, the region has been the center of agricultural and rural research (Abdulai et al., 2017; A. Abdulai & Huffman, 2000; Kansanga et al., 2018; Nyamekye et al., 2018; Nyantakyi-Frimpong, 2014; Vercillo et al., 2015). Likewise, Northern Ghana has been a testing ground for digital agriculture start-ups and service providers in recent years (see Etwire et al., 2017; Hidrobo et al., 2021, 2021; Nikoi et al., 2016). It is impossible to state the proliferation of these technologies in the area because of the weak government data collection system, highly informal agriculture sector, and the newness of innovations.

Given these limitations, we designed this survey specifically to explore issues of penetration and engagement in the area. A multi-stage sampling technique was applied to recruit survey participants, following earlier studies in the study area (Kansanga et al., 2018; Nyantakyi-Frimpong & Bezner Kerr, 2015). We first selected the Northern Region (the most developed of the five regions)
due to the area's key characteristics outlined earlier and the concentration of digital service providers. We then conducted preliminary research to ascertain districts and communities with digital service experiences. Four districts (Savelugu Municipality, Kumbungu District, Nantong District, and Sagnarigu District) were selected based on the concentration of services, NGO activities, proximity to the capital, and history of service provision. In each district, communities with past or current digital services were randomly selected for the survey.

**Figure 3.2 Map of study communities**

Within communities, the data were collected digitally with the help of trained research enumerators. The survey was conducted with a structured questionnaire (see Supplement 1), capturing farmer characteristics, experiences, and perceptions. Each data collector was assigned to specific communities and distributed to sections in the selected areas on the survey days. The survey participants were randomly chosen at their homes based on availability at the time of data collection and a set pattern of the third household, with the household heads being the primary target. In the absence of the head, other senior household members were surveyed. Generally, the survey included 1565 farmers of diverse socio-economic and farming characteristics (see details in Table 3.1).
Table 3.1 Household and farm-level characteristics of participants

<table>
<thead>
<tr>
<th>Variable (n=1565)</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>38.88</td>
<td>12.98</td>
</tr>
<tr>
<td>Household Size</td>
<td>15.06</td>
<td>8.69</td>
</tr>
<tr>
<td>Farm Size (in acres)</td>
<td>5.81</td>
<td>5.91</td>
</tr>
<tr>
<td>Duration in Farming (in years)</td>
<td>16.61</td>
<td>13.44</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variable</th>
<th>Options</th>
<th>Frequency</th>
<th>Percentage %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>Female</td>
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</tr>
<tr>
<td></td>
<td>Male</td>
<td>948</td>
<td>60.58</td>
</tr>
<tr>
<td></td>
<td>15-24</td>
<td>121</td>
<td>7.73</td>
</tr>
<tr>
<td></td>
<td>25-40</td>
<td>891</td>
<td>56.93</td>
</tr>
<tr>
<td></td>
<td>41-60</td>
<td>440</td>
<td>28.12</td>
</tr>
<tr>
<td></td>
<td>60+</td>
<td>113</td>
<td>7.22</td>
</tr>
<tr>
<td>Age</td>
<td>No education</td>
<td>1080</td>
<td>69.01</td>
</tr>
<tr>
<td></td>
<td>Basic education (incomplete)</td>
<td>243</td>
<td>15.53</td>
</tr>
<tr>
<td></td>
<td>Basic education (complete)</td>
<td>106</td>
<td>6.77</td>
</tr>
<tr>
<td></td>
<td>High school</td>
<td>104</td>
<td>6.65</td>
</tr>
<tr>
<td></td>
<td>Certificates/vocational</td>
<td>12</td>
<td>0.77</td>
</tr>
<tr>
<td></td>
<td>Higher education</td>
<td>20</td>
<td>1.28</td>
</tr>
<tr>
<td></td>
<td>Community lands</td>
<td>148</td>
<td>9.45</td>
</tr>
<tr>
<td></td>
<td>Family Land</td>
<td>386</td>
<td>24.65</td>
</tr>
<tr>
<td></td>
<td>Family property (Livestock)</td>
<td>310</td>
<td>19.80</td>
</tr>
<tr>
<td></td>
<td>Own private land</td>
<td>311</td>
<td>19.86</td>
</tr>
<tr>
<td></td>
<td>Own private (livestock)</td>
<td>402</td>
<td>25.67</td>
</tr>
<tr>
<td></td>
<td>Rented land</td>
<td>3</td>
<td>0.19</td>
</tr>
<tr>
<td></td>
<td>Caretaking for someone</td>
<td>4</td>
<td>0.26</td>
</tr>
<tr>
<td></td>
<td>(Livestock)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Others</td>
<td>1</td>
<td>0.13</td>
</tr>
<tr>
<td></td>
<td>Livestock only</td>
<td>2</td>
<td>0.13</td>
</tr>
<tr>
<td></td>
<td>Mixed cropping (more than one crop)</td>
<td>575</td>
<td>36.74</td>
</tr>
<tr>
<td>Farming system</td>
<td>Mixed farming (both crop and livestock/fishing)</td>
<td>905</td>
<td>57.83</td>
</tr>
<tr>
<td></td>
<td>Monocropping (just one crop)</td>
<td>83</td>
<td>5.30</td>
</tr>
<tr>
<td></td>
<td>Only feeding the family</td>
<td>474</td>
<td>30.29</td>
</tr>
<tr>
<td></td>
<td>(subsistence)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Only For sale (commercial)</td>
<td>14</td>
<td>0.89</td>
</tr>
<tr>
<td></td>
<td>Part for family and part for sales (Semi-commercial)</td>
<td>1077</td>
<td>68.82</td>
</tr>
<tr>
<td></td>
<td>&gt;GHC 1000</td>
<td>1090</td>
<td>69.65</td>
</tr>
<tr>
<td></td>
<td>G HC 1001-2000</td>
<td>248</td>
<td>15.85</td>
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<tr>
<td></td>
<td>G HC 2001-3000</td>
<td>108</td>
<td>6.90</td>
</tr>
<tr>
<td></td>
<td>G HC 3001-4000</td>
<td>62</td>
<td>3.96</td>
</tr>
<tr>
<td></td>
<td>G HC 4001-5000</td>
<td>30</td>
<td>1.92</td>
</tr>
<tr>
<td></td>
<td>G HC 5001-6000</td>
<td>11</td>
<td>0.70</td>
</tr>
<tr>
<td></td>
<td>G HC 6001-7000</td>
<td>5</td>
<td>0.32</td>
</tr>
<tr>
<td></td>
<td>G HC 7001-8000</td>
<td>5</td>
<td>0.32</td>
</tr>
<tr>
<td></td>
<td>G HC 8001-9000</td>
<td>2</td>
<td>0.13</td>
</tr>
<tr>
<td></td>
<td>G HC 9001-10000</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>GH C 10000+</td>
<td>4</td>
<td>0.26</td>
</tr>
<tr>
<td>Income In GHC27</td>
<td>Fulltime</td>
<td>1085</td>
<td>69.33</td>
</tr>
<tr>
<td></td>
<td>Part-time</td>
<td>480</td>
<td>30.67</td>
</tr>
</tbody>
</table>

27 GHC means Ghana Cedis. USD 1= GH C5.9 at the time of the research, June-July 2021
Generally, respondents had a diverse range of socio-economic and farming characteristics. There were more male (60.58%) respondents than females (39.42%). The average age of respondents and duration in agriculture was 38.88 years and 16.61 years, respectively. The average household size was 15.06 people, and most respondents (69.01%) had no education. Roughly 57.83% practiced mixed farming (with crop and animal productions), and 68.82% indicated operating semi-commercially. About 67.35% and 69.39% indicated being a part of some farming association and having access to extension/veterinary services, respectively.

For analysis, data were exported into Excel and SPSS. The two programs were used to analyze the data using various descriptive statistics (counts, means percentages) and chi-square analysis, which was used to determine whether existed significant variations in participation in digital services, activeness of participation, perceptions about services, willingness to join services and various socio-demographic characteristics, including age, gender, duration in farming, membership in associations and access to extension services.

3.6 Results and Findings

As stated in the background section, digitalization encompasses the use of digital tools and services. The results present how farmers engage with digital tools and services per the questions outlined in the introduction.

3.6.1 What are the characteristics of farmers who use digital agricultural services in Northern Ghana?

We measured farmers’ participation through a survey question on the history of engagement with digital services. Participation in services referred to whether farmers had ever been registered and received any form of agricultural digitalization services available in the area. For participation, 70.22% of the respondents had participated in digital services. Participation in our selected communities was limited to mobile climate and agronomic advisory services, radio activities, veterinary services, market connections, and isolated use of social media (WhatsApp). Gender, age, household size, duration in farming, household and farm size, level of education, commercial status,
farming models, income, association membership, and access to extension services were significantly related to participation in digital services. Specifically, participation was highest among males (73%); farmers aged 25-40 years (75%); farmers with basic education (78.60%); practiced mixed farming (89.1%); practiced subsistence (80.4%); earned between GHC6009-7000 (100.00%); fulltime farmers (72%); farmers associated with groups (89.2%); and who had access to extension services (86.4%) (see Table 3.2 and Appendix I).

Table 3.2 Chi-square for farmers participation in digital services

<table>
<thead>
<tr>
<th>Variable (n=1565)</th>
<th>$X^2$</th>
<th>$p$</th>
<th>Cramers V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>8.837</td>
<td>0.003**</td>
<td>0.075</td>
</tr>
<tr>
<td>Age</td>
<td>28.514</td>
<td>&lt;0.001**</td>
<td>0.097</td>
</tr>
<tr>
<td>Duration in Farming</td>
<td>32.531</td>
<td>&lt;0.001**</td>
<td>0.135</td>
</tr>
<tr>
<td>Householdsize</td>
<td>32.531</td>
<td>&lt;0.001**</td>
<td>0.111</td>
</tr>
<tr>
<td>Farm Size</td>
<td>72.779</td>
<td>&lt;0.001**</td>
<td>0.216</td>
</tr>
<tr>
<td>Level of education</td>
<td>20.617</td>
<td>&lt;0.001**</td>
<td>0.115</td>
</tr>
<tr>
<td>Farming system</td>
<td>365.501</td>
<td>&lt;0.001**</td>
<td>0.483</td>
</tr>
<tr>
<td>Commercial status</td>
<td>33.556</td>
<td>&lt;0.001**</td>
<td>0.146</td>
</tr>
<tr>
<td>Income</td>
<td>80.013</td>
<td>&lt;0.001**</td>
<td>0.226</td>
</tr>
<tr>
<td>Business status</td>
<td>5.228</td>
<td>0.026**</td>
<td>5.228</td>
</tr>
<tr>
<td>Membership of association</td>
<td>554.977</td>
<td>&lt;0.001**</td>
<td>0.595</td>
</tr>
<tr>
<td>Access to extension/Vert services</td>
<td>442.488</td>
<td>&lt;0.001**</td>
<td>0.532</td>
</tr>
<tr>
<td>Phone ownership</td>
<td>0.929</td>
<td>0.335</td>
<td>0.024</td>
</tr>
</tbody>
</table>

Chi2 tests indicate differences are statistically significant at 95% when $p<0.05$

The retention and activeness of farmers —which describes whether a farmer with participation was actively engaged with the digital service at the time of the research or had received service in the last year—is also critical in understanding engagement. Retention and activeness is necessary because farmers are sometimes blind beneficiaries without actively using services. Digital services' retention and activeness were predominantly low: Only 31.6% of participating farmers were active or engaged with the digital services in the last year. Retention and activeness varied by farming systems and income from farming (Table 3.3 and Appendix I).
**Table 3.3 Chi-square for farmers retention and activeness**

<table>
<thead>
<tr>
<th>Variable</th>
<th>$X^2$</th>
<th>$p$</th>
<th>Cramers V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>0.761</td>
<td>0.383</td>
<td>0.026</td>
</tr>
<tr>
<td>Age</td>
<td>3.448</td>
<td>0.328</td>
<td>0.056</td>
</tr>
<tr>
<td>Duration in Farming</td>
<td>0.338</td>
<td>0.845</td>
<td>0.18</td>
</tr>
<tr>
<td>Householdsiz e</td>
<td>4.854</td>
<td>0.183</td>
<td>0.066</td>
</tr>
<tr>
<td>Farm Size</td>
<td>1.086</td>
<td>0.896</td>
<td>0.031</td>
</tr>
<tr>
<td>Level of education</td>
<td>8.492</td>
<td>0.131</td>
<td>0.088</td>
</tr>
<tr>
<td>Farming system</td>
<td>22.948</td>
<td>&lt;0.001**</td>
<td>0.145</td>
</tr>
<tr>
<td>Commercial status</td>
<td>0.779</td>
<td>0.678</td>
<td>0.027</td>
</tr>
<tr>
<td>Income</td>
<td>22.384</td>
<td>0.02**</td>
<td>0.143</td>
</tr>
<tr>
<td>Business status</td>
<td>0.052</td>
<td>0.820</td>
<td>0.007</td>
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<tr>
<td>Membership of association</td>
<td>2.069</td>
<td>0.150</td>
<td>0.043</td>
</tr>
<tr>
<td>Access to extension/Vert services</td>
<td>1.147</td>
<td>0.284</td>
<td>0.032</td>
</tr>
<tr>
<td>Phone ownership</td>
<td>0.001</td>
<td>0.980</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Chi2 tests indicate differences are statistically significant at 95% when $p<0.05$

Considering that this research covered projects actively implemented, participation is expected to be lower when only those beyond their implementation period are considered. Many reasons accounted for the low retention of farmers: limited abilities of farmers to engage independently without support, the short-life span of projects that enroll farmers in digitalization, lack of (financial) sustainability mechanisms for projects after completion, and farmers' lack of understanding of projects at initiation or registration. Also, when NGOs or service providers offer digital solutions, they mostly do so for free or at a discounted price—making farmers used to such services. Hence, farmers discontinue usage after services begin to charge fees.

### 3.6.2 How do farmers interact with digital agricultural services?

Most farmers who participated in the services did so primarily by their involvement in NGO projects rather than personal interest in solutions. For example, 21.9% of respondents indicated participating because they were a part of a project that offered the service. Other reasons for participation included being convinced by peers (2.9%) or agents (4.7%) and just trying something new. NGOs implemented digital services to improve farmers' livelihoods, which offered opportunities for farmers to engage. However, farmers who had never participated in digitalization failed to do so due to i) low competencies, ii) high cost of services, iii) poor network in their communities, iv) lack of interest in trying anything new, v) skepticism surrounding service providers, vi) non-participation in community group activities and viii) absence at the time of registration.

Farmers who participated with digital services did so through phone calls, agents, radio, and peers because those mediums required limited skills, unlike social media, SMS, IVR, and phone
apps. Phone calls (95.75%), followed by filed agents (87.44%), peer farmers (87.94%), radio (40.55%), and social media (1.2%), were the primary forms of interactions with digital services. The phone calls involved farmers receiving calls from service providers/agents or placing calls to seek support. The field agents involved service providers using agents, who usually visit communities to interact with farmers. The use of peer farmers, or what we describe as the "point-person model," involved farmers communicating with service providers through lead farmers in their communities. Service providers used the point-person model to extend their reach. For many farmers, the interaction with digital services was need-based and when service providers offered information. Meanwhile, only 12.12% always used services or information when offered, while 87.52% sometimes did so. Hence, utilization of digital information and services was still limited by low literacy (69.01% had no education, see Table 3.1), and consequent inability to read SMS, follow IVRs or use the internet independently (see Table 3.5).

The primary source of information and knowledge about services was NGOs operating within the study area (27.70%), relatives and peers (24.89%), community events (24.25%), and outreach by service providers (12.44%). NGOs and the private sector played a vital role in the digitalization space by implementing projects as part of pro-poor initiatives, which formed the basis of farmers’ experiences. These organizations integrated digital services in partnership with service providers to make agricultural information and knowledge accessible while offering solutions that link farmers to resources, including mechanization, veterinary vaccines, and markets.

### Table 3.4 Chi-square for awareness about digital services

<table>
<thead>
<tr>
<th>Variable (n=1565)</th>
<th>X²</th>
<th>p</th>
<th>Cramers V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>0.935</td>
<td>0.334</td>
<td>0.024</td>
</tr>
<tr>
<td>Age</td>
<td>24.849</td>
<td>&lt;.001**</td>
<td>0.126</td>
</tr>
<tr>
<td>Duration in Farming</td>
<td>5.751</td>
<td>0.056</td>
<td>0.061</td>
</tr>
<tr>
<td>Householdsize</td>
<td>13.988</td>
<td>0.003**</td>
<td>0.095</td>
</tr>
<tr>
<td>Farm Size</td>
<td>28.662</td>
<td>&lt;.001**</td>
<td>0.135</td>
</tr>
<tr>
<td>Level of education</td>
<td>18.307</td>
<td>0.003**</td>
<td>0.108</td>
</tr>
<tr>
<td>Farming system</td>
<td>219.903</td>
<td>&lt;0.001**</td>
<td>0.375</td>
</tr>
<tr>
<td>Commercial status</td>
<td>19.383</td>
<td>&lt;0.001**</td>
<td>0.111</td>
</tr>
<tr>
<td>Income</td>
<td>42.055</td>
<td>&lt;0.001**</td>
<td>0.164</td>
</tr>
<tr>
<td>Business status</td>
<td>21.290</td>
<td>&lt;0.001**</td>
<td>0.117</td>
</tr>
<tr>
<td>Membership of association</td>
<td>354.969</td>
<td>&lt;0.001**</td>
<td>0.467</td>
</tr>
<tr>
<td>Access to extension/Vert services</td>
<td>335.550</td>
<td>&lt;0.001**</td>
<td>0.463</td>
</tr>
</tbody>
</table>

Chi² tests indicate differences are statistically significant at 95% when p<0.05

Awareness of the ongoing digitalization efforts, measured with a yes or no survey question on whether they knew of existing digitalization services in the area, was high among rural farmers in communities: 81.4% were aware of digital services in the region. Farmers' awareness of digital
services significantly varied by age, farm size, level of education, farming system, commercial status, income, membership in associations, and access to extension services. Particularly, the following groups of farmers were more likely to be aware of digital services in the area: farmers with less than five acres (85.0); higher education (90%); subsistence farmers (88%); full-time farmers (84.4%); farmers associated with farm groups (94.3%); and farmers who had access to extension services (93.4%) (see Table 3.4 and Appendix I). However, farmers' knowledge of digitalization was limited to using the phone to support farming and digital services provided through radio or mobile phones or field agents. Services noted by respondents included advisory and information services, market linkages, and financial access services. Hence, advanced digitalization such as drones, satellites, robotics and big data analytics and their services were unknown to rural farmers in the study areas.

3.6.3 What digital tools are smallholder farmers in Northern Ghana using?

We assessed farmers' ownership of some of the most basic digital tools known in the digitalization suit (see Figure 3.1). The mobile phone was a widely used tool among farmers. Although mobile phone usage was widespread, the majority used feature phones—earlier generation non-touch, non-smart phones with simple with mostly only voice and text functionalities—the cheapest, easiest to operate at their skill levels, and easily accessible due to "China phones" in the African market. However, smartphone ownership and access were limited; only 16.61% had a smartphone and 92.01% had feature phones (9.4% had both). Other digital tools farmers used or accessed included radio, TV, internet, computer and tablets (see Table 3.5).
Table 3.5 Farmers' ownership, access and abilities to use digital tools

<table>
<thead>
<tr>
<th>Digital resource</th>
<th>Farmers WITHOUT access</th>
<th>% Farmers WITH access</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobile phone</td>
<td>2.2</td>
<td>97.8</td>
</tr>
<tr>
<td>Radio</td>
<td>19.0</td>
<td>81.0</td>
</tr>
<tr>
<td>TV</td>
<td>33.2</td>
<td>66.8</td>
</tr>
<tr>
<td>Cellular internet</td>
<td>87.0</td>
<td>13.0</td>
</tr>
<tr>
<td>Computer</td>
<td>97.2</td>
<td>2.8</td>
</tr>
<tr>
<td>Wifi</td>
<td>97.3</td>
<td>2.7</td>
</tr>
<tr>
<td>Tablet</td>
<td>98.9</td>
<td>1.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Farmer's competencies in a digital task (n=1565)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farmers with the ability to:</td>
</tr>
<tr>
<td>answer calls on my phone independently</td>
</tr>
<tr>
<td>place calls on my phone</td>
</tr>
<tr>
<td>receive and read SMS on my phone</td>
</tr>
<tr>
<td>send SMS messages</td>
</tr>
<tr>
<td>access audio messages sent to my phone</td>
</tr>
<tr>
<td>send audio messages on my phone</td>
</tr>
<tr>
<td>follow IVR on my phone</td>
</tr>
<tr>
<td>browse the internet for information</td>
</tr>
<tr>
<td>use social media</td>
</tr>
<tr>
<td>use an independent phone app for activities</td>
</tr>
<tr>
<td>use a computer</td>
</tr>
</tbody>
</table>

Only about 13.02% had access to the internet (13.02% had cellular internet, and 2.7% had Wi-Fi access). Hence, cellular was the typical way farmers accessed the internet, primarily through their smartphones. Farmers who had smartphones but could not afford to pay for data services did not have access to cellular internet, despite the availability of the service. Likewise, poor networks in communities also explained why Wi-Fi usage was almost non-existent beyond a few educated and affluent farmers who settled in rural areas after spending time in urban areas.

3.6.4 What are the characteristics of the farmers who use mobile phones for farming?

Since the mobile phone was the widely used digital tool, we assessed the characteristics of farmers who use it for farming activities and how they used it. The phone use was measured through a direct survey question on whether that farmer had used the phone to undertake any farming-related...
activities in the last year and how ways of use were also measured through direct questioning on what they had used the phone to do in relation to farming. Most rural farmers (76.49%) actively used their phones in their farming undertakings. Phone usage significantly varied by gender; age; level of education, farming system, income, membership in associations, and access to extension services. Notably, female farmers (81.5%), farmers aged 25-40 years (81.9%), farmers with less than five acres (82.5%), subsistence farmers (79.3%), mixed farmers (89.3%), farmers associated with farmer groups (85.7%) and have access to extension (86.4%) were more likely to use their phones for farming activities (Table 3.6 and Appendix I).

Table 3.6 Chi-square for farmers use of phones

<table>
<thead>
<tr>
<th>Variable (n=)</th>
<th>$X^2$</th>
<th>$p$</th>
<th>Cramers V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>6.670</td>
<td>0.010**</td>
<td>0.066</td>
</tr>
<tr>
<td>Age</td>
<td>21.323</td>
<td>&lt;.001**</td>
<td>0.118</td>
</tr>
<tr>
<td>Duration in Farming</td>
<td>16.857</td>
<td>&lt;.001**</td>
<td>0.105</td>
</tr>
<tr>
<td>Households size</td>
<td>20.812</td>
<td>&lt;.001**</td>
<td>0.117</td>
</tr>
<tr>
<td>Farm Size</td>
<td>43.576</td>
<td>&lt;.001**</td>
<td>0.169</td>
</tr>
<tr>
<td>Level of education</td>
<td>15.779</td>
<td>0.008**</td>
<td>0.102</td>
</tr>
<tr>
<td>Farming system</td>
<td>163.237</td>
<td>&lt;.001**</td>
<td>0.327</td>
</tr>
<tr>
<td>Commercial status</td>
<td>0.613</td>
<td>0.736</td>
<td>0.02</td>
</tr>
<tr>
<td>Income</td>
<td>56.101</td>
<td>0.001**</td>
<td>0.191</td>
</tr>
<tr>
<td>Business status</td>
<td>0.003</td>
<td>0.954</td>
<td>0.001</td>
</tr>
<tr>
<td>Membership of association</td>
<td>107.303</td>
<td>&lt;0.001**</td>
<td>0.265</td>
</tr>
<tr>
<td>Access to extension/Vert services</td>
<td>139.530</td>
<td>&lt;0.001**</td>
<td>0.302</td>
</tr>
</tbody>
</table>

Chi2 tests indicate differences are statistically significant at 95% when $p<0.05$

Farmers use their phones in varied ways for farming activities. Among the 76.49% of farmers who used their phones for farm-related undertakings, making phone calls, listening to the radio, and other forms of usage, primarily mobile money was the highest used (see Figure 3.3). The high rate of phone calls and radio usage was attributed to limited skill demands to undertake the two ways of using the phone. However, texting, using the applications, browsing the internet, watching videos, using social media or listening to audio messages to access farming information was not widespread due to rural farmers' low (digital) competencies (see Table 3.5).
Likewise, the sourcing of weather information was essential to many farmers with concerns about farming purposes and task accomplishment. The common purpose of use were mobile money transactions, connection with extension agents, sourcing weather information, inquiries on prices and selling of farm produce (Figure 3.4). The connection to extension information was common as farmers sought information on practices. Likewise, the sourcing of weather information was essential to many farmers with concerns about...
climatic changes in recent times. For many farmers, practices on the farm depended much on the weather; hence they constantly made attempts to seek information by calling peers and other sources. It must be noted that farmers alluded to connecting to peers regularly, despite the limited recorded use of the phone for that purpose. Farmers in the rural communities held strong connections with peers and constantly connected with them via face-to-face interactions since communities are closely-knitted.

3.6.5 How do farmers perceive digitalization?

Farmers generally held positive perceptions around digitalization. Perceptions were measured through a five-point agree-disagree ticket scale on what farmers thought about digitalization services in the communities. About 96.2% believed digitalization was good for smallholder agriculture and 81% believed digital solutions and services could be the way forward and the future of farming in the area. These positive perceptions, which were paradoxical about the low usage, were primarily influenced by many factors, including farmers' prior experiences with digitalization in other sectors (e.g. mobile money wallet schemes), precautionary of speaking positively of anything until experiencing it, cultural beliefs, and desperation for help. The perceptions of farmers regarding the future of digital services varied significantly by gender, duration in agriculture, level of education, income, membership in associations, and access to extension (Table 3.7). Specifically, male farmers (96.2%), farmers with at least basic education (97.9%); members of farm associations (97.0%); and farmers with access to extension services (97.1%) were likely to agree that digitalization is a good phenomenon for rural smallholder farming.
Table 3.7 Chi-square for farmers perceptions about digital services

<table>
<thead>
<tr>
<th>Variable (n=1565)</th>
<th>$X^2$</th>
<th>$p$</th>
<th>Cramers V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>21.504</td>
<td>&lt;0.001**</td>
<td>0.117</td>
</tr>
<tr>
<td>Age</td>
<td>6.375</td>
<td>0.383</td>
<td>0.045</td>
</tr>
<tr>
<td>Duration in Farming</td>
<td>11.33</td>
<td>0.023**</td>
<td>0.060</td>
</tr>
<tr>
<td>Households size</td>
<td>6.132</td>
<td>0.409</td>
<td>0.044</td>
</tr>
<tr>
<td>Farm Size</td>
<td>8.482</td>
<td>0.388</td>
<td>0.052</td>
</tr>
<tr>
<td>Level of education</td>
<td>25.134</td>
<td>0.005**</td>
<td>0.090</td>
</tr>
<tr>
<td>Farming system</td>
<td>9.487</td>
<td>0.148</td>
<td>0.055</td>
</tr>
<tr>
<td>Commercial status</td>
<td>1.648</td>
<td>0.800</td>
<td>0.023</td>
</tr>
<tr>
<td>Income</td>
<td>66.203</td>
<td>&lt;0.001**</td>
<td>0.145</td>
</tr>
<tr>
<td>Business status</td>
<td>0.190</td>
<td>0.910</td>
<td>0.011</td>
</tr>
<tr>
<td>Membership of association</td>
<td>8.301</td>
<td>0.016**</td>
<td>0.073</td>
</tr>
<tr>
<td>Access to extension/Vert services</td>
<td>10.401</td>
<td>0.006**</td>
<td>0.082</td>
</tr>
<tr>
<td>Phone ownership</td>
<td>0.283</td>
<td>0.868</td>
<td>0.013</td>
</tr>
</tbody>
</table>

*Chi2 tests indicate differences are statistically significant at 95% when $p<0.05* 

Ultimately, 91.69% of farmers indicated their readiness to join digital services if the necessary conditions were favourable. Willingness to join was measured on the survey with a binary yes or no response on whether farmers were willing to join any digitalization services in the future. The willingness was high among those aware (96.65%) and those not familiar with such services (83.47%). The desire to join services significantly varied by gender, age, farm size, level of education, farming system, commercial status, income, membership in associations, and access to extension services (Table 3.8). Male farmers (95.6%); farmers aged 25-40 (93.2%); farmers with 11-15 acres (93.7%); subsistence farmers (94.5%); farmers who belonged to associations (95.4%); and farmers with access to extension services (94%) were more willing to accept digitalization in the future. However, farmers emphasized financial capabilities, (digital)literacy, and good telecommunication networks as necessary pieces for participation. For many farmers, the digitalization of diverse forms was a new phenomenon potentially worth experiencing to ascertain what it could offer to their lives.
Table 3.8 Chi-square for farmers willingness to join digital services

<table>
<thead>
<tr>
<th>Variable (n=1565)</th>
<th>$X^2$</th>
<th>$p$</th>
<th>Cramers V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>57.626</td>
<td>&lt;0.001**</td>
<td>0.192</td>
</tr>
<tr>
<td>Age</td>
<td>12.731</td>
<td>0.048**</td>
<td>0.064</td>
</tr>
<tr>
<td>Duration in Farming</td>
<td>8.356</td>
<td>0.079</td>
<td>0.052</td>
</tr>
<tr>
<td>Householdsize</td>
<td>24.868</td>
<td>0.001**</td>
<td>0.089</td>
</tr>
<tr>
<td>Farm Size</td>
<td>37.056</td>
<td>&lt;0.001**</td>
<td>0.109</td>
</tr>
<tr>
<td>Level of education</td>
<td>19.141</td>
<td>0.039**</td>
<td>0.078</td>
</tr>
<tr>
<td>Farming system</td>
<td>67.051</td>
<td>&lt;0.001**</td>
<td>0.146</td>
</tr>
<tr>
<td>Farming model</td>
<td>15.039</td>
<td>0.005</td>
<td>0.069</td>
</tr>
<tr>
<td>Income</td>
<td>49.284</td>
<td>&lt;0.001**</td>
<td>0.125</td>
</tr>
<tr>
<td>Business status</td>
<td>2.368</td>
<td>0.306</td>
<td>0.039</td>
</tr>
<tr>
<td>Membership of association</td>
<td>77.097</td>
<td>&lt;0.001**</td>
<td>0.222</td>
</tr>
<tr>
<td>Access to extension/Vert services</td>
<td>36.666</td>
<td>&lt;0.001**</td>
<td>0.532</td>
</tr>
<tr>
<td>Phone ownership</td>
<td>1.061</td>
<td>0.588</td>
<td>0.026</td>
</tr>
</tbody>
</table>

Chi2 tests indicate differences are statistically significant at 95% when $p<0.05$

3.7 Discussion: Digitalization as a Distant Phenomenon in Smallholder Africa?

Our results show a general overview of farmers’ engagement with digital tools and services in Northern Ghana. From the results, the typical farmer who uses digital technologies is a male aged between 25- and 40 years with incomplete basic education and practices mixed farming at a subsistence level. This farmer is also likely to earn between GHC6001-7000\(^28\) annually from farming, is associated with a community/farm group and has access to extension services. However, this farmer is most likely to own or have access to only a feature phone and a radio but unlikely to have internet access. The farmers would most likely minimally use the mobile to aid farming activities by only making phone calls, which is what their literacy and digital competencies can allow. Hence, he is unlikely to use the internet or any advanced digital tools or activities. This typical farmer will live in a village without access to or experience digitalization services. However, if there happen to be services in the village - which will be limited to radio, mobile SMS, or agent-delivered information and advisory services- the farmer would be aware of them and positively perceive digitalization. The farmer would have also probably participated with one of such services through a free or discounted offering by development NGOs or technology service providers. However, he is unlikely to be active on the service long after free and discounted offerings elapse.

Generally, farmers’ engagement with digitalization is low in terms of tools and services. The ubiquity of mobile phones makes them the most accessible and hence commonly used tool (Duncombe, 2016; Emeana et al., 2020; GSM Association, 2020b; Tsan et al., 2019), while

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\(^{28}\) GHC6001-7000 = USD 1017-1186 at time of the research June-July 2021
engagement with higher-level digitalization like precision techniques or drones are non-existent among smallholder farmers in our study areas. Poor access to digital resources, including smartphones and the internet, partly explains the limited use of such innovations. However, even farmers with access to these resources are still constrained by very low competencies (McCampbell et al., 2021), such as the inability to send SMS, follow IVR, browse the internet or use computers. Also, since the majority of available digital agricultural services were a part of pro-poor interventions (Abdulai, 2022; Birner et al., 2021; Kim et al., 2020; Tsan et al., 2019), the retention and activeness beyond the project’s timeframe were low: of 70.22% who had participated in digital services, only 31.6% were still actively interacting with services, but this figure included people in ongoing projects. Hence, the true activeness is expected to be lower when only projects beyond their active implementation are considered. This finding confirms research by Hidrobo et al. (2021) and Palloni et al. (2018), which found that farmers discontinued usage of Vodafone Farmers club projects in Africa after free or discounted service elapsed. Also confirming the findings of Hidrobo et al. (2021) and Etwire et al. (2017), farmers' willingness to pay for services is low, which often undermines the long-term engagements with digitalization. This retention issue explains why sustainability – continuous provision of services and usage by farmers over long periods–of digital agricultural services remains a concern in Africa, as observed by Emeana et al. (2020) and Kim et al. (2020). Farmers' general lack of interest emanating from perceptions of other demanding challenges (including climate change, lack of access to inputs, etc.), low capabilities to sustain engagements, and the long-term expectations of receiving free support from development activities partly account for this challenge. These discussions of low engagement mean that full-scale digitalization that encompasses the vast array of tools and services shown in Figure 3.1 is not currently a reality in smallholder systems but rather a distant goal.

Hence, the digital lived realities of the typical smallholder farmer contrast the transformational promotions surrounding digitalization in Africa, as evident in Chapter Two. Discussion of swarms of mini-tractors powered by tablets and uber-like rental services in smallholder systems shows a disconnect from farmers' lived realities. The results showed most smallholders couldn’t even access the Internet or smartphones nor have the essential digital competencies to use such systems. Remarkably, the literature promoting digital agriculture grossly overestimates farmers’ readiness (McCampbell et al., 2021) or what we describe as the existence of the basic building blocks, including digital competencies, access to digital tools, and willingness to engage among
smallholder farmers. Hence, this finding underscores the need for the critical exploration of the contextual realities of smallholders to inform the discourses and practices of digitalization better.

3.8 Conclusion and Reflections

In conclusion, digitalization is unfolding for farmers in Africa, but proliferation and engagements are constrained and limited at best. Farmers’ experiences are not established enough to match claims of widespread digitalization or any potential anticipated revolutionary, disruptive, and "game-changing" transformations (Atanga, 2020; Tsan et al., 2019). Therefore, the anticipated digital revolution discourses in African agriculture can not be limited to the technicalities of creating such innovations; they must be re-focused on sensitivity to farmers' contextual social realities (Kansanga et al., 2018), including inequities in access to digital tools and competencies. If digital agriculture has any chance of having an impact amongst smallholder farmers, then we need to [in essence] “walk before we can run” and explore what kind of farmers have the most basic of digital things such as accessing a smartphone, internet or are able to send texts, browse the internet or follow IVR. Only by understanding these very elementary building blocks of digital agriculture will we have any chance of predicting how much more complex and sophisticated tools may be applied.

Hence, we call for creating “digitalization for smallholders” or a “digitalization for Africa,” which is different yet contextually relevant to the structural conditions in the area. For example, as farmers use phones as the most accessible digital tool, a “digitalization for smallholders” must focus on leveraging the devices to gain understanding, acceptance, and ultimate engagement by farmers before any talk of advanced tools. Likewise, a “digitalization for smallholders” must think beyond traditional and individualized approaches to digital access. As noted in the case of “Uber for Tractor” use cases in Africa and India (Daum et al., 2021) and confirmed in this research, the limitations of smallholder farmers (e.g. low literacy and low willingness to pay) constrain direct digital engagements at individual levels. And farmers may still be structurally constrained to prefer the human touch to their activities rather than being burdened with the technologies, further explaining why traditional face-to-face interactions continue to operate in the digital services space. Effective integration of field agents and leveraging point persons in communities with digital approaches is needed to reach the otherwise digitally excluded farmers. Only then can further efforts be made to introduce a high level of digitalization, such as digital-enabled precision farming techniques or the actual application of uber-for-tractors- when necessary.
3.9 References


https://thesis.eur.nl/pub/55705


4.0 Towards inclusive smallholder digitalization: Gender, farmer groups, extension services, digital competence, and mobile phone ownership/access influence the likelihood of farmer participation in digital agricultural services in Northern Ghana

4.1 Preface to Chapter Four

In this chapter, also a standalone manuscript, I build on the previous chapter to explore the factors that affect farmers' participation in digital services. In Chapter Two, I concluded that more research is needed to understand the contextual realities of how farmers engaged with digitalization in Africa. Chapter Three answered that call by exploring the dynamics of engagements of rural farmers with digital tools and services in Northern Ghana. Chapter Three noted that digitalization was still a distant goal because farmers' engagement and retention were minimal and constrained. However, I also introduced issues around farmers' participation in digitalization (section 3.6.1), showing that a wide range of influencing factors may determine who participates or otherwise. In concluding the Chapter, I called for more research to understand the contextual factors that may affect farmers' participation.

Using the survey data presented in Chapter Two, this chapter picks up the calls made in Chapter Three using a polynomial modelling technique to create a predictive engagement model with digital agriculture. I followed the approach of KC et al. (2016; 2019) to assess the effects various socio-economic and farmers' conditions have on participation in digital agricultural services. Hence, this chapter takes the findings of Chapter Three further and responds to its concluding call to explore structural issues that influence participation by statistically modelling the level of effects a change in various socio-economic characteristics and factors may have on the involvement in digitalization. I show through the modelling that associations to farmer groups, access to extension services, ability(competence) to place phone calls, access to mobile phones (digital resources), and gender positively affect participation in digital services. Paradoxically, access to the internet has a negative effect on participation, which I partly attribute to the current proliferation of services that are essentially non-dependent on the internet at the user levels.

The findings in this chapter underscore the importance of paying attention to the potential unequal access to opportunities, and resultant power implications, in the digitalization of agriculture in Africa. The empirical approach in the chapter provides contextual data to support claims in the literature (Carolan, 2020b) and Chapter Two that existing structural issues in rural communities
may undermine equity in access and benefits of digitalization while digitalization may also create newer inequalities among farmers. The findings thus confirm the claims made in Chapter Two and further contribute to the literature discussions on the need to pay attention to the socio-political-economic implications of agricultural digitalization (Carolan, 2020b; Klerkx et al., 2019; Rotz et al., 2019).

Keywords: Digitalization; rural smallholders; Africa; digital participation; inclusive digitalization.

4.1.1 Preface references


4.2 Publication Details (Tentative)
Authorship: Abdul-Rahim Abdulai, Krishna Bahadur KC, and Evan Fraser.
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4.3 Abstract

Participation in digital services is critical for the inclusiveness of digitalization in smallholder Africa. This paper thus employs a cross-sectional survey of 1,565 farmers in Northern Ghana to explore the factors that affect the likelihood of farmers’ participation in digital agricultural services. We applied a polynomial regression model to show that gender, affiliations to farmer groups, access to extension services, ability to place phone calls, and ownership/access to mobile phones increase the probability of participation in digital services. However, paradoxically, access to the internet negatively influences the likelihood of engagements. Thus, farmer characteristics, digital competencies, and access to digital resources are critical in determining who participates in digitalization. We argue that access and impacts of digitalization could be exclusive due to existing equities in the essential elements for participation. Hence, strategies sensitive to the drivers in engagements are required for inclusiveness and the long-term sustainability of digitalization for smallholders. We, therefore, recommended policy strategies that strengthen farmers’ interest in associations/groups, increase access to extension services, build digital skills, and scale access to digital tools (including mobile phones).

4.4 Introduction

As digital agricultural services are increasingly promoted for smallholder Africa (Kim et al., 2020; Tsan et al., 2019), their adoption and use must be well-understood to inform scaling across areas. Particularly, assessing the participation in digitalization services could propel progress toward solving the challenges that hinder Africa’s 33 million smallholders from attaining their productivity and economic potential (Deutsche Gesellschaft für Internationale Zusammenarbeit, Mercy Corps AgriFin, et al., 2021; Kim et al., 2020; Technical Centre for Agricultural and Rural Cooperation, 2019). Likewise, however transformative digitalization’s potential may be proclaimed in existing literature (see Chapter Two), attaining such goals partly depend on the beneficiaries’ ability to take
advantage of emerging digital services. Yet, the literature on digitalization in Africa remains silent on the factors that may influence the adoption and participation in digital services for diverse groups of farmers (FAO, 2019). Hence, a substantial issue in understanding emerging digital agriculture continues to be the limited empirical, systematic, and official data on the topic across different regions and places (ibid). This paper contributes to closing this important gap by empirically exploring how a range of factors may influence farmers' participation in digital agricultural services in Northern Ghana.

Rural farmers' existing conditions and characteristics are critical to their participation in interventions (Abegunde et al., 2020; Ali, 2012; Sulo et al., 2012) and potentially undertaking any form of digitalization practices. Rural people are the economic bedrock of many African countries; not only are they the majority in most areas, but their contribution through agricultural activities is central to development (Barrett et al., 2017; Dixon, 2015; Osabuohien, 2020). Meanwhile, the conditions under which rural farmers undertake their livelihood activities and everyday practices are mostly far from ideal. Poor infrastructures such as roads, electricity, and now telecommunication to lack of social services like education and health, the plights of rural communities and people have always been at the centre of rural development scholarships, as well as development interventions (Barrett et al., 2017; Briceño-Garmendia et al., 2009; Cook, 2011). Notably, the outcome of these many problems is more rural poverty and thwarted abilities to embrace innovations and change entirely. For example, the lack of education in rural areas leads to low literacy, hindering people’s access to information, including digital tools and services. Ultimately, the practice(s) of digital agriculture hinges on how rural people are situated to adopt, use, and participate in the phenomenon.

This paper uses a cross-sectional survey in four districts in Northern Ghana to assess the factors that may influence adoption and participation in digital services. By showing the effects of various farmer characteristics on the involvement in digitalization, we provide empirical and practical insights into how the everyday realities of rural people in Africa may influence the goals of the anticipated digital revolution in the region. The rest of this paper is structured as follows. The following section presents background on agricultural digitalization in Africa. Thereafter, the research design and data collection processes are outlined, followed by the empirical approach, where the variables are defined, and the model for the research is stated. The results section then presents the outcome of the probit regression modelling and how each variable influences participation. Then the discussion expands and provides reasons for the four significant determinants (association to farmers groups, gender, ability to place calls, and access to cellular internet) of participation in digital
services. The conclusion and way forward summarise the findings and call for attention to diverse groups of farmers' access to resources and digital literacies in digital interventions.

4.5 Background

4.5.1 Agriculture digitalization use in smallholder systems

In 2019, the Food and Agriculture Organisation released *Digital technologies in agriculture and rural areas—status report* (FAO, 2019). The report emphasizes the growing application of many digital tools, including mobile advisories, precision advisories, satellite imagery, blockchains, and drones in many aspects of rural smallholder food and agriculture value chains. In the same year, the CTA released *The Digitalisation of African Agriculture Report 2018–2019* (Technical Centre for Agricultural and Rural Cooperation, 2019). The report detailed the growing number of digital innovations, such as call centres, market platforms, blockchain solutions, and social media. Two reports released by GIZ and partners in 2021 (Deutsche Gesellschaft für Internationale Zusammenarbeit, Mercy Corps AgriFin, et al., 2021; Deutsche Gesellschaft für Internationale Zusammenarbeit, Mercy Corps, et al., 2021) also emphasized how digital tools and services are becoming embedded in everyday activities of farmers and rural people in Africa. Similar information on the subject can be found in the World Bank (Kim et al., 2020), GSMA Association (GSM Association, 2020), the African Union (African Union Commission & OECD, 2021), and many other organizations. In all these reports, the common theme is the emergence of a new potentially transformative technology and phenomena that are rapidly penetrating through the fibre of rural communities and activities. This view is also heavily supported in the academic literature on digitalization, which engages the subject while acknowledging the growing proliferation of digitalization in African rural agriculture (Babcock, 2015; Ekekwe, 2017; Evans, 2018; Munyua et al., 2008)

Specifically, the ubiquity of digitalization and accompanying services lies in the diverse range of tools and services emerging from the phenomenon (see Sections 1.2 and 3.4). These innovations mainly provide solutions to the many challenges smallholders face in the current food regime, including climate change, poor access to inputs, and limited access to information. For example, market access solutions directly seek to connect an otherwise disconnected smallholder population to markets and bridge price information asymmetries (Deichmann et al., 2016; Etwire et al., 2017; Magesa et al., 2014). Likewise, capital solutions such as mobile money, one of Africa's most typical
forms of digitalization, promote financial inclusion for disconnected rural populations (Babcock, 2015). The ability of these innovations to provide solutions for African farmers emerges the push to encourage their adoption and use of digital services.

According to the CTA, about 33 million smallholders registered for digital services in 2019, and the number is expected to reach 200 million by 2030 (Tsan, et al., 2019). However, little is known about the factors affecting farmers' digital services participation. Researchers have shown that various factors broadly influence people's adoption of ICTs and digitalization in agriculture. Socio-demographic and economic conditions such as education, gender, income, social category, and age variedly affect farmers' adoption and application of ICTs (Alabi, 2016; J. Ali, 2012; Ayanwale & Adekunle, 2008; Ayim et al., 2020; Etwire et al., 2017; Tata & McNamara, 2016). Likewise, Ajani (2014) and (2022) note that literacy and digital skills are critical to scaling digitalization for smallholders in rural Africa. Specifically, illiteracy, financial illiteracy, and digital illiteracy, as Babcock (2015) found with mobile payments, are barriers to successful adoption and use.

The literature on the farmers' use of digitalization has been skeptical about unequal access and equity among diverse groups (Bronson, 2018; Carolan, 2020b; Duncan et al., 2021; Klerkx et al., 2019; Rotz et al., 2019). Hence, there is no denying in the literature that digitalization, despite the potential, may not be available for all farmers (Emeana et al., 2020; Xie et al., 2021), and access and use could be dependent on a diverse range of factors. This concern is confirmed in Chapter Three of this dissertation, where farmer characteristics, including age, level of education, commercial status, farming models, income, membership in associations, and access to extension, have varied relationships with participation in digitalization. This finding, coupled with prior concerns on the potential non-inclusiveness of access and benefits of digitalization (Abdulai, 2022), peaked my interest in further exploring this subject. This paper, therefore, assesses the effects of a range of factors on participation in digital services within rural Northern Ghana.

4.6 Research Design and Data Collection

This paper uses data from a cross-sectional survey administered in the Northern Region of Ghana in 2021. The study's goal was to assess the perceptions and preparedness of rural smallholders for the ongoing digital revolution. A multistage sampling method selected participating smallholder farmers (n=1565). First, four districts (Savelugu, Nantong, Kumbungu, and Sagnarigu) (see Figure 1) were chosen due to their proximity to the regional capital district, Tamale Metropolis. Their locations make these areas potential beneficiaries of digital services of urban communities yet are primarily
peasant-based enough to offer insights into rural digitalization. Their closeness to the regional capital also makes them accessible to the many NGOs that operate from the city and provide agricultural interventions for rural smallholders. These communities presented an opportunity to view people who have or are currently experiencing digitalization and non-beneficiaries in such communities.

Figure 4.1 Map of the study area and communities

The communities (27) were selected through a simple random sampling from a pool of areas that received digital agriculture interventions. Finally, a systematic sampling technique was used to choose household units by selecting every third house where the research team first entered the community/village. The survey covered different areas of digitalization, including household preparedness, perceptions of usage, impacts, challenges, and pathways to sustainable and inclusive digitalization. Ethical approval was granted by the University of Guelph Research Ethics Board.

The data was collected from in-person administered surveys through tablets in a digital format with the help of research assistants. The survey was conducted with a structured questionnaire, capturing farmer characteristics, experiences, and perceptions. The enumerators were trained on the study and the data collection and assigned communities and distributed to sections in the selected areas on the survey days.
4.7 The Empirical Approach

We adopted the following probit model equation following the methods in the literature (KC et al., 2016; Kc et al., 2019)

\[
\ln \frac{p}{1-p} = \beta_0 + \beta_i \sum_{i=1}^{n} X_i
\]

Where \( p \) = the probability that a farmer participates in the digitalization of agriculture services, and \( \beta_0 \) and \( \beta_i \) are coefficients. Participation in digitalization was measured through a simple survey question on whether participants had engaged with digitalization services or not. Since the propensity index is not directly observable, it is treated as a latent variable to develop a model that explains the probability a farmer is likely to participate in digital agricultural services (1=yes, participated in digital service, 0=no, no participation in digital services) when a change occurs in any of the explanatory variables (\( X_i \)) pertaining to the farmers’ socio-economic conditions (gender, age, education, membership in association, and access to extension services), digital competencies (ability to place phone calls, send SMS, follow IVR, or browse the internet), and access to digital tools and resources (phones and internet) (see next section for details).

Ultimately, we apply the model that tried to understand the propensity of a farmer to participate in a digital service offered in their communities by service providers. After multiple modelling iterations, we established a robust model of participation based on 11 variables (Table 1). The 11 variables were concluded based on researchers’ experiences in the field, anticipations of important determinants, preliminary qualitative insights, and elimination of incomplete and redundant variables. Microsoft Excel and R statistics were used for the relevant analysis. Excel was used to compute frequencies and percentages, and R statistics was used for the statistical analysis.

4.8 Results and Findings

4.8.1 Summary statistics for key variables

Eleven independent variables were considered to assess their relationship with farmers’ participation in digital services.
Table 4.1 Summary of key variables in the model

<table>
<thead>
<tr>
<th>Farmer characteristics</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>38.88</td>
<td>12.98</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variable</th>
<th>Options</th>
<th>Frequency</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>Female</td>
<td>617</td>
<td>39.42</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>948</td>
<td>60.58</td>
</tr>
<tr>
<td>Age</td>
<td>15-24</td>
<td>121</td>
<td>7.73</td>
</tr>
<tr>
<td></td>
<td>25-40</td>
<td>891</td>
<td>56.93</td>
</tr>
<tr>
<td></td>
<td>41-60</td>
<td>440</td>
<td>28.12</td>
</tr>
<tr>
<td></td>
<td>60+</td>
<td>113</td>
<td>7.22</td>
</tr>
<tr>
<td>Level of education</td>
<td>Basic education (incomplete)</td>
<td>243</td>
<td>15.53</td>
</tr>
<tr>
<td></td>
<td>Basic education (complete)</td>
<td>106</td>
<td>6.77</td>
</tr>
<tr>
<td></td>
<td>High school</td>
<td>104</td>
<td>6.65</td>
</tr>
<tr>
<td></td>
<td>Certificates/vocational</td>
<td>12</td>
<td>0.77</td>
</tr>
<tr>
<td></td>
<td>Higher education</td>
<td>20</td>
<td>1.28</td>
</tr>
<tr>
<td>Membership of association</td>
<td>No</td>
<td>511</td>
<td>32.65</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>1055</td>
<td>67.35</td>
</tr>
<tr>
<td>Access to extension services</td>
<td>No</td>
<td>479</td>
<td>30.61</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>1086</td>
<td>69.39</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Respondents' access to digital tools and resources</th>
<th>Percentage WITHOUT access (%)</th>
<th>Percentage WITH access (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respondents with access to:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phone</td>
<td>2.17</td>
<td>97.83</td>
</tr>
<tr>
<td>Internet</td>
<td>86.96</td>
<td>13.04</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Farmers digital competencies</th>
<th>Percentage WITHOUT ability (%)</th>
<th>Percentage WITH ability (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>place calls</td>
<td>10.35</td>
<td>89.65</td>
</tr>
<tr>
<td>send SMS messages</td>
<td>68.75</td>
<td>31.25</td>
</tr>
<tr>
<td>follow IVR</td>
<td>79.23</td>
<td>20.77</td>
</tr>
<tr>
<td>browse the internet for information</td>
<td>82.75</td>
<td>17.25</td>
</tr>
</tbody>
</table>

Most respondents were male (60.48%), while females (29.42%) were the minority. Most respondents were between the ages of 25 and 40 (56.93%), and the average age was 38.8 years. Most farmers had no education (69.01%). However, the majority of farmers belonged to associations (67.35%) and had access to extension services (69.39%). While most farmers owned or had access to mobile phones (97.83), only 13.04% had internet access. The commonest competencies among farmers were the ability to place (89.65%), and the least digital competence was browsing the internet for information (17.77%). Generally, as the complexity or level of skill required to undertake a particular digital task increased, the percentage of farmers who could complete such a task decreased (Table 1). Finally, the dependent variable measured was farmers' participation in digital agriculture services in the area: 70.22% of the respondents had participated in digital services.
4.8.2 Critical factors associated with farmer participation in digital agricultural services

The probit regression illustrated that a range of factors explained farmers' participation in digital services. The overall regression model explained participation reasonably well ($R^2 = 0.376$). The explanation power was acceptable in line with a cross-sectional dataset like this study (Kc et al., 2019). Table 4.2 outlines the findings of our general model for participation in digital agricultural services.

Table 4.2 Determinants of participation in digital services

<table>
<thead>
<tr>
<th>Variable n=1565</th>
<th>General model Coefficient (Standard error)</th>
<th>General model marginal effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept)</td>
<td>-1.902 (0.335)</td>
<td>-0.397</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 if a participant is male; 0 otherwise</td>
<td>0.322*** (0.089)</td>
<td>0.067</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age of household head (years)</td>
<td>-0.003 (0.003)</td>
<td>-0.001</td>
</tr>
<tr>
<td>Level of education</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 if a farmer 'has completed at least basic school; 0 otherwise</td>
<td>0.089 (0.139)</td>
<td>0.018</td>
</tr>
<tr>
<td>Membership of association</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 if a farmer is a member of an association; 0 otherwise</td>
<td>1.318*** (0.100)</td>
<td>0.275</td>
</tr>
<tr>
<td>Access to extension</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 if farmer has access to extension; 0 otherwise</td>
<td>0.820*** (0.102)</td>
<td>0.171</td>
</tr>
<tr>
<td>Phone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 if farmer has a phone; 0 otherwise</td>
<td>0.528** (0.265)</td>
<td>0.110</td>
</tr>
<tr>
<td>Internet access Cellular</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 if farmer has cellular internet; 0 otherwise</td>
<td>-0.737*** (0.123)</td>
<td>-0.154</td>
</tr>
<tr>
<td>I can place calls on my phone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 if a farmer can place calls; 0 otherwise</td>
<td>0.747*** (0.130)</td>
<td>0.156</td>
</tr>
<tr>
<td>I can send SMS messages</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 if a farmer can send SMS; 0 otherwise</td>
<td>0.055 (0.133)</td>
<td>0.0115</td>
</tr>
<tr>
<td>I can follow IVR on my phone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 if a farmer can follow IVR; 0 otherwise</td>
<td>-0.165 (0.198)</td>
<td>-0.034</td>
</tr>
<tr>
<td>I can browse the internet for information</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 if farmer can browse the internet; 0 otherwise</td>
<td>0.139 (0.220)</td>
<td>0.029</td>
</tr>
<tr>
<td>Constant</td>
<td>-1.902***</td>
<td></td>
</tr>
<tr>
<td>-------------------</td>
<td>-----------</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.335)</td>
<td></td>
</tr>
<tr>
<td>Log Likelihood</td>
<td>-594.829</td>
<td></td>
</tr>
<tr>
<td>McFadden's Pseudo R-squared</td>
<td>0.376</td>
<td></td>
</tr>
</tbody>
</table>

Note: *p<0.1; **p<0.05; ***p<0.01

Firstly, gender had a significant positive relationship with participation in digital services. Specifically, male farmers were more likely to participate than women. The marginal effect computation indicated that a unit increase in men in farming led to a 6.7% increase in participation in digital services. This study thus confirms the existence of unequal access to resources (Food and Agriculture Organization of the United Nations, 2018), as male farmers are more likely to participate in digital services. The main reason for the difference is the emphasis on development interventions at the household level, which places men as household heads at the advantage of participation. Likewise, the finding is unsurprising since women are still 13% less likely to own a mobile phone than men in sub-Saharan Africa, which is crucial for digital participation (GSMA Association, 2021). However, recent studies have revealed the gradual blurring of such gendered barriers. In the study of agrarian transformation, Speijer (2016) found transformations in access to inputs, land, technology and labour at gender levels. Speijer found that the long-held beliefs of division between male and female crops are blurred as technologies alter access to horsepower for farm activities, confirming Doss's (2002) and Lambrecht et al. (2018) findings on disappearing gender myths on limited access to resources by women in Africa. However, as this study partly reveals, there is still room for improvements despite the blurring of gender constraints. Hence, interventions promoting and offering African digital services must continuously integrate gender-sensitive assessment into planning and implementation processes.

Secondly, membership in an association(s) also had a strong and positive effect on farmers' participation. Farmers associated with groups were more likely to participate in digital services. Notably, farmers who belonged to farm associations and groups were more likely to participate in digital agricultural services. Service providers sometimes put farmers into groups as a prerequisite for receiving digital services, which partly explains why people associated with groups are more likely to participate. Importantly, this finding confirms earlier research that farmer groups and cooperatives improve the adoption of innovations and technologies in agriculture (Abegunde et al., 2020; Ainembabazi et al., 2017; Ayanwale & Adekunle, 2008; Mwaura, 2014; Sulo et al., 2012; Wossen et al., 2017) by sometimes speeding the process of farmers engagement (Ainembabazi et al. 2017).
Thirdly, access to extension services was also strongly associated with farmers’ participation in digital services. The estimated model coefficient for access to extension services was positive. Hence, access to extension services increased the probability for farmers to join digital services. This finding is unsurprising, as it confirms earlier research that access to extension can facilitate innovation diffusion among farmers (Ali & Rahut, 2013; Emmanuel et al., 2016; Tata & McNamara, 2016; Wossen et al., 2017). We therefore empirically add to this claim and extend the literature by showing that extension is also essential in the diffusion and use of digital agricultural technologies.

Fourthly, the overall model also expressed the estimated coefficient for access to mobile phones as positive. Particularly, access to mobile phones increased the probability of involvement in services. This finding was anticipated due to the current space of digitalization in Africa. Mobile phones anchor the current agricultural digitalization ecosystem in smallholder Africa and beyond, confirming earlier studies on the need for mobile penetration (Duncombe, 2016; GSMA Association, 2021). This finding ultimately underscores the essence of digital devices and resources in promoting smallholder digitalization.

Fifthly, farmers’ ability to place a call had a significantly positive coefficient and increased farmers' participation in digital services. Particularly, farmers who can place phone calls were more likely to participate in digitalization. This finding confirms and underscores the essence of digital competency in the digital agriculture space, which earlier research has hinted to be lacking. Ajani (2014) notes that when it comes to smallholders in rural Africa, issues of low literacy and digital skills continue to undermine any real stride in the adoption and use and ultimate transformation of ICTs. Specifically, as Babcock (2015) found in mobile payments, digital illiteracy is a barrier to a successful rollout of digitalization. Likewise, Atanga (2020) confirms the challenge of literacy when he found that low technical ability among farmers hinders digital financial services' capacity to make impacts for smallholders in Ghana. Establishing the essence of digital skills (placing phone calls in this case) opens further conversations on developing digital competencies in rural areas.

Finally, and sixthly, access to cellular internet had a negative coefficient. The marginal effect computation showed that a unit increase in farmers with access to cellular internet decreased the probability of participation in digital services by 15%. These counterintuitive revelations contrast the established scholarship that internet access is critical in the expanding digital agriculture space (Evans, 2018; Lehmann et al., 2012). However, many reasons may have accounted for this observation. Access to the internet was limited among the rural population%: 13.04. Such low
numbers mean that the effect is limited within the model. Also, digital services are currently created outside the internet space at the individual level, mainly delivering services through SMS, calls, and field agents. Hence, farmers can participate in services without access to the internet, which minimizes the effect of the models. However, it is important to not discount the role of internet access in digitalization futures in Africa (Deutsche Gesellschaft für Internationale Zusammenarbeit, Mercy Corps, et al., 2021; FAO, 2019; Sundmaeker et al., 2016; Tsan, et al., 2019). Because, as internet access grows and digital services expand to include internet-based platforms as being experienced in the developed world, access would be critical to participation and use of digital services.

4.9 Discussion

4.9.1 Digitalization as an uneven phenomenon for smallholder participation?

The results show variations in the probability and likelihood of participating in agricultural digitalization services. Specifically, different characteristics of farmers engender different effects on farmers’ interest and desire to use available services. The revelation of how these elements variably affect the likelihood of participation speaks to issues of potential uneven access and benefits in digitalization. As noted, 69.01% of the rural population had no formal education; 86.96% had no internet access; 68.75% and 79.23% could not send a simple SMS or follow IVR, respectively (see Chapter Three). Likewise, 10.35% could not place a phone call, and 2.17% did not own or have access to a mobile phone. Meanwhile, the model shows that the ability to place phone calls and ownership of mobile phones significantly increases the likelihood of participation. Hence, groups such as women, digital illiterates, people without access to extension services, and those not affiliated with farm associations could be excluded from participation and potential benefits. Certain groups having a more substantial likelihood mean that others not in those categories risk being excluded. The findings confirm and empirically support Chapter Two's claims (Abdulai, 2022) that digitalization may be unevenly accessible and inclusive to all farmers.

Hence, as previously discussed in the political economy and critical science and technology studies of agricultural digitalization (Carolan, 2018, 2020a; Rose & Chilvers, 2018; Rotz et al., 2019; Duncan et al., 2021), just as with previous innovations, digitalization risk entrenching inequities of the benefits of change. In particular, it could further deepen existing inequalities among rural
smallholders (including gender and literacy disparities) while also creating newer classes along the lines of groups with advantages of access. Hence, differences in potential benefits emanating from unequal participation may put digitalization similar to earlier technological waves that have divided smallholders along different lines, including gender, age, and education. In essence, digitalization may not be that different from other technological innovations criticized for creating, entrenching, and thriving on existing and newer socio-economic inequities.

4.9.2 Some policy directions for inclusive digital services participation

The model shows differential effects of varied farmers' characteristics on the scaling of digitalization among smallholders. Hence, we draw normative policy directions from the marginal impacts of the model to make recommendations for inclusiveness and widespread participation in digital agricultural services.

The first policy direction from the model is promoting and growing farmer participation in farm/community associations and groups. The marginal effect indicated that a unit increase in association with farmer groups would increase the likelihood of involvement in digital services by 27%. Thus, there would be a corresponding increase in participation in digital services for any rise in the number of people participating in farm groups. Meanwhile, only 67.35% of the sampled population participated in farmer organizations. Hence, measures must be instituted to generate interest and grow the proportion of farmers who participate in associations or groups in their communities. These measures may include using group participation as prerequisites for development interventions or creating group-based models for digital services provisions. Providing development interventions through groups is a well-known strategy across many parts, including Africa. And since digitalization interventions are primarily situated within NGOs' projects and international development activities (Abdulai, 2022), the adoption process mimics prior development experiences. Furthermore, associations with groups are known to speed up adoption processes. For example, in the study of the adoption of technologies in the African Great Lakes regions, Ainembabazi et al. (2017) found that farmer groups are not just valuable for promoting adoption. Still, they help reduce adoption lag in smallholder systems. This paper partly confirms this assertion since much of the participation in Northern Ghana is early adoption of digital services. Hence, attention must be paid to farmer grouping in rural areas in the face of emerging technologies.
The second key policy direction is increasing farmer access to extension services. The model showed that a unit increase in access to an extension would increase the probability of participation in digital agricultural services by 17%. Hence, a move from not having access to extension extends the likelihood of participating in digital services. And as earlier noted, 69.39% of the farmer population had access to extension services. Thus, pursuing inclusive access to extension services through strategies that make agents available and farmers interested in using them could be recommended to attract participation. Evidence shows that extension services are used by government and private entities to introduce and facilitate technology and innovation diffusion in agriculture (Eastwood et al., 2017; Ruttan, 1996; Sodiya et al., 2008). Hence, policy activities that enhance farmer extension access would increase the probability of people participating in digital services and improve the inclusiveness of digital innovation scaling in smallholder systems.

The third policy direction from our model is growing farmers’ access and ownership of mobile phones. The marginal effect calculation revealed that a unit increase in farmers who can place phone calls increases the probability of participation in digital services by 11%. Hence, any increase in the proportion of farmers with mobile phones will grow participation in digitalization by 11% among the smallholder population. Thus, prioritizing inclusive access to mobile phones would increase people’s interest in experiencing various digital services. This policy direction is critical as current digitalization efforts primarily rely on mobile phones as the primary tool for connecting to farmers. Thus, efforts to increase farmers’ access to mobile phones must be seen as a prerequisite to scaling digitalization in smallholder systems.

Our fourth and final policy recommendation from the modelling is to develop farmers’ digital competencies, including their ability to place phone calls. About 89.65% of farmers could place phone calls independently. Meanwhile, a unit increase in this competence would increase the probability of participating in digital services by 15%. Since most digital services are mobile-based, either through SMS advisories or call centres, both of which use the ability to operate a phone (Babcock, 2015; Emeana et al., 2020; GSM Association, 2020; Tsan et al., 2019), digital competencies must be identified at the centre of discussions of the digitalization future in African agriculture. Measurements that increase farmers' digital competencies are needed to prepare smallholders to participate in digitalization services. Farmer training programs, informal education schemes, or farmer-to-farmer education that focuses on digital literacies must be instituted in rural communities to train farmers in various digital competencies required for effective adoption and participation in digitalization.
4.10 Summary and Conclusion

The paper has explored the factors that influence the likelihood of rural smallholder participation in digital agricultural services. The results showed that gender, membership in farm associations, access to extension services, ownership and access to mobile phones, access to cellular internet, and ability to place calls primarily increased the likelihood of participation in digital services in Northern Ghana. Age, level of education, ability to send SMS, follow an IVR, and browse the internet did not significantly affect farmers' participation in digital services. However, these elements (except the ability to follow IVR) had positive coefficients and increased farmers’ involvement in digital services. These results represent an exploration of the variables at the time of the research. Hence, the significant elements must not be considered exclusive or exhaustive. Most digital services are currently a part of development interventions, which could ultimately define who can potentially access, participate and benefit from them (Chapter Two). Hence, care is needed in interpreting the results due to changing circumstances and requirements of digital services in the study settings. Further research must explore other dimensions of participation in diverse contexts and across times.

The findings lend critical policy insights for inclusive agriculture digitalization in smallholder systems. In particular, a place-based understanding of factors that drive participation, penetration and scaling of digital services is essential. Development stakeholders must pay attention to the socio-political-economic conditions of smallholders when designing and implementing digital initiatives. Specifically, strategies must be pursued to increase farmers' access to digital resources (e.g. phones, internet, etc.). Likewise, attention must be placed on digital literacies among farmers. Governments, NGOs, and all rural development actors need to institute and prioritize education and training programs that enhance the competencies of rural people. Also, measures that increase access to and encourage extension services are needed. Finally, farmer associations and groups must be encouraged in rural areas, and incentives created to promote participation and belonging to such groupings. Ultimately, through these policy directions and strategies, governments and development agencies would have effectively empowered diverse rural people to participate in digital services and propel inclusive digital futures.
4.11 References


https://doi.org/10.1300/J108v08n01_05


5.0 Beyond Transformations: Agricultural digitalization and the changing practices of rural farming in Northern Ghana, West Africa

5.1 Preface to Chapter Five

Following the call made in Chapter Two and across all the preceding chapters to explore the contextual implications of digitalization due to the potential political-economic concerns, this Chapter examines the everyday change dynamics of digital agriculture in rural smallholder systems. This manuscript examines if digitalization thus leads to change in farming practices and what mechanisms such changes manifest. The chapter aims to provide base information for further research on any potential impacts that may emanate from digitalization. Exploring changing practices aims to ascertain what livelihood processes are likely to be affected by digital innovations and, by extension, who may be advantaged or disadvantaged.

Still drawing on the survey data in Chapters Three and Four, this chapter introduces qualitative interviews and focus groups on answering the two questions of interest: I) how do rural farmers perceive digitalization regarding changing farming and livelihoods? And II) how do agricultural digitalization services cause change to smallholder farming at the primary level? I make a theoretical turn from political economy to an explicit social practice approach to understanding rural change to answer these questions. Specifically, following social practice theorists (Røpke & Christensen, 2013; Schatzki, 2002; Warde, 2013), I introduce and conceptualize farming and digital agriculture as a social practice that rural farmers perform as part of their everyday lives. I then employ this conceptualization to show that rural farmers perceive digitalization as a mechanism that changes their farming activities through alterations to planning season, choosing planting crops, planting decisions and activities, everyday farm care practices, harvesting activities, post-harvest management, and marketing and sale activities. Furthermore, I show that farmers’ mundane engagement with mobile or agent-based digitalization is changing the everyday dynamics of rural farming by reshaping the definition of farming, what and how farmers do activities and relationships in smallholder systems.

Like the previous chapters, this chapter is an expansion of the growing literature on the social implications of digitalization in Agriculture (Klerkx et al., 2019; Rotz et al., 2019). Specifically, my conception and application of social practices introduce this social theoretical ontology of change into how we assess and understand digitalization as a potential transformative phenomenon within smallholder (Agri)culture as defined by the socio-political-economic realities. I, therefore, open space for further engagement with social practices in the growing interest in
unpacking the embedded implications of digitalization, including who’s activities are changing and how? And who gains or loses from such changes?

5.1.1 Preface references


5.2 Publication Details

Tentative Authorship: Abdul-Rahim Abdulai, Ryan Gibson, Evan Fraser
This manuscript has been submitted to the *Journal of Rural Studies* at the time of dissertation submission.
5.3 Abstract

In the nascent agricultural digitalization literature, the dynamics of how digitalization may change everyday farming practices remain underexplored, especially in smallholder farming systems. Here, we employ a mixed-method approach (1565 surveys, 16 focus group discussions, and 22 interviews) to assess how digitalization reshapes the routines of rural smallholders through a social practice theory lens, where digitalization becomes the unfolding constellations of digitally-enabled everyday activities in farming. We used farmers' perceptions and experiences with digital services in Northern Ghana to show that mundane digital technologies are changing farmers' routines. First, we show a general affirmative perception among diverse farmers that digitalization changes farming practices and rural livelihood activities. Secondly, the information delivered through mobile advisories or services rendered through digitalization introduces new patterns of actions in seasons planning, how and when farmers plant, undertake husbandry activities, harvest, market, and sell outputs. Hence, no matter how mundane agricultural digitalization manifest, they potentially reshape the definition of farming, what and how farmers do activities, and relationships in smallholder systems. Ultimately, we argue that digitalization redefines rural life and communities by re-patterning farming activities, altering the routines and rhythms of farmers' daily lives and using space and time to achieve their goals. Our paper, as we know, is the first attempt to examine the social dimensions of digitalization through an explicit practice lens, and more so to directly do so in the context of smallholder farming systems in Africa. Hence, we have shifted the discourse from the overemphasis on transformations and disruptions to opening the space for interest in possible changes to mundane everyday practices.

Keywords: Digitalization; Social practices; rural change; smallholder farmers; Africa

5.4 Introduction

As noted above in the previous chapters, existing structural inequalities in access to resources and competencies may undermine digitalization. However, a broad literature still believes these tools are likely to change farming practices (Carolan, 2017a). But, I) how do farmers perceive digitalization on changing rural livelihoods and farming practices? And II) how do agricultural digitalization services cause change to smallholder farming at the primary level? We use the social
practices approach – study of the unfolding constellations of everyday activities – to explore these questions within digital agriculture services use cases in African rural smallholder systems. It is well documented that previous technological breakthroughs disrupted and transformed farming activities to ‘automate previously manual tasks and create new forms of life’ (Bear & Holloway, 2015). For instance, the introduction of tractors, irrigation, planters, and harvesters changed agriculture's labour demands and the time-space rhythms of farming.

Consequently, emerging digital tools, such as robots, drones, mobile phones, and AI, are anticipated to change further farming activities (Carolan, 2017b, 2020a; Holloway & Bear, 2017; Vasconez et al., 2019). The introduction of robotic milkers is also noted to alter the socio-cultural values around cattlemanship and the relationships between farmers and bovines (Holloway & Bear, 2017). Bear and Holloway (2015) argued that even the very ‘ostensibly mundane’ technological innovations can considerably change what it is to ‘be a farmer.’ Yet, there is limited literature to understand how digital innovations alter the everyday practices of farmers (see Carolan, 2020b; Holloway & Bear, 2017; Vasconez et al., 2019), especially in rural smallholder farming systems. Thus, this paper examines how digitalization— the use of any form of digital technology to aid farming processes— alters the performance of rural smallholder farming in Africa and Ghana in particular.

In 2019, the Digital technologies in agriculture and rural areas - Status report (FAO, 2019) emphasized the growing application of many digital tools, including mobile advisories, precision advisories, satellite imagery, blockchains, and drones in many aspects of rural activities. Two reports released by GIZ and partners in 2021 (Deutsche Gesellschaft für Internationale Zusammenarbeit, Mercy Corps AgriFin, et al., 2021; Deutsche Gesellschaft für Internationale Zusammenarbeit, Mercy Corps, et al., 2021) also emphasized how digital tools and services are becoming embedded in and changing everyday rural activities in Africa. Similar reports on the subject can be found from the World Bank (Kim et al., 2020); GSMA Association (GSM Association, 2020); the African Union (African Union Commission & OECD, 2021); and many other organizations. In all these reports, the common theme is the emergence of a new potentially transformative technology and phenomena rapidly penetrating and changing the fibre of farming and rural communities. Whether these technologies would become transformative is yet to be fully understood. Nonetheless, digital tools and services, whether in the form of mobile advisories, marketplaces, farm management systems, or precision systems, could potentially alter the practices of smallholder agri-food actors (Fabregas et al., 2019; Tsan et al., 2019).
Hence, this paper employs a mixed-method approach. We combine surveys with qualitative interviews and focus group discussions on exploring how rural farmers perceive and experience changes to their activities as they engage with digital services. We show that mundane digitalization through mobile-based agronomic, climate information and market connection services reshapes the time-space organization of farmers’ activities. The paper proceeds as follows in the next section; we introduce social practices as the unfolding constellations of everyday activities- to set the theoretical guidance for this paper. We then review prior literature on digitalization and changing (social) farming practices. The materials and methods section then outlines our study cases and the elements of our mixed-method approach. We then present our results and findings in two key thematic areas; 1) farmer perceptions of changing farming practices; and 2) how digital information and services are changing smallholder practices. The discussion offers insights into digitalization as a transition in the everyday practices of smallholder farming. We end with a conclusion that summarizes the essential findings and reflects on the novel contributions of our work.

5.5 Background

5.5.1 Digitalization and changing rural practices of farming

Social science perspectives on agricultural digitalization are growing, primarily questioning the socio-cultural implications on society (see, for example, Bronson & Knezevic, 2016; Carolan, 2017a, 2020b; Eastwood et al., 2017; Klerkx et al., 2019; Rotz et al., 2019). According to Klerkx et al. (2019), the social science research on digitalization converges around five key thematic areas; 1) Adoption, uses and adaptation of digital technologies on the farm; 2) Effects of digitalization on farmer identity, farmer skills, and farm work; 3) Power, ownership, privacy and ethics in digitalizing agricultural production systems and value chains; 4) Digitalization and agricultural knowledge and innovation systems, and 5) Economics and management of digitalized agricultural production systems and value chains. These and many more on the socio-cultural implications of agricultural digitalization have been thoroughly explored in the existing literature (for reviews, see Klerkx et al., 2019; Sam & Grobbelaar, 2021). This interest is also taken up in rural studies, including recent papers in this journal (Alam et al., 2018; Carolan, 2020c; Fraser, 2021; Gardezi & Stock, 2021; Rotz et al., 2019). Like much of the literature, these papers, which primarily reflect the Global North's experiences, set the foundations for rural scholars to explore the interactions of agricultural digitalization in rural spaces. However, our interest in this literature is understanding how
digitization shapes and changes the everyday performance and social life of farmers in the often neglected spaces of rural smallholder systems.

Like prior technologies, digitalization may change farming routines and ultimately alter rural dynamics and subjectivities in myriad ways (Carolan, 2020b; Holloway & Bear, 2017; Sam & Grobbelaar, 2021; Vasconez et al., 2019). The introduction of automated systems such as robots and drones could drastically alter the basic activities humans and ‘other things’ do in farming spaces. This change may involve the shifts from the current hands-on practices in farming to one that is data-driven and/or (semi)autonomous (Carolan, 2017a; Driessen & Heutinck, 2015; Holloway & Bear, 2017; Rotz et al., 2019). Historically, robots have been successfully employed in agriculture to undertake the repetitive task to reduce workloads, reduce stress, optimize processes, cost and efficiencies in areas such as land preparation, irrigation, milking, and harvesting (Carolan, 2020b; Driessen & Heutinck, 2015; Vasconez et al., 2019). These processes not only (re)produce human-robot interactions but also alter farming’s very performance. Likewise, as Carolan (2019) puts it, these tools could ‘discipline’ farmers’ work routines in specific ways. Hence, as these technologies continue to engage and are embedded in the (Agri)cultural fibres of different farming systems, it is quintessential that we understand the kind of subjectivities and performance they may engender.

However, the research on the dynamism between digitalization and farmer practices is limited, especially in rural smallholder systems. Specifically, as Sam and Grobbelaar (2021) note in their review of the current field literature, there is still limited research on the changing farmer routines emanating from digitalization. Meanwhile, different tools and services may engender diverse forms of change. For example, while robotics could make farming less hands-on, mobile advisories are likely to reduce time spent on the farm without necessarily providing similar routine-altering dynamics. Nonetheless, the literature in this area has focused mainly on high-end digital tools, such as robots and drones (Driessen & Heutinck, 2015; Vasconez et al., 2019), thus under-exploring other forms of digitalization, such as simple mobile advisories. Moreover, these studies have primarily been presented in Global North, where agricultural activities are capital intensive and more industrialized. Yet, the supposed digital revolution is also anticipated and has already been experienced in smallholder farming systems in Sub-Sahara Africa (Baumüller & Kah, 2019; Ekekwe, 2017; Kliemann, 2020).

More importantly, digitalization, including mobile advisories, market platforms, and precision advisories, will help small-scale farmers ‘upgrade’ the way they farm (Kliemann, 2020) and
revolutionize agriculture’s modus operandi…”(Deutsche Gesellschaft für Internationale Zusammenarbeit, Mercy Corps, et al., 2021, p. 2). Specifically, the routines and everyday activities that make smallholder farming what it is could be altered. For example, Salkovic et al. (2015) showed in the case of Ghana that the use of Esoko (a call and SMS based weather and market price platform) has significantly influenced rural culture and how ‘interpersonal communications and relationships are enacted, experienced, performed, and even maintained” (p.1). Likewise, Barnett et al. (2019) found that all farmers who participated in mobile nutrition and agriculture advisories in Ghana acted on at least some of the advice to change specific agricultural practices. However, as already noted, there is limited understanding of how the adoption and use of digital tools affect smallholders' everyday routines. And one way to better understand these changing dynamics is to explore the constitution of everyday social life (of farming) (McMillan, 2017; Schatzki, 2002). Hence, this paper invests in these issues through empirical studies on the perceptions and experiences of digitalization and changing performances of everyday farming practices of smallholder farmers in Northern Ghana. The focus on ‘practices of farming’ offers a practical approach to assessing how digitalization (could) alter the routines of farming and ultimately disrupt rural life.

5.5.2 Theoretical context: Social practices and everyday dynamics

Social practices (or practices) may offer an approach to understanding how digitalization (potentially) alters agriculture's dynamics. Although there is no unified definition, practices are the unfolding of constellations of everyday activities (Feldman & Worline, 2016). According to Reckwitz (2002, p. 256), practices are the "routinized way in which bodies are moved, objects are handled, subjects are treated, things are described, and the world is understood." Practices "appear at different locales and times and are carried out by different bodies/minds" (Reckwitz 2002, p.250). Practices entail the everyday temporary assemblages of acts filling space and time. Thus, practices involve sets, nexus, or an array of human activities. This description is concisely captured in the many works of Theodora Schatzki (Schatzki, 2001; Schatzki, 1997, 2002; Schatzki et al., 2005; Schatzki & Schatzki, 1996), where practices are described as 'open-ended spatial-temporal manifolds of actions' (2005, p. 77) spread out over objective space and time (Schatzki, 2013).

In setting out this definition of practices, Schatzki (1996) distinguishes between ‘integrative’ and dispersed practices. Dispersed practices are the generic doings and sayings in everyday life. These sayings and doings may manifest across different practices. Examples of such practices
include speaking, ‘describing, explaining, questioning, reporting, examining and imagining’ (Schatzki, 1996: p.91).

Integrated practices –‘complex practices found in and constitutive of particular domains of social life’ (1996, p. 98) have been the central focus of the concept throughout the millennium. Examples of such practices include farming, cooking, and business practices. In Sustainable Practices, Warde (2013) explained eating as an interconnected and a compound practice. Specifically, eating is at the intersection of several integrative practices, including nutrition, cooking, the organization of meal occasions, and aesthetic judgments of taste. Each of these human activities involves bodily doings and sayings integrated into the broader practice of eating. Similarly, Shove (2003) described this integration when they put forward the concept of bundles of practices. Practices that form a ‘bundle’ are interrelated aspects or activities that make up our daily lives. “For example, through being co-located in a kitchen, an office or some other spatial or temporal ‘container’ – in these cases, practices have a separate existence, the only shared aspect being that of time and/or space” (Pantzar & Shove, 2010, p. 12). So, practices of different forms fill up people’s day as they are performed across spaces and time (Schatzki, 2013). And it is this aspect of practices that are of interest to us, i.e., farming as a dispersed practice.

Given these descriptions, every activity undertaken by a farmer is either a practice or a constituent of a practice. For example, a farmer calling a helpline to seek information is undertaking an act of placing a call, but this act forms a part of the general practice of agriculture. Likewise, a crop farmer who wakes up in the morning may spend some time on the farm spraying weeds, applying fertilizer, or harvesting produces, each of which is practiced and exists separately. The collective timings of these activities or practices can be regarded as temporal rhythms that pattern farmers' daily lives (Southerton, 2020). The time spent doing each of these practices can be competitive with other daily routines, such as entertainment, family time, and social occasions. Following this conception of farming as an integrative practice, a smallholder farmer's activities become a squeeze of practice-related injunctions of sequencing, coordination and personalized scheduling (Shove et al., 2012) when they interact with digital tools. As Røpke and Christensen (2013) posited, integrating digital technologies into everyday activities softens time and space constraints by changing what, where, and how people undertake specific actions and the time used. For instance, the introduction of smartphones and the internet makes it possible for people to combine practices of reading news and other activities such as waiting to board a bus (Røpke & Christensen, 2013). Hence, how agriculture's specific activities and routines are altered through
interactions with digitalization should be of interest in an increasingly transforming world. We, therefore, loosely and conveniently conceive farming as a social practice integrated within different activities, including planning practices, planting procedures, husbandry practices, harvesting practices, and marketing practices. This conception provides a conceptual and analytical guide to our results.

5.6 Materials and Methods

We employed a mixed-method approach (Clark & Ivankova, 2015; Creswell & Creswell, 2017), combining surveys, interviews and focus group discussions. We used this approach to explore issues of changing practices within three use cases of digital solutions and services in Northern Ghana (See Figure 1 and Table 1). Northern Ghana has a strong smallholder and rural agricultural system that makes it a centre of interest to researchers in rural life and agriculture (see Abdulai et al., 2017; Abdulai & Huffman, 2000; Nyantakyi-Frimpong, 2014; Nyantakyi-Frimpong & Bezner Kerr, 2017; Vercillo & Hird-Younger, 2019). Likewise, the region is home to many agriculture-based NGOs and programs that offer farmers experiences with interventions. More importantly, the area has had experiences of diverse digital agricultural innovations in recent years and has been a centre of research on the subject in Ghana (see Etwire et al., 2017; Hidrobo et al., 2021). These characteristics make the setting an excellent socio-technical environment for understanding digitalization’s interactions with society.
Figure 5.1 Research setting and communities

Source: Map prepared by Marie Puddister, University of Guelph.
Table 5.1 Case services

<table>
<thead>
<tr>
<th>Technology service provider</th>
<th>Contextual services received by farmers in study areas</th>
<th>Methods applied to cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Esoko Ghana (E)</td>
<td>Farmers specifically received climate and weather information and market price alerts from Esoko through SMS in our coverage areas. Farmers also accessed services by calling the Esoko helpline and receiving random calls on weather and agronomic advice from the service provider. Services: The communities we covered were beneficiaries of Farm radio Uliza services. Specifically, farmers helped create radio programs while utilizing digital services to engage with producers. Farmers call or beep into a program to receive specific information on weather, particular crops, or agronomic advice.</td>
<td>Surveys, interviews, and focus groups</td>
</tr>
<tr>
<td>Farm Radio International (F)</td>
<td>In our study, Agrocenta conducted profiling and purchased farm produce from smallholders. Using the digital app, agents profiled and provided agronomic advice to farmers within the farming season while also offering them an assured market for outputs at the end of the season.</td>
<td>Surveys, interviews, and focus groups</td>
</tr>
<tr>
<td>Agrocenta (A)</td>
<td></td>
<td>Interviews and focus groups</td>
</tr>
</tbody>
</table>

In each of these cases, we employed a combination of methods to delve into the dynamics of changes. Since the research was undertaken within the rural settings of Northern Ghana, all procedures followed the cultural ethos of the area. Community entry protocols were observed, including prior information before visits, announcements of visits through chiefs and religious leaders, and paying homage to leaders before starting the work. These procedures were in line with ethics approval for research as granted by the University of Guelph Research Ethics Board.

5.6.1 Survey

We administered a cross-sectional survey to assess smallholder farmers' perceptions of the changing practices from digital interventions. The perceptions of farmers are essential to understanding interventions’ potential impacts (Johnson et al., 2019). Hence, the survey primarily assessed how the general population perceived the changes in digitalization and gauged the users' experiences on whether their farming practices have been altered. Following prior works on a survey of rural smallholders in Africa (for example, Baiyegunhi et al., 2018; Kansanga et al., 2018; Nyantakyi-Frimpong, 2014), we surveyed 1565 farmers across four districts in the Northern region of...
Ghana (Savelugu, Nantong, Kumbungu, and Sagnarigu) (see Table 5.2). The survey was conducted between May to August 2019.

A multistage sampling method was used to select participating smallholder farmers. First, the four districts were selected due to their proximity to the regional capital district, Tamale Metropolis, making them accessible beneficiary areas for rural digital agriculture interventions. Their closeness to the provincial capital also makes them accessible to the many NGOs that operate from the city and provide agricultural interventions for rural smallholders. Secondly, the communities (28) were selected through a simple random sampling from a pool of communities compiled through preliminary field activities. Finally, we used a systematic sampling technique to choose participating households. Every third house was used within communities after field assistants were assigned to segments in communities. The survey participants were randomly selected at their homes based on availability at the time of data collection and a set pattern of the third household, with the household heads being the primary target. In the absence of the household head, the wife or other senior household members were surveyed.

The data were collected digitally with the help of twenty-five research assistants. Specifically, we employed the kobo toolbox to digitalize the data collection process. We trained the enumerators on the survey and the software before the data collection. In terms of design, questionnaires included both open and closed-ended questions (Nardi, 2018). The survey focused on understanding the characteristics of respondents, their perceptions of the impacts of digital technologies, challenges, and the social conditions that influence adoption. Our choice of the survey was because of its ability to reach out to a large number of participants and capture a broad scope of a phenomenon while enhancing the validity of study findings (Moser et al., 2017; Nardi, 2018).

5.6.2 Interviews

We adopted face-to-face interviews to assess the changes individuals using digital services experience. Specifically, semi-structured interviews were used, where the researcher is free to seek clarification (McIntosh & Morse, 2015; Paine, 2015). We interviewed twenty-two (22) farmers for the study.

Farmer respondents were selected based on purposive sampling because of their role in leadership and connection with digital services. The farmers selected were mainly key informants as they served as lead farmers or group leaders in particular digitalization interventions. In attempt to
ensure we cover the diversity of smallholder agriculture, interviews included farmers with different systems (subsistence=5 semi-commercial=17); gender (male=18, female=4); ages (less than 25=2; 26-60=16; 60+=4); length of engagement with digital tools (from 0-5 years); and types of digital engagements.

Generally, the number of farmers interviewed was based on the availability of participants at the time of visits, scheduling, and willingness to participate. Hence, following Barrett and Rose (2020), the sampling was based on ‘an achievable and pragmatic number feasible within the time and circumstances of the research.’ Each interview lasted between 30 minutes to 90 minutes. A semi-structured interview guide was employed for all participants, with variations for each group of respondents. All questions were open-ended, allowing us to explore further the topics of interest (McIntosh & Morse, 2015; Rowley, 2012). Topics covered ranged from the nature of engagement with digital tools to the changes in everyday practices experienced by farmers. Interviews occasionally moved away from the guided questions to explore broader issues affecting farmers in the area, including access to inputs. All discussions were audio-recorded and with extensive notes also taken with a tablet. Interviews took place in different locations, including offices for officials, homes, farms, and community centres for farmers and were all conducted by the lead author.

### 5.6.3 Focus group discussions

We conducted focus group discussions with farmer groups to assess how digitalization changes practices in their communities. Focused group discussion involved interaction between the lead researcher and six to twelve purposefully selected informants (Carey et al., 2016; Krueger, 2014; Stewart & Shamdasani, 2014). Sixteen focus group discussions were held across thirteen communities. To capture the diversity in smallholder groups, we conducted 14-mixed groups, one male-only and one female only. A variety of reasons informed the selection of participants, including participation in digital services, availability at the time of discussion, and willingness to participate. Participants were included in consultation with lead farmers or digital advisor agents and community leaders. However, in three communities, participation was informed with people available at the meeting point at the meeting time. Discussions took place at locations desired by participants and mainly were at community centres, the chief’s house, the home of a lead farmer, and communal seating places within communities.
The focused group discussions covered many smallholder experiences with change in their communities. A focus group discussion guide was employed to guide the discussions. The guide included prompts that allowed us to engage in conversations on agricultural transformation issues, motivations of engagement with digital tools, experiences with digital services, impacts, challenges, and expectations. All discussions were recorded with a recorder, and notes were taken with an iPad.

Table 5.2 Breakdown of participants across methods

<table>
<thead>
<tr>
<th>Variable</th>
<th>Survey n=1565</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Standard Deviation</td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>38.88</td>
<td>12.98</td>
<td></td>
</tr>
<tr>
<td>Farm Size</td>
<td>5.81</td>
<td>5.91</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variable</th>
<th>Options</th>
<th>Frequency</th>
<th>Percentage(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>Male</td>
<td>948</td>
<td>60.58</td>
</tr>
<tr>
<td>Age</td>
<td>Female</td>
<td>617</td>
<td>39.42</td>
</tr>
<tr>
<td></td>
<td>15-24</td>
<td>121</td>
<td>7.73</td>
</tr>
<tr>
<td></td>
<td>25-40</td>
<td>891</td>
<td>56.93</td>
</tr>
<tr>
<td></td>
<td>41-60</td>
<td>440</td>
<td>28.12</td>
</tr>
<tr>
<td></td>
<td>60+</td>
<td>113</td>
<td>7.22</td>
</tr>
<tr>
<td>Farming system</td>
<td>Mixed cropping (more than one</td>
<td>575</td>
<td>36.74</td>
</tr>
<tr>
<td></td>
<td>crop)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mixed farming (both crop and</td>
<td>905</td>
<td>57.83</td>
</tr>
<tr>
<td></td>
<td>livestock/fishing)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Monocropping (just one crop)</td>
<td>83</td>
<td>5.30</td>
</tr>
</tbody>
</table>

| Interviews n=22        |          |          |               |
| Gender                 | Male     | 18       | 81.82         |
|                        | Female   | 4        | 18.18         |
| Age                    | less than 25 | 2     | 9.09          |
|                        | 26-60=   | 16       | 72.73         |
|                        | 60+      | 4        | 18.18         |
| Type of farming        | Subsistence | 5     | 22.73         |
|                        | semi-commercial                  | 17        | 77.27         |

| Focus groups           |          |          |               |
| Mixed focus groups     | 14       | 87.50    |
| Male only              | 1        | 6.25     |
| Female only            | 1        | 6.25     |

For analysis, the survey data were exported from Kobo Toolbox into XLS and CSV files for further research. This information was later exported into SPSS and R-Statistics, combined to process and create relevant tables, diagrams and descriptive statistics. For qualitative data, thematic and content analysis was used. That process involved recording, listening, coding and analysis. First, we renamed the interview and focus group files based on their number in the recording and
corresponding case. For example, the first interview we undertook was renamed F1-A, where F refers to Farmer and A, meaning the respondent spoke about Agrocenta(A). F5-E means the respondent was a farmer participant for Esoko(E). The same approach was used to rename the focus group discussions. The first focus group was FG-1-A, which was conducted with beneficiaries of Agrocenta (A). Having renamed the files, we uploaded them to Nvivo for audio coding. The lead author and research assistant independently listened to the files and coded them based on predetermined and emergent themes. Each coder transcribed the resulting quotations and stories corresponding to the identified themes. We then applied latent content by taking words literally (Hay, 2016). We aim to describe what is said to ensure content stay close to respondents' words, which adds more validity to qualitative information.

5.7 Results and Findings

In this section, we present the results of our data on changing farming practices and outline our findings based on i) Farmer perceptions of changing farming practices in rural communities and ii) Experiences of changing farming routines and rhythms.

5.7.1 How do rural farmers perceive digitalization as changing rural livelihoods and farming practices?

We assessed farmers' perceptions of how digitalization (information services) influenced rural livelihood activities and farming practices. Off 1271 that responded to the perception questions, most farmers perceived digitalization to change livelihood activities in their communities. Specifically, 72.15% of farmers think digitalization is changing rural practices and livelihood activities, while only 6.1% did not believe so, and 21.72% were unsure. The perceptions were generally uniform across groups. Chi-square analysis at a 95% confidence level showed farmers' perceptions of livelihood changes varied significantly across districts (P<0.001) and gender (P=0.030). Particularly, farmers in Nantong (85.5% of responding farmers in the District) and female farmers (74.3% of female respondents) were more likely to perceive that digitalization changes livelihoods in rural communities (see Table 3.5).
Table 5.3 Farmers perception of digital services and changes to farming and livelihoods

<table>
<thead>
<tr>
<th>Variable</th>
<th>Options</th>
<th># who said DA is NOT causing changes (% within groups)</th>
<th># who said DA is MAYBE causing changes (% within groups)</th>
<th># who said digital ag is causing changes (% within groups)</th>
<th>Total in %</th>
<th>Chi-square score</th>
<th>Cramers V</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td># who said DA is NOT causing changes (% within groups)</td>
<td># who said DA is MAYBE causing changes (% within groups)</td>
<td># who said digital ag is causing changes (% within groups)</td>
<td>Total in %</td>
<td>Chi-square score</td>
<td>Cramers V</td>
</tr>
<tr>
<td></td>
<td></td>
<td># who said DA is NOT causing changes (% within groups)</td>
<td># who said DA is MAYBE causing changes (% within groups)</td>
<td># who said digital ag is causing changes (% within groups)</td>
<td>Total in %</td>
<td>Chi-square score</td>
<td>Cramers V</td>
</tr>
</tbody>
</table>

Do you feel digital technologies (DA) are changing how you or people in this community go about your livelihood activities? (n=1271)

<table>
<thead>
<tr>
<th>District</th>
<th>Kumbungu</th>
<th>7(3.2)</th>
<th>42(18.9)</th>
<th>173(77.9)</th>
<th>222(17.5)</th>
<th>X^2=49.191</th>
<th>P&lt;0.001</th>
<th>V=0.139</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nantong</td>
<td>9(3.1)</td>
<td>33(11.4)</td>
<td>248(85.5)</td>
<td>290(22.8)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sagnarigu</td>
<td>11(5.3)</td>
<td>39(18.8)</td>
<td>158(76.0)</td>
<td>208(16.4)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Savelugu</td>
<td>53(9.6)</td>
<td>140(25.4)</td>
<td>358(65.0)</td>
<td>551(43.3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>Female</td>
<td>20(4.1)</td>
<td>105(21.6)</td>
<td>361(74.3)</td>
<td>486(38.2)</td>
<td>X^2=7.004</td>
<td>P=0.030</td>
<td>V=0.074</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>60(7.6)</td>
<td>149(19.0)</td>
<td>576(73.4)</td>
<td>785(61.8)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>15-24</td>
<td>6(6.6)</td>
<td>18(19.8)</td>
<td>67(73.6)</td>
<td>91(7.2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>25-40</td>
<td>52(6.8)</td>
<td>146(19.2)</td>
<td>562(73.9)</td>
<td>760(59.8)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>41-60</td>
<td>16(4.7)</td>
<td>73(21.3)</td>
<td>253(74.0)</td>
<td>342(26.9)</td>
<td>X^2=2.828</td>
<td>P=0.830</td>
<td>V=0.033</td>
</tr>
<tr>
<td></td>
<td>60+</td>
<td>6(7.7)</td>
<td>17(21.8)</td>
<td>55(70.5)</td>
<td>78(6.1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>80(6.3)</td>
<td>254(20.0)</td>
<td>937(73.7)</td>
<td>1271(100)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Do you feel digitalization is changing how you or people here farm? (n=1271)

<table>
<thead>
<tr>
<th>District</th>
<th>Kumbungu</th>
<th>4(1.8)</th>
<th>40(18.0)</th>
<th>178(80.2)</th>
<th>222(17.5)</th>
<th>X^2=25.496</th>
<th>P&lt;0.001</th>
<th>V=0.100</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nantong</td>
<td>23(7.9)</td>
<td>378(12.8)</td>
<td>230(79.3)</td>
<td>290(22.8)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sagnarigu</td>
<td>4(1.9)</td>
<td>17(8.2)</td>
<td>187(89.9)</td>
<td>208(16.4)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Savelugu</td>
<td>27(4.9)</td>
<td>62(11.3)</td>
<td>462(83.8)</td>
<td>551(43.3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>Female</td>
<td>27(5.6)</td>
<td>106(21.8)</td>
<td>353(72.6)</td>
<td>486(38.2)</td>
<td>X^2=70.498</td>
<td>P&lt;0.001</td>
<td>V=0.236</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>31(3.9)</td>
<td>50(6.4)</td>
<td>704(89.7)</td>
<td>785(61.8)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>15-24</td>
<td>9(9.9)</td>
<td>15(16.5)</td>
<td>67(73.6)</td>
<td>91(7.2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>25-40</td>
<td>28(3.7)</td>
<td>97(12.8)</td>
<td>635(83.6)</td>
<td>760(59.8)</td>
<td>X^2=17.513</td>
<td>P=0.008</td>
<td>V=0.083</td>
</tr>
<tr>
<td></td>
<td>41-60</td>
<td>15(4.4)</td>
<td>42(12.3)</td>
<td>285(83.3)</td>
<td>342(26.9)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>60+</td>
<td>6(7.7)</td>
<td>2(2.6)</td>
<td>70(89.7)</td>
<td>78(6.1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>58(4.6)</td>
<td>156(12.3)</td>
<td>1057(83.2)</td>
<td>1271(100)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Chi2 tests indicate differences are statistically significant (P<0.05)

Having established farmers' perceptions of changes to rural livelihood practices, we focused on what people think about digitalization and farming practices. Like the perceptions on rural changes, most farmers perceived digitalization to change farming practices: 83.2% said digitalization changed farming practices. In comparison, 4.6% did not think it changed how they or others farm. The highest category of farmers who perceived changes in farming practices were farmers in the Sagnarigu District (89.9% of respondents in the District), male farmers (89.7% of male respondents) and older farmers of 60+ years (89.7% of farmers in that age range). Chi-square analysis revealed
significant relationships between perceptions of farming changes and genders (P<0.001); age (P=0.008); and districts (P<0.001) (see Table 5.3).

Despite some variations in perceptions among groups, farmers generally believed that changes to farming practices served as an example and a channel through which digitalization affects rural livelihood activities. Because rural livelihood activities are primarily connected to agriculture, for instance, agri-food trade and the sale of labour time on farms. Hence, we further assessed perceptions among those who had used digital services regarding seven critical areas of farming activities and practices (see Table 5.4).

<table>
<thead>
<tr>
<th>Area of practice</th>
<th>Description of change</th>
<th>Agree (%)</th>
<th>Disagree (%)</th>
<th>Not sure (%)</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning season</td>
<td>Digital climate forecasting helps farmers decide what and when to plant, minimizing time spent planning</td>
<td>91.1</td>
<td>1.3</td>
<td>7.6</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td>Digital agronomic and climate information aid farmers choose which specific crops to plant. Likewise, knowing what crops farmers easily find digital advice shifts smallholders' attention. Farmers also choose crops based on digital market price information systems.</td>
<td>83.7</td>
<td>7.8</td>
<td>8.5</td>
<td>100.0</td>
</tr>
<tr>
<td>Choosing planting crops</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planting decisions and activities</td>
<td>Climate and forecast alerts help farmers decide what time to plant.</td>
<td>84.2</td>
<td>4.9</td>
<td>10.9</td>
<td>100.0</td>
</tr>
<tr>
<td>Everyday farm care practices</td>
<td>Weather information allows farmers to decide when to visit farms for fertilizer application, weeding, and pest control Climate and weather information influence when farmers decide to harvest.</td>
<td>80.1</td>
<td>10.2</td>
<td>0.7</td>
<td>100.0</td>
</tr>
<tr>
<td>Harvesting activities</td>
<td>Price and market connections also affect when a smallholder decides to harvest and transport produce.</td>
<td>89.6</td>
<td>1.6</td>
<td>8.8</td>
<td>100.0</td>
</tr>
<tr>
<td>Post-harvest management activities</td>
<td>Farmers are using weather alerts to decide when to dry farm produce.</td>
<td>85.8</td>
<td>2.0</td>
<td>12.2</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>79.4</td>
<td>4.7</td>
<td>15.9</td>
<td>100.0</td>
</tr>
</tbody>
</table>
Among all seven areas, most respondents indicated having their practices changed because of engagement with digital tools and services. For example, season planning was the highest change respondents indicated. This was followed by changes to harvesting activities and post-harvest management activities. However, changes to everyday farm practices had the highest percentage of no change. Decisions on the choice of crops, changes to planting decisions, and marketing and sale activities followed respectively in the practice areas with less experienced changes among smallholders. We found that the intensity of experienced changes was partly attributed to the nature of the information provided and the applicability within specific periods of a farmers’ season. For example, farmers indicated that service providers always try to engage them actively at the start of the season, which allows them to use more of the information provided in those periods. Likewise, farmers’ desperation to find markets after harvest meant they paid attention and applied the information provided during those periods. Generally, farmers indicated having experienced some change in their routines and practices from using digital tools and services, which points to high usage of digital information by participating farmers.

Summarily, the results show that rural smallholder farmers perceived digitalization to change their farming practices. Many farmers spoke about the issue of change based on having access to timely and essential information that they probably won’t have without digital services. One farmer, when speaking on the subject of changing ways of farming, noted:

“We have been fortunate to have these tools and services. Before, we were in darkness, but now, I can say that everyone in this group has benefited from our information. It has changed different aspects of how we farm in this community, and I mean changes that my peers can attest to. Now I don’t waste my fertilizer by spraying and having the rain carry it away that same day, and this is from the information I get about rain before I make any move, you see” Dasana, a focus group in Kuldaanaali (FG6-F)

The experience of Dasana was shared by many farmers in our interviews and focus group discussions. These testimonies pointed to digitalization-driven alterations in routines. The following section will expand this theme of changing patterns and practice by showing how smallholders experienced changes through specific use cases.
5.7.2 How do agricultural digitalization services cause change to smallholder farming at the basic level?

Using the three use cases outlined in the methods, we employed qualitative interviews and focused groups in selected communities to explore four primary services: agronomic advice (Farm Radio); weather information (Farm Radio and Esoko); market/price information (Esoko); and market connections (Agrocenta).

Interviewees shared that digitalization offered mechanisms to change farming activities. More importantly, farmers saw digitalization as the services provided, rather than just the technologies; “we know there are new methods to reach us with all the phones and things, but I think for us here it’s about the knowledge we get, and you the new things [services] they do for us in the community. Because many of us didn’t go to school, we cannot use technologies, but we benefit from the information” (F4-F). Hence, farmers constantly spoke of receiving information through the phone, in diverse forms, as the anchor to digitalization. Thus, digitalization in smallholder systems is more about the services created from digital tools. Nonetheless, farmers were still particular about how the new technologies, particularly phones, changed their longstanding practices. Table 5 outlines some of the change mechanisms respondents mentioned and corresponding quotes.

Table 5.5 Summary of farmer experiences of changes from digital services

<table>
<thead>
<tr>
<th>Digitalization service and solution use case</th>
<th>Some change mechanisms noted</th>
<th>Corresponding quotes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Agronomic advice</strong></td>
<td>Alterations of time spent on on-farm practices. E.g., Planting (n=6)</td>
<td>“When I beep [call], I know what to do, you know. I don’t waste time on things I don’t.” F4-F</td>
</tr>
<tr>
<td></td>
<td>Reduction in overall time spent on farm care practices (n=11)</td>
<td>“Because of the advice, I know when to go to the farm, not every day now.” F5-F</td>
</tr>
<tr>
<td></td>
<td>Making quick decisions on what and when to do on-farm in specific cases (n=7)</td>
<td>“They tell us what we can grow, so sometimes I listen to them and follow. I mean, change things.” FG7-F</td>
</tr>
<tr>
<td></td>
<td>Changes to choice of the crops to grow based on advice (n=3)</td>
<td>“You see, the radio program is perfect for us, we have learnt so much from Farmradio, and this has meant many people in this community now do things that we were taught from it...we can’t say we have not seen any change” FG7-F</td>
</tr>
<tr>
<td></td>
<td>Altering planting periods (n=6)</td>
<td></td>
</tr>
</tbody>
</table>

133
Weather information

Times of planting now informed by alerts (n=8)
Decisions on crops to plant based on information received (n=2)

Times of fertilizer application informed by weather alerts (n=12)
Farmers make decisions on when to spray fields based on weather information (n=13)
Post-harvest practices, such as drying of groundnut, informed by weather alerts (n=8)
Changes to days farmers visit markets (n=6)

Market/price information

Changes in market farmers decide to access (n=5)
Price information influences who farmers sell (n=5)
Changes in when farmers decide to sell (n=6)
Opening new markets for farmers (n=3)

Farmer make decisions on what to cultivate based on market information (n=2)

Market connections

Farmers access markets right at their doorsteps rather than transport to markets (n=8)
Decisions on size of production based on available connected market (n=5)
Elimination of sourcing market from rural farming routine (n=7)

“When I see the messages, I know planting today is not good, so I change the plans” FG7-F

“I changed wanted I wanted to plant because the message was that not much rain in that year” F8-E

“Sometimes, my wives depend on the information on when to dry groundnut. When I get the text in the morning, they ask, and I tell them no drying today or let dry early today….” F6-E

“I wait to see the text before I go and spray. Even others call me to know and act on it…..” FG7-F

“The price information means I can choose where I go, I mean any given time, you see…..” F8-E

“Now I don’t have to sell to without knowing the price. That thing I mean, let us here decide when and where to sell. Good for us…..” F6-E

“Ohh Agrocenta, they bought what we produced, so we all didn’t spend time going to market..” F12-A

“I produced more acres when they promised they would buy later..after harvest. In fact, I have since increased my farm size because I know the market is here, I don’t need to spend more time thinking about how to sell. I just focus on farming.” FG1-A

From Table 5, we found within our study cases that farmers' experiences and testaments to changes emanating from digitalization focused on the specific services offered. Hence, we expand on the routine altering experiences of the services as reflected by respondents.
5.7.2.1 Agronomic advice and changing practices

Farmers view the delivery of agronomic advice through radio, SMS and calls as integral to how they farm. For many farmers, mobile agronomic advice was critical to what, when and how to plant and spray. For example, at a focus group discussion on Farm Radio programming, a participant noted that:

“our prayers have brought you, people, here…. serious, we have been looking to talk to Farm radio again. What Farm radio did in this community with the radio programme, you know they talked to some of us, we called in too, we did many things with them, but everyone in this community really can say they changed how we farmed. We didn’t know you could plant rice in rows, but we followed the programs, and they reminded us on the phone, now everyday plant that way. And then the fertilizer thing and how to take care of our crops, I do, and I think other people here will tell you, we follow what they say, and farming has never been the same since they came, many things have changed. In part of my plot, I even stopped growing yam because they made us know that soil was not good for it” FG7-F.

The farmer was adding his views on experiences of change they have seen as the result of engagement with digital services and solutions in their community. And like many others across our cases, the farmer emphasized mainly how the digital delivery of agronomic information has allowed them to change the ways they cultivated rice in the community. Likewise, farmers switched crops in some seasons based on their radio programming and calling to ask the experts. The ability of digital information to open them to knowledge quickly was crucial in how farmers made decisions on what they do on their farms throughout the season. Being able to reach agronomic information faster also meant that they could respond to emergent issues quickly and in varied ways, as a lead farmer noted: “because I easily connect to them when the fall armyworm came, and we didn’t know what to do, we called, they provided directions, but people were also able to learn from the radio and engage in finding solutions to their unique farm issues” F4-F. Many farmers shared this view, but mostly those actively engaged with the program.

5.7.2.2 Weather information and changing practices

The provision of weather and climate information was a common form of digitalization with apparent routine changing experiences. Farm radio and Esoko programs incorporated this element within our case areas by delivering information via SMS, phone calls, and radio. We found that providing climate and weather information via these channels allowed farmers to change different aspects of their farming routines. A respondent who has received both services and continues to actively do so talked about how the services informed the family’s farming activities:
The weather alerts have been essential for me, they don’t always come true, but they mostly do, which changes many things for me and others in this community. I have paid for it for about five years now, and people come to ask me what it says daily. When we have that information, it brings to light many things. They tell me the forecast, so I plan my planting and spray based on it. Before that, we just spray, and sometimes rain will wash it away, and your time and money go like that. It's different with Esoko…you know what? Even when we harvest groundnut and want to dry, I tell my wives that alerts just ensure they don’t waste time bringing things out and rushing to the store again because of unexpected rain. F4-F

Specifically, we found this information to change practices in planting, crop management and post-harvest activities. When farmers receive weather alerts, they apply the knowledge to inform their livelihood activities, including specific procedures related to farming. Farmers plan farming activities based on the alerts rather than through past uncertainties. Thus, digital weather information clarifies farmers’ routines, allowing them to efficiently plan and execute specific tasks. As noted in the extract above, the information enables farmers to plan when to plant, produce, spray, and undertake certain post-harvest management activities, such as when to dry their crops. And for farmers, the key to changing routines, in this case, is the effect of time use and efforts put into undertaking the specific farming task.

5.7.2.3 Market/price information and changing practices

We found that farmers employed market information alerts to alter their marketing channels and activities. Many farmers traditionally sell at nearby open markets as they blindly send produce without information, exposing them to poor rates. Farmers also mentioned that intermediaries came to communities to buy produce at their set prices, which is most unfavourable. However, the engagement with market price alerts has since altered many ways they go about their sales. For example, some farmers mentioned that when they know the prices at different markets through the alerts, they can make good decisions and “choose where and when to go and sell” (F8-E).

Likewise, market price information allowed them to change how they negotiate with buyers at home and market sites. When farmers know prices beforehand, their marketing strategies change to incorporate added knowledge. A farmer of over 60 years made the following assertion: “when everything is good, then I am no more a blind farmer forced to sell; I decide when I want to go to the market, the days, and when we get there, it becomes easy because I don’t have to be calling people asking for prices” (F8-E). The added knowledge and advantage in negotiating sale activities are crucial for many farmers' interaction with other value chain actors, including go-betweens and wholesalers.
In the case of F8-E, she refers to when everything is good, meaning when they are not financially strapped to sell. This assertion implies that farmers alter their marketing practices based on circumstances. So, even with the information, the rules sometimes stay the same when other barriers- including poverty and emerging financial needs- undermine the realistic applicability of the knowledge.

5.7.2.4 Market connections and changing practices

In a conversation with F4-A, who happened to be the youngest most active farmer that has participated in this digital-enabled market connection, he was quick to point to the diverse ways farming has changed in the last three years:

Lead author: you have experienced this program for a while, so how has that changed your ways of farming?

F4-A: so many ways Afa, I think for me, it's the freedom from hustling for the market. I concentrate on just farming.

Lead author: can you shed light on freedom and concentration? What has notably changed in your farming routines?

F4-A: I changed many things…at least, I haven’t gone to the market centre for two years, at least not to sell my maize or sorghum. When I harvested in the past, I travelled several miles to market, sometimes many times. And sometimes, I don’t even get buyers, and I carry the maize back. Think of the struggle. Things were different when they came and registered us, provided us inputs in the first year, and the agent continued to visit and advise us. I call him to come for what I have, don’t go anywhere. They even pay me on my mobile money..you know that’s anything because now no fear of losing money in travels.. cash is secured. You see, these are all peace of mind…

Throughout our interviews, farmers who participated in market connection programs over the years shared a sense of peace of mind from the certainty of produce sale, as Jonathan noted. And the changes that come with that, within farming activities or broader social life, were considered instrumental in solving problems they face, in this case, access to the market and security of money. Farmers viewed these changing dynamics of how they go about sourcing markets as an essential step in reducing the work they had to do or what it meant to be a farmer. For example, struggling to find buyers for farm produce and all the activities associated with that is what the typical person will describe rural farming. Still, emerging digital market access solutions changes this conception for some farmers. F4-A later added in our conversation, “what is expected for us farmers is changing…and if these services become widespread, many people will sell through the program instead of travelling long distances to markets. As I said, we will do our farming on the farm, and that’s it”. By concentrating on just activities on the farm, a digital solution may just be offering pathways to changing farmers' everyday routines across different practice areas.
The results presented here show that digitalization is changing the practices of farmers by repartening farmers' use of time, space, and relationships. More importantly, rural farmers were generally happy with the changes experienced. Because 89.89% of our survey respondents indicated that they were excited about the changes to their activities from engagement with digital tools and services. Likewise, about 86% indicated they were looking forward to the future due to the benefits they or others have experienced with the services. The reasons for potential future use were past positive experience (65%), curiosity (45%), and openness to anything that adds new farming information (62%). Hence, farmers generally perceived digital information and services as a positive change in their activities.

5.8 Discussion: Digitalization Catalyzing Changes in Routines and Rhythms of Rural Farming?

As presented, farmers from our different study districts, genders, and ages perceive that digitalization services are changing the way people undergo their livelihood activities. Consequently, there is a significant relationship between gender, age or district and farmers' perceptions of change. Nonetheless, there is a uniformity of agreement that emerging digital services are altering rural livelihood activities. Changes to farming practices offered one conduit through which digitalization transforms rural livelihood activities.

Specifically, digitalization has changed how farmers use materials, space, and time to accomplish their goals. Through engagement with digital services, farmers changed when and how they plan and prepare for the farm season, plant, and undertake agronomic activities, such as weeding, pest control, and fertilizing. Specifically, agronomic advice allowed farmers to change their daily routine and interactions with the farm. At the same time, digital price alerts and connections to markets meant that the relationships and interactions farmers have with actors along the value chain are being reshaped. Changes were also experienced in post-harvest practices, marketing and sales. The changing farmers' routines and their interactions and connections to the land, crops and other actors (e.g. middlemen and market women) as they engage with digital services confirm Bear and Holloway (2015, 1) claims that even the very ‘ostensibly mundane’ technological innovations can considerably vary what it is to ‘be a farmer, a farm advisor or a farm animal.’ Hence, the practice-altering mechanisms of mobile-based digital services enrich our understanding and experiences of how the digital revolution reshapes rural subjectivities (Rolandi et al., 2021; Rose & Chilvers, 2018)
and, in the process, either strengthen and undermines certain elements within rural areas (Carolan, 2020a).

It is essential to understand the theoretical mechanisms of how digital services lead to farming and rural changes. When asked how digitalization has changed agriculture and life in the community, a participant in a focus group discussion noted:

“These innovations have done a lot for us here, really have changed how we see and farm in this community. Yakubu already mentioned how that weather prevents us from wasting our fertilizer, that is true, but they also help us know how to apply inputs. The change is really in how we now plan and use our day, what we decide to do and when. You see, the information and the alerts make us do these things. In the past, I used to say I would plant today, but I got to the farm and no rain. But now I sometimes plan based on their forecast, they can say expect the first rain in one week, so I know what to do. In the end, you just know whether to do more or less of activity in your life because you have information. It has changed many aspects of my life because all we do is just the farming…you know” FG5-F- Focus group at Pahazaa

As we have noted earlier, agriculture transformations partly manifest through specific changes in practices that make up farming and rural life. Following Warde's description of eating as an interconnected and a compound practice (Warde, 2013) and earlier works on bundles and constellations (Shove et al., 2012), farming shares similar attributes of being an integrated practice (Schatzki & Schatzki, 1996). Farming comprises different components, including planning, land preparation, planting, weeding, fertilizing, harvesting, marketing, sales, and judgments of good agriculture. However, within each of these practice areas now lies digitalization altering mechanisms, i.e., reducing time spent on the farm and altering when and how to undertake specific tasks. For example, when a farmer changes when and how to plant, fertilize, or market due to reliance on digital tools, they invariably alter the basic makeup of their social practices, social interconnection, and the social structuration of what it means to be a farmer. When the respondents who benefitted from market access talked about their concentration on farming and foregoing visiting market centres to sell, they spoke to changes in the very traditional setup of agriculture, as new marketing and sale processes replaced older ones.

Furthermore, we argue, and in consonant to practice theory (cf McMillan, 2017; Schatzki, 2002; Shove et al., 2012; Røpke & Christensen, 2013; Southerton, 2020), that the ability of digital tools and services to alter rural communities may lie in how they reshape the routines and rhythms of farming life and the connections to other activities. More particularly, as many farmers noted, how the services allowed them to reorganize what and how they farm lays the foundations for social change. As Shove et al., (2012, p. 3). put it, “…understanding society's spatial and temporal rhythm
is, in essence, a matter of understanding how some practices flourish and others fade; how qualities of frequency, duration and sequence emerge…” As the results showed, digital services and solutions allow farmers to alter the frequency, duration and sequence of planting activities, crop care, harvesting and marketing strategies. For example, respondents noted how weather alerts have minimized the frequency and time spent going to the farm on certain days and only to ‘return soaked in the rain and having nothing done.’ Planning daily activities based on the information means that the rhythms of farmers’ livelihood activities increasingly rely on digital technologies (cf Røpke & Christensen, 2013). And since farmers do more or less of the same practices every day (cf Lefebvre, 2013), based on product, location and time of the year, digital services now allow them to scheme what and how they go about routines temporally. For instance, we found that on a typical day in late April to May (the start of the farming season), an ordinary rural farmer in Northern Ghana undertakes the following routine: wakes up, takes breakfast, rides, or walks to the farm, does field preparation or planting, riding back home, visiting family, and talking to peers at community ground. However, on days of an alert indicating rain in the morning, the routines are reshaped to exclude, for example, visiting the farm and planting. Instead, the time is used to do other activities, such as spending time with children. These tidal movements and performance of everyday farming experiences constitute the ‘softening’ of farming time and space (cf Røpke & Christensen, 2013). Digital information and services engender social restructuring as farmers’ life become a ‘squeeze of practice-related injunctions of sequencing, coordination and personalized scheduling’ (Shove et al., 2012).

The changes discussed may offer opportunities for positive development in smallholder livelihood systems. Our research shows that farmers generally perceive these changes, such as less time usage from ‘blind visits’ to farm and wastage of money from having rain wash away fertilizer, as burden easing on time, financial resources, and stress of farming. Specifically, digital tools and services engender functional changes among farmers and are positively described as “huge help because they introduce information and knowledge that makes our farming better now” (F3-A). These types of optimistic anticipations of farmers corresponded to the early expectations and technological romanticism that digital tools have received among development organizations and some researchers, especially within the context of the Global South (Abdulai, 2022).

However, it is still important to approach these changing practices with caution. Two key reasons make the need for caution critical. The first is that, I have shown in previous Chapters that farmers use of digitalization is limited at best and the building blocks for widespread engagement is weak. Hence, any potential changes to practices may still be confined to the few elite farmers who
are prededged to engage. The second reason is that, previous research is also concerned about the possible undesirable socio-political-economic consequences that may result from digitalization across spaces and groups (Bronson & Knezevic, 2016; Carolan, 2017a, 2020b; Duncan et al., 2021; Klerkx et al., 2019; Rose & Chilvers, 2018; Rotz et al., 2019). For example, Carolan (2017, p. 145) found producers expressing anxieties over "how this (digital technologies) "seemingly 'objective' technology amplifies particular characteristics while undermining other qualities that they believe are essential for creating healthy rural communities." The anticipated changes at different scales may strengthen or weaken structures and experiences that form the foundation of rural farming, including farmers’ connection to the land and the environment. Such changes hold socio-political implications on the constitution of farming and farming lives within rural communities (Bronson, 2018; Carolan, 2018; Klerkx et al., 2019; Rolandi et al., 2021; Rose & Chilvers, 2018). For example, digital tools depend on farmers’ ability to operate mobile devices and, more importantly, literate enough to read and understand. This requirement means that educated farmers may have an unfair advantage. Likewise, having digital information be the source of farmers’ action could mean the role of who has influence within communities shift from holders of traditional socio-ecological knowledge to the educated, and more so to the ‘seemingly objective’ technologies and services that offer advice.

From the ensuing discussion, we have established that the everyday use of digital technologies and services in farming presents mechanisms through which the practices of agriculture and rural are potentially reshaped. However, we must be clear that we have neither confirmed nor refuted any claims of positive or negative impacts of digital tools as our results are non-directional and non-judgemental on the merits or otherwise of these changing practices.

5.9 Conclusion and Policy Implications

This paper draws on the social practice theory to discuss the evolution and changes in farming practices in Northern Ghana, a region characterized by smallholder farming systems, specifically rain-fed cereal and livestock production. We established that digital tools and services redefine rural life by altering the routines and rhythms of farmers' daily practices and how they use space and time to achieve their livelihood goals. This paper presents the first attempt, to our knowledge, to examine the social dimensions of digitalization through an explicit practice lens in the context of smallholder farming systems in Africa. Our paper contributes and provides empirical backing to earlier assertions that digital technologies may rescript and change rural farming and communities (Carolan, 2020b; Rolandi et al., 2021; Rose & Chilvers, 2018) by showing that the phenomenon may alter when and
how of farming practices. More importantly, our paper lays the foundation to significantly shift the
discourses around digitalization from their broad focus on transformations and disruptions to a
refocus on mundane changes experienced by farmers in their everyday life.

Hence, our findings on the specific ways digital services affect change in farming present
inputs to programming in the sense of a deep-dive space for identifying potential impacts of
digitalization. It is crucial to focus digital transformations on incremental progressive change in
people's practices rather than transformations and disruptions. This shift is critical considering the
findings of weak building blocks for digitalization and potential political-economic implications in
everyday farming activities (See Chapters Two and Three). Since change manifests in the practices,
they help show what activities to focus on when designing programs that affect farmers' livelihoods.
Hence, stakeholders could use these everyday practices to measure what and where changes happen
when interventions are implemented and who is likely to embrace such changes.

However, while we show that digitalization leads to changing practices, we do not claim to
provide an exhaustive stock of the ways digital tools may or may not change farming and
communities. Neither have we evaluated the implications in terms of possible outcomes, i.e. related
to power, wealth, ecological feedback, and impacts. Instead, we have outlined how these
technologies redefine what farming means and how it is done within rural smallholder settings.
Hence, the changes to farming practice must not be taken uncritically. Further research on the
inclusiveness and sustainability of the changing patterns would be needed. Likewise, research is also
needed on whether these changes lead to desirable and undesirable impacts on diverse farmers' social
well-being and socio-economic sustainability and farmer-environment relationships. Future research
must also assess the nature of advice and services and the kind of world views they propel.
5.10 References


Bronson, K., & Knezevic, I. (2016). Food studies scholars can no longer ignore the rise of big data. *Canadian Food Studies / La Revue Canadienne Des Études Sur l’alimentation, 3*(1), 9. https://doi.org/10/ggt3s3


6.0 Towards digitalization futures in smallholder farming systems in Sub-Saharan Africa: A social practice proposal

6.1 Preface to Chapter Six

I have shown the importance of or lack of operational pre-conditions for digitalization throughout the earlier chapters. I have also emphasized digitalization's role in entrenching inequalities in Africa, including rural people, smallholders, and women. This chapter builds on this line of thought and draws on the social practice theory introduced in Chapter Five to offer futuristic and directional guidance to smallholder digitalization in Africa. More importantly, this Chapter aims to guide thinking and intervention for digital agriculture.

Specifically, I use qualitative key informant interviews to move forward with my novel social practice understanding of the digitalization of agriculture in Chapter Five. I expand on the social practice approach by moving from theoretical understanding to a more practical application. Here, Shove et al.’s (Shove et al., 2012; Shove & Pantzar, 2005; Shove & Walker, 2014) three elements framework for the formation of practices (materials, competencies, and meanings) and their application in the constitution of everyday life is introduced and applied to digitalization in Africa. I show that just like previous practices discussed in the literature (Hand et al., 2005; Morley, 2016; Shove & Pantzar, 2005), the introduction of digital agriculture can be thought of as the emergence of a new practice, which will require the integration of materials, competencies, and meanings to bring the phenomenon to life in smallholder systems.

This chapter extends Chapter Five by applying the conception of digital agriculture as a practice but doing so through the practical application of the approach to understand and guide processes of interventions. My application of the social practice approach to the future formation of digitalization in Africa allows for moving beyond the technologies to value competencies and meanings of the technologies, which are also critical in unpacking the socio-political-economic implications I have emphasized throughout this dissertation.
6.1.1 Preface references


6.2 Publication Details

6.3 Abstract

This paper contributes to the digitalization of rural agriculture literature by proposing a social practice approach. Digitalization (practices) is conceived as an unfolding constellation of everyday farming activities manifested by practically conscious people meaningfully integrating materials elements of life. Thirty-one key informants' interviews were conducted on experiences and pathways for the future success of digital agriculture. Thematic and content analysis of the interviews revealed that materials (access to digital tools, enabling digital infrastructure, supporting social infrastructure), competencies (digital literacy among farmers and extension officers, IT and data education among populaces), and meanings (connecting digitization with local customs and norms and aligning digital tools with the values/perceptions of what farming is) are critical to establishing and embedding digital tools and services in everyday agriculture in Africa. Thus, I propose a practice approach to understanding, researching, and guiding processes of rural smallholder digitalization. The proposed approach would allow for interventions that focus on the building blocks that bring agriculture digitalization practices to life. I offer the first application of the social practice lens to establishing digitalization in smallholder systems and provide an outlook that moves beyond the technologies to value competencies and meanings equally.

Keywords: Digitalization; social practice; smallholders; African agriculture; rural change

6.4 Introduction

Digitalization of agriculture —leveraging digital tools to enhance agricultural processes — is suggested as a pathway to transformational futures in smallholder farming and livelihoods in Africa (Duncan et al., 2021; Tsan et al., 2019). Specifically, digital services are anticipated to affect the outlook and everyday practices of smallholders by, for example, bridging information asymmetry that hinders agricultural activities across the value chain (Babcock, 2015; Evans, 2018; Technical Centre for Agricultural and Rural Cooperation, 2019). Meanwhile, challenges such as farmers’ resistance to change, low willingness to pay for services (Hidrobo et al., 2021), low digital literacies and poor rural infrastructures continue to impede digitalization penetration (Tsan, et al., 2019). Yet, despite the hope for a digital transformation in Africa (Atanga, 2020; Babcock, 2015; Farayola et al., 2020), the literature is limited in directionality or ability to offer guidance to future success in the context of operational limitations within African farming systems, including uneven access to resources. Likewise, current studies ignore the potential to consider the digitalization of agriculture as
an unfolding social phenomenon situated in people’s everyday lives. Meanwhile, digital technologies may still affect and impacts everyday practices (cf Røpke & Christensen, 2013), including how farmers use space and time to accomplish their goals (see Chapter Five). These gaps lead to lingering questions on the future of digitalization in Africa, including what are elements needed for the formation and embedment of digitalization in smallholder farming systems? This paper aims to answer this question and (re)shape how we think, discuss and act about smallholder and rural digitalization, from one that considers its process entirely technical to one that emphasizes its (re)formation as an unfolding social practice of agriculture that requires conscious attention to the foundational building blocks for digital innovations.

Here I employ social practices theory—an approach that focuses on everyday acts' saying and doings (Reckwitz, 2002; Shove et al., 2012)—to highlight the essential building block required, as deduced from the sayings and doings of actors in the African digital space. Specifically, I interviewed agricultural development practitioners and technology service providers (n=31) actively engaged in designing, implementing, monitoring and evaluating digital agriculture programs, innovations, tools and services across Africa. The shared experiences of these actors offer valuable insights into the practical workings of the digital agriculture ecosystem, including the use cases of digital tools and services, successful interventions, challenges, and, more importantly, how to achieve robust, sustainable, and inclusive integration into smallholder systems.

Hence, I draw on the experiences to argue that the emergence and persistence of digitalization in African agriculture partly hinge on paying attention to its formation as a social practice, defined as the routinized (Reckwitz, 2002) doings and saying of everyday life (Schatzki, 2001) that connected by elements (Shove et al., 2012). Paying attention to the creation and integration of the needed components for embedding digitalization practices into smallholder and rural farming systems is critical. In what follows, I first provide an overview of early efforts to digitalize smallholder agriculture in Africa and then describe social practices theory, which forms the theoretical lens through which data are interpreted. Critically and as described below, social practice theory involves three key concepts: materials, competencies, and meanings. Next, I present the findings that show how understanding these three key elements are integral to any successful digital agriculture future in Africa. The discussion applies the three elements to highlight what social practice of digital agriculture could re-shape interpretation, thinking and acting on digitalization, and draw practical implications for that approach. The conclusion reflects the approach's value and how it can influence the digital agriculture practice space.
6.5 Background

6.5.1 Smallholder agricultural digitalization in Africa

In Africa, smallholder agriculture is increasingly positioned within the conversations of the digital economy. Mobile phones, radio, computers, drones, satellites, artificial intelligence, cloud computing, the internet, and big data have become a part of the fibre of agricultural systems in Africa and across smallholder systems (Food and Agriculture Organization of the United Nations & the International Telecommunication Union, 2022). Actors deploy these tools to create new and novel services that are anticipated to change the everyday practices that form the crust of agriculture, such as preparation of land, crop management, seeking inputs, harvesting, post-harvest management, and marketing produce. Digitalization services range from simple advisory to smallholder farmers through mobile phones to high-end use of drones and satellites for precision soil and nutrient management on farms (see Deutsche Gesellschaft für Internationale Zusammenarbeit et al., 2021; FAO, 2019; Tsan, et al., 2019). These technologies are generally thought to improve livelihood conditions in rural areas through their efficiency-enhancing capabilities by providing access to critical information and services (Etwire et al., 2017). Notably, digitalization is proclaimed a transformative and disruptive innovation in agriculture (Kim et al., 2020; Tsan et al., 2019).

However, despite the transformative potential, scholars from science and technology studies caution that technologies inevitably must interact with people, culture and social practices, and it is out of the mixture between the functional and the social dynamic of technology that transformations may occur (Carolan, 2020; Klerkx et al., 2019; Rose & Chilvers, 2018; Rotz et al., 2019). For example, according to Carolan, digital technologies may amplify certain elements in rural communities while undermining others. Accordingly, scholars from responsible innovations have called for careful consideration of the ethical issues around the development and deployment of these technologies (Bronson, 2018; Eastwood et al., 2017; Klerkx & Rose, 2020; Rose & Chilvers, 2018). These discussions open space for engagement in the future directions of digitalization, and it is from this pretext I situate this paper. Mainly, the paper contributes to the futuristic-focused arrangements with emerging digital innovations by exploring what it may take for digitalization to truly manifest within the social context of rural Africa. This paper, therefore, extends the literature in this direction by introducing a practice theory approach to building the core blocks for agricultural digitalization.
6.5.2 Theoretical Underpinning: The Constitution of Social Practices

As just discussed, digitalization is increasingly embedded in African agriculture. And social practices theory could offer essential guidance for the future directions of the phenomenon. "…social practice theory is a distinct approach that focuses on the dynamic unfolding of constellations of everyday activities or practices to other practices both within the same time and space and across time and space" (Feldman & Worline, 2016, p.304). The approach focuses on understanding practices, their constitution, and dynamics (Nicolini, 2017; Shove et al., 2012; McMillan, 2017). For Reckwitz (2002), practices are the "…routinized way in which bodies are moved, objects are handled, subjects are treated, things are described, and the world is understood." (p.256). Hence, practices are the unfolding constellations of everyday activities (Feldman & Worline, 2016) which are manifested as practically conscious people meaningfully integrate material stuff of life. Though there are different strands of explaining social practices, one of the most familiar and simplified approaches to understanding and study practices is the proposals by Shove et al. (Shove et al., 2012; Shove & Pantzar, 2005; Shove & Walker, 2014), where practice emerge and change from the integration of materials, capabilities, and meanings (Figure 6.1).

![Figure 6.1: Elements of social practices](source: Adapted from Shove et al. (2002))
Materials are the things and stuff used to accomplish practices. Specifically, materials include the items, technologies, tangible physical entities, and the stuff of which objects are made and used in everyday practices (Shove, 2010; Shove et al., 2012). The notion of material as integral to practices is discussed widely among practiced theorists (see Hand et al., 2005; Schatzki, 2010; Shove, 2010). In the many works of Latours (see Latour, 2007, 2009), he emphasized the role of “non-human things” in the construction of social life. Likewise, Reckwitz argues that “artifacts” or “things” necessarily participate in social practices just as human beings do’ (2002: 208). Undertaking practices require ‘using particular things in a certain way” (Ibid., p.252). Morley (2016) used technologies, specifically automated ‘machines,’ to move forward the discourse on materiality in practice. With central heating and fully automatic factories, they argue that materials — technologies — are not just constituents of practices but move practices beyond the direct relationship of human performance. Hence, material, artefacts, things, and non-humans can no longer be ignored in discussions of social life in our highly technology dependent social world (Maller, 2015).

Examples of materials commonly discussed in the practice literature include walking sticks, roads, planes, cars, refrigerators and bathrooms. As evident in the examples, materials describe any tangible thing that can be utilized by people to undertake activities. Hence, in the case of digital agriculture, materials could include, among other things, phones, computers, drones, roads, and telecommunication networks.

As simplified by Shove et al., the second element of practice is the competencies needed to undertake everyday activities. Competencies describe the abilities, skills, know-how and technique to undertake routines (Shove, 2010; Shove et al., 2012; Shove & Pantzar, 2005). It involves the background knowledge of human beings in undertaking specific tasks and judging the quality of such tasks when others partake in them. Like materiality, competencies are extensively rooted in the works of practice theorization (Reckwitz, 2002). As Shove et al. (2012) put it, “knowledge and understanding are taken to be crucial whether in the form of what Giddens (1984) describes as practical consciousness, deliberately cultivated skill, or more abstractly, as shared understandings of good or appropriate performance in terms of which specific enactments are judged” (p. 22). And though knowledge of performance may vary from evaluating the performance (Warde, 2005), both know-hows come together to form practices. Therefore, they are lumped to describe Shove et al. to represent the broader element of competence. Hence, competence is all general know-how related to the performance and enactment of practice at both the individual and the societal levels. Examples of competence may include the knowledge of kicking a football, scoring a goal, and what makes for a
good football play. Likewise, for agriculture, the skill to sow a plant or drive a tractor, plough a field, read soil maps, and so on are integral to what may make an individual a good farmer or otherwise.

Finally, the last element in Shove’s model is meanings. These meanings refer to symbolic meanings, ideas and aspirations associated with specific everyday practices (2012, p.8). Meanings are the beliefs, understandings, and emotions linked to the materials of practices. For example, as Holtz (2014) shows, the meanings of one's mode of transport could be price, environmental effect, social status and/or flexibility. Hence, an individual may choose a specific mode, for example, bus, due to low cost or free time for socializing (ibid). For every human action, individuals and society have generally associated understanding. This understanding could be true for farming, as farmers partaking in different farming activities, such as organic farming and agroecology, may have a particular knowledge of their practices. These shared or distinct insights and values are equally valid for the kind of technologies individual farmers may leverage.

The three-element model provides a practical framework for interpreting real-world research and a foundation for understanding some of the social implications of digital changes for farming in Africa. This model helped advance everyday life's dynamics by showing how practices "emerge, persist, shift and disappear when connections between elements are made, sustained or broken" (Shove, 2012: p.8). This sketch of practice and change has been applied to understand, among many others, energy consumption changes, nordic walking, food behaviours, and cleaning behaviours. Hence, in this paper, I loosely and somewhat imprecisely apply the three-elements model of practices as a heuristic framework to explain what it may take for digital agriculture to take hold in African agriculture. I do so by conceiving digital agriculture as an emerging social practice emanating from interactions of digital tools with the social rubrics of African agriculture (Cf Røpke & Christensen, 2013).

6.6 Materials and Methods

As common with practice theory methods (Shove & Pantzar, 2005), this paper is a qualitative exploration of Africa's digital agriculture ecosystem. This study aims to understand the African digital agriculture ecosystem and determine what is needed for the new phenomenon to fit into the African agricultural system and work for the collective good of smallholders and rural people. Hence, the specific themes of the research that emerged from the data allowed data collection based on this
broad objective without necessarily having pre-determined theoretical anticipations (Birks & Mills, 2015; Charmaz & Belgrave, 2007).

The data is an outcome of 31 semi-structured interviews with African digital agriculture experts between October 2022 to February 2021. The number of respondents was determined by saturation as common in qualitative methods (Hay, 2016). These experts included officers of NGOs funding and working on the subject, technology hub operators, development practitioners, and technology service providers across Africa. Participants included officials from inside and outside Africa with expertise on the subject; the majority of respondents were, however, working in the digital spaces in Ghana, Kenya, Ethiopia, Kenya, Tanzania, Zambia, and Nigeria- which are among the hubs of agricultural digitalization in Africa (GSM Association, 2020). Others, such as officials of international donor organizations, were stationed outside Africa but actively worked with entities in the digital agricultural ecosystem. Experts were sourced online through advertisements of the research on LinkedIn, FAO e-agriculture community, and emails to officials found on websites of known digitalization services, NGOs, and development actors. Participation was open, and inclusion was based on availability and willingness to engage in the research. The interviews were conducted online between December 2020 and March 2021. All participants were asked a series of questions, including, using your experiences, what has helped digitalization in Africa so far? What structural elements have supported/hindered digital services and solutions for smallholders in Africa? How do we move digitalization to an established system within African agriculture? What measures are needed for a successful digital future for smallholder agriculture? Each participant was asked varied iterations of these broad questions in interviews that lasted between 45 minutes and 1 hour 15 minutes, with an average of 50 minutes. All interviews were recorded and transcribed with Express Scribe for onward analysis. Participants were assigned pseudo-names in the transcription process, which were later used in the research and writing of this paper.

The transcripts were analyzed through thematic analysis (Braun et al., 2019; Nowell et al., 2017), where the focus was on drawing out the key themes from the conversations. First, the transcripts were printed and read to draw more prominent themes using an inductive approach—where the themes are derived from the data rather than pre-determined. From the first review, we identified three key themes: I) the material elements that could make digital services and solutions come to life; II) competencies required to use and turn materials into practical activities and; III) Shared meanings and understandings that will drive stakeholders to accept and act on digitalization. These themes led us to use practice theory as a framework to present and interpret the results in the next
section. Secondly, the transcripts were uploaded into Nvivo 12 software, where further thematic analysis was applied through a deductive approach of identifying extracts that expanded on the themes identified in the first stage. To ensure transparency and minimize the researcher’s theoretical propositions or biases in the coding, a colleague undertook a second coding and developed themes [from a neutralist's viewpoint]. The results were compared and combined for content-based analysis—a strategy proposed by Emerson et al. (2011). The specific themes and supporting ideas were extracted to present the results in this paper. This approach allowed extracting direct quotations to echo the voices of the interviewees—and to ensure that contents stay close to respondents’ words, a situation which adds more validity to qualitative research (Assarroudi et al., 2018; Flick, 2018).

6.7 Results: The Three Elements Essential for Digitalization of Agriculture Practice

The interviews with key informants revealed that Shove’s three elements for the formation and performance of practices are essential to organizing digitalization in Africa (Table 2).

Table 6.1 Summary of key Issues noted by respondents

<table>
<thead>
<tr>
<th>Key element</th>
<th>Key themes</th>
<th>Example and application</th>
<th>Illustrative quotation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Material elements</strong></td>
<td>1. Access to digital tools</td>
<td>Farmers access phones, TVs, radio and other tools</td>
<td>“I think we have to think about developing the technologies in our context first. And I mean from the farmer up. Farmers need good phones, but we need to have good networks too for things to work.” — Joshua, Extension Agent.</td>
</tr>
<tr>
<td></td>
<td>2. Enabling digital infrastructure</td>
<td>Rural roads, electricity, etc</td>
<td>“Enabling environment would be a big thing to pursue, you know the telecommunication, roads, and policies. So everything that can support digital.” — Founder of a tech company.</td>
</tr>
<tr>
<td></td>
<td>3. Supporting social infrastructure</td>
<td>Telecommunication infrastructure</td>
<td></td>
</tr>
<tr>
<td><strong>Competencies required</strong></td>
<td>4. Digital literacy among farmers</td>
<td>Education and literacy of farmers</td>
<td>“Right now, literacy is low among farmers, so even usage is hard. So we need to work on that aspect.” — Ken, International Development Officer</td>
</tr>
<tr>
<td></td>
<td>5. Digital literacy among extension officers</td>
<td>ICT skill development for farmers</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6. IT and data education among populaces</td>
<td>ICT and data education to create novel services</td>
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<td></td>
<td></td>
<td>New skills required to farm</td>
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<td></td>
<td></td>
<td>ICT education for extension officers</td>
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<tr>
<td><strong>Meanings and understandings</strong></td>
<td>7. Connecting digitization with local customs and norms</td>
<td>Identifying farming values across communities</td>
<td>“These are new to farmers and the industry, so making people understand it is important.” — Kwabena, Implementation Officer</td>
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</table>
6.7.1 The material elements that could make digital services and solutions come to life

The centrality of material elements or materiality was ever-present in our discussions of the digitalization of agriculture in Africa. Respondents consistently referred to how important it was to provide infrastructures, tools, and technologies to drive digitalization. Specifically, the need for rural farmers to have phones and internet access was consistently stressed. In a conversation with Uche, he noted the essence of the availability of technologies and tools in the digital space:

**Interviewer:** having worked with implementing digital solutions as part of your work, what key elements must be present for digitalization for smallholders?

**Uche:** I will say a phone is an essential tool at the local level and for smallholders to have any meaningful digital service.

**Interviewer:** That is interesting. So, when you say phone, can you elaborate on why it is crucial, and how that applies in your activities?

**Uche:** Sure… let me put it this way. The ideal situation for us is for the farmers to have a smartphone and have internet access; that’s the ideal to support digital service. The next ideal situation for us is for the farmer to have a feature phone and a phone network so that the farmer can make a phone call. So, in terms of material support, we could say that providing smartphones for farmers is the support that makes our services possible, but it doesn’t also make sense because farmers do not have internet access for now. But then, providing feature phones for farmers would also make sense, but there is also the possibility that some farmers in areas with no phone network. So that could be a challenge (Uche is a founder of a digital agriculture solution in Nigeria)

This conversation with Uche, who has extensively engaged with earlier efforts to digitalize smallholder agriculture in Nigeria, puts forward materiality by explicitly talking about tools—phones—for digitalization. To put it simply, Daniel [extension agent for a service provider in Ghana] stated, “you see, we cannot talk of digitalization without the digital…and of course, the digital in essence is built on the tools that make them possible”. Here, the emphasis is that mobile phones are critical to making the digital possible and are, therefore, one of the first elements to consider in the digitalization future. Mobile phones are the medium for delivering information to smallholders through SMS, phone calls, Interactive Voice Responses, and even smartphone apps for many digital solutions in Africa. Respondents pointed to many examples of digitalization initiatives that require
these material tools. For instance, Esoko, a climate and market advisory service solution that works across many African countries, delivers information to smallholders via text on mobile phones. The same medium is leveraged by Arifu in Kenya, Digital Green in East Africa and Farmerline in Ghana. Likewise, the call centres—a common digitalization medium in many countries like Ethiopia's 8028 Hotline—require phones’ material presence for smallholders. So, without the material elements of the phone, smallholder digitalization would be severely hampered. Though materials support, including phones and internet infrastructure, have increased drastically in many African countries, respondents believe enormous room for improvement exists if the phenomenon's actual value is realized.

Furthermore, respondents emphasized the need for material support for digitalization at different levels, from the individual (phones) to organizational to national/regional (rural internet infrastructure). We refer to this as “scaler materiality,” which we define as the multi-scaler interlinking of ‘things’ that brings practices to life. Since practices may not always be within the space of the individual but also defined by broader societal structures, materials for digital agriculture must consider current structural inadequacies, say internet infrastructure and electricity:

**Pascal:** Let me say some specific areas OR countries that the benefit has not been captured because mostly in African countries, farmers don’t even have smartphones. They are facing a lot of challenges, not just smartphones. Even if they have a feature phone, they face many challenges like electricity problems. So even though they have, in many cases feature phones or smartphones, cheap smartphones in the countries in Africa, they are not reaping the benefit of digitization for an extension due to a lack of many things like support infrastructure (Pascal, a field officer of mobile-based digital solution in Ethiopia)

**Judith:** If they have a mobile phone and don’t have electricity, it [digitalization] won’t work. However, even though we don’t have to wait to electrify entire Africa, […] developing alternatives, e.g. a solar system, is suitable for agriculture. We need to ensure that the farmer will be, for example, be able to charge their phones to benefit from digital services (Judith, a monitoring and evaluation officer for an international NGO currently implementing digital solutions in Africa).

Respondents alluded to diverse materials, but these elements cut across scales more importantly. While emphasis could be on the immediate digital tools for farmers, respondents found structural materials equally important. Structural materials are materials whose availability, at levels beyond the individual (farmer), makes it possible to establish a practice. For instance, for digitalization to work, the regional electricity, roads, telecommunication and internet infrastructure are as essential as the availability of phones at the individual level. Specifically, almost all digital solutions are built on telecommunication and internet systems and thus require these in rural areas for farmers to fully take advantage of the services provided. A farmer seeking agronomic advice cannot place a call into a call centre without a good network. Neither can they use a smartphone application
to source information without good internet. Likewise, mobile advisories are also functional as long as farmers can keep their phones powered to keep up with up-to-date alerts. As Paul (a field extension officer in Rwanda) notes, “when we don’t have the roads for people to access our communities, or when there is no electricity, then we cannot be talking about digital,” The absence of critical infrastructure—materials—thus plays into the challenge for establishing the digital futures in Africa.

6.7.2 Competencies required to use and turn materials into practical activities

Another vital element in Shove et al.’s framework is competence, which describes the abilities, knowledge, skillsets, and capabilities to undertake everyday activities. Among many others, respondents noted the newness of digital tools to smallholders and rural farming; therefore, new capabilities are required to operate such tools and facilitate their operationalization. For example, when asked what it will take for farmers to benefit from the digital revolution fully, Joshua, a field operator with a digital technology service provider in Tanzania, spoke extensively about digital literacy:

Joshua: maybe some of these policies should be targeting existing opportunities or challenges that I was talking about within this field of digital agriculture. So, let’s say, for example, this challenge of digital literacy: that’s also a challenge that maybe I didn’t mention before, but you might have the right technology in place, right? Perhaps digital infrastructure is in place, but as long as farmers don’t have the ability to use these technologies, that’s what we call digital literacy issues, that will be an issue. So, an intervention could be implemented to train the farmers on using the technology itself. Maybe use or introduce some of the leaders, as the cooperative leaders, to ensure that we have this technology, but it has to benefit farmers. They have to know how to use it- so that’s one thing.

Digital literacy in this context describes the ability to understand and operate the tools and services presented by digitalization. Among all respondents who talked about smallholders, the theme of knowledge and skills to understand and use digital information, thereby practicing digital farming, was an ever-present issue. The emergence of this theme speaks to the centrality of knowledge in the smallholders’ digital futures. At the basic scale, digital literacy is critical for rural farmers to fully immerse themselves in the power of information on their mobile phones. For instance, delivering agronomic and weather advice through mobile technologies to farmers, the commonest forms of digitalization is heavily hampered when smallholders cannot operate a mobile phone or even read. A farmer who cannot read is unlikely to utilize SMS-based advisory systems. Likewise, the farmer who cannot place a phone call may not reach the helpline or follow IVR.
Furthermore, precision agriculture advisories and livestock and farm management software require some language and digital skills for successful adoption and utilization in Africa.

Also, the results indicated the knowledge required for digitalization goes beyond the smallholder farmer; the capabilities that create diverse digital solutions are equally important. As John [a field officer in Ghana] noted in his remarks, “you see, we need people to go into IT and develop the solutions for farmers. We need to develop that knowledge to help us solve the challenges in smallholder farming”. John emphasizes the high-level digital literacy needed to create services for smallholders. One respondent pointed out, “the growth of digital solutions referred to the CTA 2019 report that showed that about 60% of the reported 390 solutions were created in the three years prior, indicating why the skillsets are needed”. This assertion reinforces the need for skill force development, which many agreed was a collective responsibilities stakeholders must accept, especially governments, to make digital futures possible. Others shared their view of skill force development as they pointed to how increasing interest in the area has led to the springing up of start-up service providers driven by the youth. With the development of digital skills across scales in agriculture, Ken (A project officer in Kenya) asserts that “digital farming will surely become what we know of smallholder farming in the future.” The anticipations of what digitalization could become heavily reflect the development and proliferation of knowledge, skills, and capabilities that bring digital tools to life and translate them into valuable and practical solutions that alter smallholder practices in diverse forms.

6.7.3 Shared meanings and understandings that will drive stakeholders to accept and act on digitalization

The final element of Shove et al.’s framework is the meanings and understanding associated with practices. Respondents often highlighted the essence of meanings and creating some sense of digital tools and solutions. For example, when speaking to an official of a service provider that has proven highly successful so far, she noted, after being asked what has made their services acceptable and successful thus far, that:

[...] you know, I think where we found the most success is when you can partner technology with existing organizations and individuals on the ground, in the villages, so that the digital part can be connected to the real-world aspect of the physical nature that is agriculture. I mean, fundamentally, agriculture is a very physical kind of thing...(yeah)...you have a farm, and you are producing actual things, harvest a commodity. And so, you need to have a bridge between the technology or virtual world and the real world to create meaning for what you are doing. And when service providers only approach it from the virtual, farmers can’t relate to it [Musonda, implementation Officer for a digital service provider in East Africa].
From this extract, two key highlights emerge. First, digitalization may resort to new meanings that differ from traditional agricultural understandings in rural Africa. As digitalization takes hold in farming, perhaps the definition of a farmer, a tractor, and owning equipment could change. For example, the emergence of uber-like tractor services like Trotro Tractor in Ghana and Hello Tractor in Nigeria could potentially change the very essence of owning such equipment in rural African settings. Second, the extract emphasizes connecting digital services to existing structures on the ground to create shared meanings. By this connection, the linkages referred to here relate to what farming means to rural smallholders and what digital tools may offer. For instance, connecting digital to existing physical, social and institutional structures like peer-to-peer learning and extension systems may be critical for creating shared local meanings and understandings of emerging digital practices. Hence, integrating emerging digital tools and services, such as digital climate advisories and information solutions, into established and trusted systems farmers rely upon are noted to align and create shared values and understanding relatable to rural folks, ultimately acceptance and adoption. As pointed out by some participants:

[....] the farmers you know don’t believe it (i.e., digital services). And that's also why, in our case, even when we are doing the videos, why we find it important to feature local farmers in the various communities we work. Because the first question that farmers ask when they watch these videos is not about the economic sort of return on investment of the practice; instead, what the farmer's name in the video and which village they are from. By knowing that they can identify with the service as well understand the values—[Judith, an implementation Officer for a digital service provider in East Africa]

[......] I think I mentioned earlier that you have to know where you introduce a digital service. For example, introducing a digital service in the northern part of Ghana is easier than introducing it in the southern part of Ghana. But going down to farmer specific, one I can say that is difficult for them to embrace it immediately because of, you know, beliefs and misconception about those things. So that is one thing that one needs to know. So, what we do because of these things we usually come up with and typically develop a strategy to ensure or a campaign to address..... you know this cultural belief. I don’t want to go into specific. Still, I am looking at it from a bigger perspective. So the campaign at the end picks out or collect in a specific area the myth and misconception on the type of service or on the digital service that we want to introduce in that particular area, then we factor those myths and misconception in our design, so we look at it from four different perspectives—[Kwabena, an Implementation Officer for digital services in Ghana].

The notion of trust was noted as critical in farmers' acceptance and adoption of any form of innovation, and digital solutions are no exception. And leveraging the understandings and values of farmers to attain trust is essential. Using a farmer known to others, as Judith stated, speaks to aligning the innovations to the shared values of a place, which further requires building meanings relevant to each socio-cultural context of target groups. The extract also subtly reflects the importance of place in defining and expressing meanings, understandings, and values. Understandings vary from place to
place and person to person; hence, as the interviewee refers to farmers inquiring about the identity of persons in videos, they are subtly speaking to the need to build placed-based meanings of digitalization. When farmers know that their peers relate to innovation, it (in)directly provides meaning to them, and they are more likely to try them.

Likewise, Kwabena’s description of experiences of introducing new technologies in Ghana reveals some essential considerations for digitalization, including the importance of place-defining and creating shared understandings that align with existing beliefs and overcoming misconceptions that stand in the way of the institution of emergent meanings of digitalization. For example, some farmers may resist accepting digital advisories when the information provided is contradictory rather than complementary to their traditional ways of doing things. Likewise, farmers may conceive market-connection digital services as innovations that contradict traditional market channels built on trust and intimate relationships between actors. Variations in thoughts, primarily place-based and influenced by various socio-cultural, economic, and institutional factors, inform people’s willingness to accept, adopt and propagate innovations, including digital solutions. Hence, Kwabena refers to the collection of misconceptions related to innovations as a first step to targeting interventions to subdue them. Thus, understanding digital services’ emergent meanings and experiences and how they differ from existing ones would be crucial to establishing any form of digitalization in any context. Such endeavours would allow for effective targeting of solutions and overcoming misconceptions around potential changes to practices engendered by digitalization.

6.8 Discussion: The Emergence and Stabilization of Agriculture Digitalization (practice) Futures

In the preceding section, the extracts from key informants showed that the formation and emergence of digitalization in agriculture in Africa would require careful attention to materials, competencies, and meanings sensitive to digital futures. The finding that these three elements are critical building blocks for digitalization means that the phenomenon is conceivable as a social practice. For practices, when new materials are introduced (for example, a feature or smartphone for mobile advisory or drone for precision farming), or capabilities altered (example, farming now requiring knowledge on using a phone or reading text on the phone, or using a drone to analyze soil), or the meaning shifts (example, from food provision to economic activity or digital farmer), then new practice of digital farming is set to emerge to replace older methods. Given the critical elements
noted in the interviews, I argue that digitalization is the dawn of new agriculture practices in smallholder systems. Its constitution requires novel materials, competencies, and meanings (See Figure 6.2). Hence, the success or otherwise of the phenomenon may hinge on how the material elements of digital agriculture are connected with competencies and meanings across scales. To better understand the argument, I expand how each element is situated in changing farming and potentially establishing digitalization futures.

**Figure 6.2 Elements of digital agriculture practice(s)**

As noted in the literature and established in the results, digitalization requires the introduction of new materials and tools, including phones, computers, robotics, and drones, into the agricultural space (Bergvinson, 2017; Carolan, 2017; Kim et al., 2020; Wolfert et al., 2017). Likewise, it may involve leveraging digital systems such as the internet, AI, big data and cloud computing to create novel solutions and services to farmer challenges, such as linkage to input distribution and wholesalers, online input marketplaces, shared economy for mechanization, pay-as-you-go irrigation, and digital connection to both inputs and markets (Technical Centre for Agricultural and Rural Cooperation, 2019). The introduction of new tools and services would engender changes in farming futures. For example, mobile-based price alerts may mean farmers change when and where they sell their produce. The introduction of digital marketplaces and connections may mean smallholders do not physically transport produce to the market but instead rely on platforms systems that connect and
purchase outputs from communities. Likewise, the emergence of digitally-enabled input connections and hiring services may mean farmers can access mechanization with their phones (a new material introduced into the farming space) without owning such equipment (Daum et al., 2021). Likewise, digital payment systems like mobile money allow rural farmers to conduct transactions digitally and alter the basic material ways of interacting with buyers (Babcock, 2015). Hence, whether focusing on the technologies or the latest solutions and services, digitalization requires new material components in the architecture of agriculture and everyday farming practices. These emerging material rearrangements are needed to ultimately reconfigure the time and space dynamics of how farming is done towards digitalization. But more importantly, as the results indicated, introducing such services requires the availability and access to the tools that bring the services to life, including digital and social infrastructures.

Furthermore, the results showed that digitalization requires new competencies, including digital literacy and IT skills, to create services. Particularly, farmers need skills and knowledge to operate in the digital future. As reconfigurations of farming practices emerge with new tools and services, there is a need to reorientate competencies and skills towards new ‘hows’. For example, as digitally enabled marketplaces, connections to markets, and inputs take hold in many African countries, farmers will require new digital skills to utilize such services (Food and Agriculture Organization of the United Nations & the International Telecommunication Union, 2022). Specifically, as earlier noted, competencies such as placing a call to a call centre, following an IVR, browsing the internet for information, and literacy to understand the information provided in advisory and information services would become standard requirements for the practice of agriculture in digitalization futures. Ultimately, as Bergvinson (2017) and Salemink et al. (2017) already emphasized, digital literacy becomes essential in how people farm. Hence, digitalization cannot fully emerge within the African context until farmers have the skillsets, knowledge, and capabilities to access the tools and services and turn information and advisories emanating from them into real-life farming practices.

Finally, the changing practices towards digitalization would require alignment and embedding of emerging meanings and values of farming into smallholder systems. It is established in the literature that digitalization initiatives strive to change the face and outlook of farming as presented through transformations and game-changer claims (Abdulai, 2022; Tsan et al., 2019). And as earlier explained in the results, respondents were explicit about aligning digital farming understandings to specific values in the local context(s) and correcting potential common misconceptions that people
may hold about digital services and tools in agriculture. By this finding, and as previously argued by Bear and Holloway (2015) and Butler et al. (2012), technological innovations like intelligent farming (digitalization) force us to redefine basic socially embedded subjectivities such as "what is a (good) farmer?" "what do new equipment ownership arrangements mean?" “how is farming done?”; and “who becomes a farmer?”. For instance, new understandings and perceptions of the rural smallholding farmer could shift from the rudimentary, resource-poor, low knowledge-intensive endeavour to a high-tech, high-skilled, data and information-rich practice. Such redefinitions emerge the need to (re)establish and (re)align the new meanings to known values of smallholding within each diverse context(s).

From the preceding discussion, the digitalization of agriculture practices in Africa is emerging from introducing new materials requiring specific skills to embark on everyday farming activities, potentially redefining farming meanings. Hence, just as with the reinvention of Nordic Walking (Shove & Pantzar, 2005), (digital)farming is being re-invented by the linking of the three elements: digital tools and solutions, digital skills to access and utilize emerging technologies, and shifting meaning of farming in the digital age. By this proposition, I argue that the stabilization of the social practices of digitalization hinges on creating and linking these elements across scales and places in Africa.

The arguments and proposal are critical in the digitalization process as it expands the frame of interventions. The materiality of digitalization stands at the forefront of current attention through focus on technologies used in agriculture, such as phones, drones, AI, cloud computing, and big data (Deutsche Gesellschaft für Internationale Zusammenarbeit et al., 2021; FAO, 2019). For example, *The Digitalisation of African Agriculture Report 2018–2019* BY CTA (2019) emphasizes the growing number of technologies and start-ups creating solutions. A similar focus is evident in the World Bank’s *Scaling Up Disruptive Agricultural Technologies in Africa* (Kim et al., 2020). In all these, interest in the emerging technologies and the services made possible through them are prominent- which speaks to the materiality of digitalization. While the process may start with the material tools and accompanying solutions (e.g., marketplace platforms, drones for spraying, mobile advisory, etc.), the transformative potential of the digital age is unattainable if not followed by changing competencies (people need new skills) and aligning values of rural smallholders. With the right combination of the three practice elements, digitalization could become an established practice with high recruitment of performers and agents across regions (cf Shove et al., 2012; Shove & Pantzar, 2005). Thus, the success of digitalization would require the needed material foundations, the
capabilities to use, and the social values and meaning for acceptance. Likewise, for a practice like
digital farming to persist, it must recruit more practitioners and agents (more farmers) to adopt and
utilize tools, services, and solutions.

6.9 Practical Implications of Social Practices of Digitalization

Digitalization as a practice has practical policy implications for the future of agriculture in
Africa. I draw out three critical policy implications and lessons apparent in this approach:

The first policy implication of the practice approach is the multidimensionality of
digitalization futures. The three elements and their change mechanisms in shaping the future of
farming practices draw attention to digitalization's technical and social dimensions, which I argue are
critical for the future. Specifically, the approach emphasizes that as materials of farming change with
the introduction of phones, computers, drones, and so on, so too must the approach to capabilities,
perceptions, and value re-developed to match the context. In this case, the socio-cultural perspectives
to adopting newer digital services must be considered a part of interventions (Tanko, 2020; Warren et
al., 2016) as much as the creation and deployment of novel technologies and tools. Interventionists
can use these elements to simultaneously identify and emphasize the technical (e.g. broadband,
drones, big data, electricity, roads, mobile phones) and social (e.g. digital literacy, cultural value
alignments) dimensions required for the digitalization of agriculture to emerge across scales, time,
and spaces.

The second implication is the multiscalar actions required for digitalization. The three
elements discussed offer a heuristic (core building blocks) adaptable at multiple levels of
interventions, including internationally, nationally, regionally, locally, organizational, and the
individual. For instance, digitalization requires the availability of materials from the individual, for
example, mobile phones, to national telecommunication infrastructures. Likewise, the formation of
practices described in this chapter emphasizes activities from the individual to international scales.
Hence, the practice approach means that any successful digital futures need critical policy
interventions that span multiple scales.

The third practical policy lesson is the placeness of social practices and agricultural
digitalization. As noted in the results and from the literature (Shove et al., 2012), the performance of
practices across space and time may vary from place to place, primarily due to variations in
understandings and meanings. Due to this critical feature of practices, my research would allow interventions to shift away from a holistic understanding of digitalization to seek place-based dynamics that fit the specific characteristics of diverse African smallholders. Similar to practices, rural people are not always homogeneous; hence, digitalization practices would allow the identification of the diversity of representations and the development of digital futures that fit each group. For example, when establishing a mobile advisory service, service providers would be able to understand the values of smallholding and their structural limitations to align the procedures, information and values of services. Likewise, smallholders speak different languages across the continent; hence, digitalization through the practice approach will allow interventions to target diversity in implementing solutions.

6.10 Concluding Reflections

The article's main aim was (re)shaping the conversations around the digitalization of smallholder farming systems from a purely technical process to one that considers its formation a social practice embedded in people’s everyday livelihoods. I argue that we must begin to think of the digitalization of agriculture as the emergence of social practice(s), which can be constituted through the suitable combination of the three core building blocks of materials, competencies and meanings. My argument is situated in the scholarly tradition that social practices are the building blocks of society (Shove et al., 2012; Shove & Walker, 2014). Thus, we can understand how innovations emerge, take hold, and disappear over time and space. While I do not present myself as a practice theorist, I find some merit in the approach, thus proposing this approach for the future of digital interventions in rural smallholder systems in Africa. The practicality of practice for investigating ‘the social’ opens opportunities for an alternative re-interpretation of agriculture and change in embedded contexts, especially when digital tools are increasingly interacting and redefining the social composition of farming activities. This social practice proposition opens an area for theoretical and practical engagements that (social) researchers, including political-economist, should further engage in understanding how digital technologies usages (may) emerge, persist, interact, and change everyday agricultural agents’ behaviours in Africa (cf Boamah & Rothfuß, 2018). More importantly, it is an avenue for guiding the interactions between structural changes (technological advancements) and social systems in ways that build on the core constitutions of people’s lives.

This article provides three critical advancements. First, this is the first application of social practices to explain the process of innovation diffusion for smallholders and rural people in Africa.
Second, the paper shifts attention from the many adoption studies that primarily consider the process within the sphere of the individual characteristics (Alabi, 2016; Wafula-Kwake & Ocholla, 2007). Third, I open a new space for further empirical and theoretical examination of Africa's technology/innovation process, particularly digitalization, where practices become the focus of inquiries.

However, while I present a case for the practice approach, I do not profess it as a standard or exclusive method for the future of digitalization. Instead, it must be considered an option available to researchers and practitioners to inform digital agriculture interventions, which have become the mainstay of international development in the last two decades. This proposal is a simple heuristic recommendation that would guide actors to consider digitalization as a change to everyday farming with socio-technical dimensions that require deliberate acts to enact. Also, my proposal must not be misconstrued as propagation of primacy of technological innovations evident in current food regimes (Anderson et al., 2019) nor a presentation of digitalization as an uncontestable transformative solution to smallholder issues. Further scholarly inputs from diverse theoretical and analytical approaches, including responsible innovations (Fielke et al., 2022; Jakku et al., 2022; Klerkx & Rose, 2020) and the political economy of digitalization (Abdulai, 2022; Carolan, 2020; Duncan et al., 2021) is critical to ensuring the phenomenon does not reinforce existing inequalities. Digital transformations cannot happen without careful analysis of the political and economic implications of the phenomenon, including for rural communities and smallholders (Abdulai, 2022; Carolan, 2017; Rotz et al., 2019). The high cost of services, low digital literacies, and poor rural infrastructure, among other challenges (including lack of readiness due to low limited capacities — McCamphell et al., 2021) noted to undermine smallholders’ engagement, and participation with digital services need further explorations (Food and Agriculture Organization of the United Nations & the International Telecommunication Union, 2022). Broadly, the risks associated with digitalization, such as the potential to create inequities and entrench power imbalances in current food systems, must be explored and measures instituted to minimize them. In essence, further research on the local socio-cultural and political-economic issues (including implications on power, access, benefits, interests, and redistributive impacts) would be essential for any future of digitalization in Africa and across all smallholder systems.
6.11 References


7.0 Tying up the Research: Summaries and Conclusions

7.1 Summary of Research Findings and Conclusions

This research aimed to explore the contextual dynamics of the unfolding agricultural digitalization and the potential socio-political-economic implications in smallholder farming systems in Africa and Ghana. I have remained flexible, reflexive and pragmatic in addressing this goal by crossing over multiple empirical methods (qualitative and quantitative) and theoretical approaches (political-economy and social practices). This approach has helped reveal critical insights into agricultural digitalization dynamics in Africa and the potential for future advancements. These insights are summarized in this section in line with the five objectives of this dissertation outlined in Chapter One.

7.1.1 Identify and discuss the anticipated impacts, motives, and drivers of agricultural digitalization in Africa

Chapter Two aimed to explore the narratives, motives, and drivers of rhetoric around the anticipated impacts of agricultural digitalization in Africa.

The results showed that the narratives of smallholder digitalization are primarily carried by international development organizations, donors, corporations, and private agri-businesses (Birner et al., 2021; Kim et al., 2020). These actors are also the proponents and drivers of the growing implementation of digital innovations (Chapter Two) as they promote digitalization’s transformative and disruptive abilities (Tsan, et al., 2019). Notably, they perceive it as means to move smallholder systems from primitive, low productive, inefficient, and unprofitable ventures to modernized, efficient and commercially viable (Agri)businesses.

Particularly, the hype of digitalization is centred on pro-poor outcomes as actors anticipate digital innovations to have seven key impacts: 1) bridge information and knowledge gaps in agriculture; 2) ensure efficiencies; 3) promote food security; 4) increase climate change/environmental sustainability; 5) provide employment and empower the youth; 6) promote gender and women empowerment, and 7) enhance livelihood resilience in rural areas. Through these anticipated impacts, agricultural digitalization is mainly described as a revolution and game-changer (Atanga, 2020; Tsan et al., 2019), with little recourse to the diversity of farmers lived experiences.
The lines of narratives cast highly positive outlooks on digitalization, one which I argue is nothing different from the long unfolding neoliberal incursions into smallholder agriculture systems. Furthermore, I found the narratives to follow the footsteps of Green Revolution technological advancements rhetoric in Africa, which are primarily motivated by the neoliberal goals of the proponent organizations, who, by their motifs, thrive on integrating systems into global capitalist markets (Frankema, 2014; Vercillo & Hird-Younger, 2019; Dawson et al., 2016; Vercillo et al., 2015a). Hence, the activities of these entities favour private sector engagement in digitalization as they persist in justifying development interventions in the area and laying the foundation for the interests of development and corporate actors.

However, I also found that the digital agriculture narratives ignore the consequences of the neoliberal system that promotes and seeks to absorb rural and traditional African farming processes. These narratives risk undermining and making longstanding smallholder practices and structures obsolete. Meanwhile, the potential uneven access and benefits of digitalization processes emanating from challenges such as the digital divide, low scalability of services, and weak enabling environment remain underexplored within the current narratives and must be given adequate attention. Likewise, the prospects of digitalization to create and-or entrench unfair power dynamics and deepen inequalities evident in neoliberal food system structures continue to be neglected in current discourses.

Thus, I conclude that the common positive outlooks of development organizations regarding agricultural digitalization need careful and critical political-economic considerations because of the potential blindsides to contextual issues that have shaped and continue to define smallholder systems in Africa, including inequities in access to resources and power imbalances. Importantly, digitalization in agriculture cannot be fully understood or successfully unfold without carefully considering how existing locally-embedded structural elements dictate or are being affected by the phenomenon. This call from Chapter Two formed the basis for my practical explorations in the following chapters.

7.1.2 Assess the nature of the unfolding agricultural digitalization in rural smallholder farming

Having established the anticipations and narratives by proponents of digitalization through the secondary review in Chapter Two, Chapter Three drew from the in-depth empirical survey in
Northern Ghana to examine how rural smallholders engage with digital tools and services. I made some initial steps in unpacking and accentuating embedded structural issues within rural farming related to facilitating or undermining the digital reality of smallholders.

I found digitalization to have a different outlook and generally limited in the smallholder systems in Northern Ghana than widely purported. Most farmers do not have digital access beyond the phone and radio, with only a few accessing smartphones, the internet and other digital resources. Hence, digitalization for smallholders was limited to using simple tools and services offered through such mediums. Thus, the widely transformative technologies such as the use of drones and precision technologies reported in much of the literature in the Global North (Carolan, 2020; Rotz et al., 2019; Wolfert et al., 2017) and also widely claimed as the future of agriculture (Sylvester et al., 2018) is mostly missing in the smallholder system. While there exist isolated cases of advanced digitalization (FAO, 2019; Tsan et al., 2019), those are primarily relegated to pilot programs with limited engagement beyond live projects. Furthermore, digital agricultural services use digital tools at the organizational level, where there are no direct interactions between farmers and the technologies. Farmers are unaware of technologies and are only interested in the service received in most cases.

I also found that many operational issues in rural smallholder systems made it difficult for full-scale digitalization. Some barriers revealed included high formal illiteracy, limited access to digital tools (smartphones, computers, internet, etc.), and low digital competencies in performing simple tasks such as sending SMS, following IVRs, and browsing. These findings showed that the basic building blocks required for digitalization are not fully developed among rural farmers and communities.

Likewise, digital services' active use was low, especially after farmers exhaust-free or subsidized benefits. Much of the engagement revealed in the research formed a part of development interventions to improve agricultural efficiencies, enhance climate change resilience and sustainability, reduce poverty, and enhance rural development (see Chapter Two). Hence, participation outside the frame of development programs was still limited, as private services are mainly in incubation and early development. Farmers also exhibited a low interest in seeking digital services, resulting partly from decades of experience obtaining free services and the current weak enabling environment for sustainability of services.
The findings in Chapter Three move forward my discussion of the socio-political-economic implications of digitalization by showing smallholder farmers' limited and unequal engagement. The results show that digitalization is still a distant goal in smallholder systems despite some promises of transformative change for farmers. It is an exaggeration to describe it as transformative, disruptive or revolutionary within the current conditions. The ideals of full-scale digitalization are unattainable within the existing operational environments.

7.1.3 Determine the factors that influence farmers' participation in digital agricultural services

In the context of the growing yet limited digitalization in Northern Ghana revealed in Chapter Three, I assessed the factors affecting farmers' participation in digital agricultural services. Specifically, I created a polynomial model to explain the level of influence rural farmers' current structural characteristics and conditions have on their involvement in digital services. This modelling exercise picked up from the conclusion call made in Chapter Three to assess the differential effects of various factors to ascertain who is likely to benefit from digitalization at the expense of others.

The results showed that male farmers, farmers who belonged to farmer groups, farmers who owned mobile phones and farmers who could place phone calls were more likely to participate in services. Hence, gender, access to resources (mobile phones and extension services), and farmers' digital literacy (ability to place phone calls) positively influence participation in digital services. However, somewhat paradoxical but critical, I found that access to the internet negatively affected participation in digital services. Notably, farmers who had internet access were less likely to join digital services. As shown in Chapter Three, digitalization is presently based on mobile or radio or agent-based services, which generally do not require internet access to operate.

Based on the differential influences of various factors on participation in digital services, the findings empirically confirmed my assertion in Chapter Two that the benefits of agricultural digitalization are likely to be uneven across groups. Existing structural variations in socio-economic characteristics and conditions, such as gender, age, literacy, and access to resources, will likely push digitalization to entrench inequalities and exclude certain groups. Hence, conscious efforts are required to make the phenomenon inclusive and sustainable. As revealed in Chapter Four, the key factors driving participation offer critical points for policy interventions to start conversations and actions towards inclusive digitalization.
7.1.4 Evaluate how new digital agricultural technologies change the everyday practices of farming

Despite the conclusion that digitalization was a hype in smallholder systems, I was still interested in understanding the potential for change from farmers’ limited engagements. My interest was peaked by growing consensus in the literature that the digitalization of agriculture may impact farming practices and rural communities (Barrett & Rose, 2020; Carolan, 2020; FAO, 2019; Klerkx et al., 2019; Rotz et al., 2019).

I found that rural farmers perceived digitalization to cause change to their livelihood practices and community dynamics. Mainly, changes were experienced through interaction between new forms of farming made possible by the digital tools and services and established structures and processes in rural smallholder agriculture. Changes in farmers' everyday practices typify one mechanism that digitalization reshapes farming and rural communities. Specifically, farmers perceived digital tools and services to change how they plan their seasons, choose crops, undertake husbandry activities, harvesting, marketing, and sales. Farmers experienced changes in these activities as new digital information/advisory and market connection services reshaped and redefined how they partitioned their daily routines and rhythms to accomplish the various task. These changes are also reflected in how farmers use space, time and materials of farming to undertake their activities.

Ultimately, just as Holloway and Bear (2017), I conclude that the applications of mundane technologies (digitalization) such as mobile phones and mobile advisories in agriculture would lead to changes in the fibre of agriculture and rural areas. Hence, as digitalization limitedly penetrates smallholder communities, everyday practices across different scales and farming processes would be rescripted (Rose & Chivas, 2018). Such changes would ultimately redefine the socio-political-economic dynamics of rural farming and communities. For example, changing practices from digital engagements could be limited to the selected privilege with access, thereby providing such groups with power in cases of positive impacts.

7.1.5 Offer guidance towards understanding and scaling digital technologies in food and farming systems.

In Chapter Six, I shift my attention from unpacking the realities of digitalization to a forward-thinking interest in guiding the future of the phenomenon in Africa. I found that three main pillars and elements are critical for a successful digital future: I) the material elements that could make
digital services and solutions come to life; II) **competencies required** to use and turn materials into practical activities, and III) **Shared meanings and understandings** that will drive stakeholders to accept and act on digitalization. First, we must ensure that the material and technological tools needed to practice digitalization is available and accessible to all actors. These materials may include phones at the individual level to telecommunication and other social infrastructures at regional and national levels. Secondly, the required competencies to practice digital is essential. These competencies include digital literacies for farmers and extension agents to higher-level computer and AI competencies that allow people to create digital solutions to smallholder problems. Thirdly, the newness of digitalization must be aligned with established meanings and values of farming in diverse contexts across Africa.

Hence, to create a digital future that overcomes the operational challenges highlighted in this dissertation, I propose adopting an approach embedded in the everyday realities of users. Thus, as my adapted three-element findings show, Shove et al.’s social practices conceptual and analytical approach (Shove et al., 2012; Shove & Pantzar, 2010; Shove & Walker, 2014) offer a frame for understanding and guiding contextually-sensitive futures for digitalization. Specifically, the formation of digitalization centers on our ability to contextually integrate materials, competencies, and meanings of the unfolding phenomena. Thinking of digital technologies as forming social practices helps shift the focus to basic building blocks of social life (cf Shove et al., 2012); thus, taking steps towards an inclusive digitalization that minimizes the socio-political-economic challenges speculated to entrench inequalities further.

In summary, this research revealed growing attention, interest, and support for agricultural digitalization in Africa as development actors drive the phenomenon with promises for transformation (Chapter Two). However, farmers' engagement on the ground is limited due partly to underdeveloped basic building blocks for digitalization (including digital competencies and access to resources)- which indicates a disconnect between the claims and smallholders' lived realities (Chapter Three). Meanwhile, existing differences in farmer characteristics and conditions influence who is more likely to participate in digitalization or not (Chapter Four). Nonetheless, digital tools and services still have the potential to impact smallholder farmers by altering their everyday practices (Chapter Five). Hence, ultimately, the future of digitalization may depend on how we create and integrate the new materials, competencies, and meanings in introducing digital innovations within smallholder systems (Chapter Six).
7.2 General Conclusions

Through these critical findings outlined in the preceding section, I draw four main conclusions from this dissertation: I) Digitalization is a highly promoted phenomenon disconnected/detached from the lived realities of farmers. II) While prospects for digital-enabled change exist, the disruptive digital transformations of smallholder food systems are unlikely now as the core building blocks, such as digital competencies and equal access to resources, are under-developed. So, III) uncritical promotions of digital innovations may only reinforce structural imbalances and unfair power dynamics. Thus, IV) we must move beyond the transformative rhetoric and work towards a 'digitalization for smallholders' and a 'digitalization for Africa', where expectations and impact goals are geared towards incremental progressive change in social practices embedded in local socio-political-economic realities of Africa. Each of these conclusions is unpacked below.

I) Digitalization in smallholder systems is detached from the lived realities of farmers. Proponents carry the rhetoric about the potential for digital innovations with big ideas of impacts that do not align with the current experiences of farmers (McCampbell et al., 2021). As I have shown, digitalization in rural Africa is less about automation and precision for smallholders and more about using simple digital tools and access to information, knowledge, and communication. Particularly, mobile phones, radio, and services that leverage such tools, together with services that offer information through human-human contacts, are at the centre of the phenomena in Africa. Discussions of automation and concerns about data, which are at the heart of current digitalization promises, are superficial because farmers are not enthusiastically engaging with essential mobile technologies. Hence, transformative smallholder digitalization anticipated for smallholder farming is a distant goal than reality in Africa, at least for now.

II) Following Béné (2022) political-economic argument, I also conclude that digital transformation as promoted by development agencies and agribusiness cannot happen within existing structural conditions. To put it simply, digital transformations will remain wishful thinking without context-based solutions to the weak foundations. The neoliberal ideals that drive the disruptive narratives of digitalization and the actors that lead the course are far detached from the wishes and realistic potentials of smallholders of diverse forms. For example, farmers may prioritize issues considered more challenging (including access to inputs, climate change, etc.) than merely adopting some saviour digital technologies. Hence, while the potential for digital innovations to improve livelihoods may be real, as evident in the initial changing practices of farmers in Chapter Five, the
basic building blocks for successful digital futures (transformative) are so lacking that this potential is unlikely to be realized in the near term. High illiteracy, low digital literacy, digital divides, poor telecommunication infrastructures, and farmers' resistance to newness are some of the many challenges currently entrenched in smallholder systems that hinder the penetration of services. Likewise, uneven access to digitalization emanating from these structural issues means that these innovations are unlikely to be fully utilized, and the ultimately envisioned transformations may not happen.

III) The desire to uncritically apply digital innovations to rural smallholder problems will likely only reinforce unfair power dynamics in the system. As I have shown, access and participation in services remain uneven across diverse socio-economic groups, including gender, age, education levels, and resource access. Meanwhile, research has shown that power imbalances exist along the lines of these conditions (Tall et al., 2014; Tavenner & Crane, 2018). Also, I have shown in Chapter Two that digital innovation opens the agri-food sector to new stakeholders, such as including technology companies and emerging service providers, into the agri-food space. So, blindly promoting and imposing digitalization without dealing with these structural inequities is a recipe for the entrenchment of challenges and ultimate failure. For example, in the absence of reasonable levels of digital competency among farmers, there is a real potential that these tools will attract funding and government policy, but the elite will capture all the benefits. Likewise, the new actors entering the sector through digitalization would likely shift some power sources from older actors while also entering with newer forms of powers previously unknown in the smallholder systems. Specifically, digital innovations may entrench and create newer classes, where some empowered groups -for example, people who can read and write or/and are digitally literate or/and have access to digital resources- become more prosperous at the expense of others. Thus, a new trajectory of the *haves and have-nots* could be formed in rural digital futures.

IV) Ultimately, it is necessary to move beyond uncritical universal promotions of digital innovations and work towards what I would refer to as a 'digitalization for smallholders' or 'a digitalization for Africa.' Such a digitalization would have features peculiar to the unique context of smallholders and Africa, including, for example, 1) expectations, goals weathered down from the transformational bandwagon towards progressive change in people’s everyday lives; 2) focus on leveraging available tools and the limited competencies to create suitable solutions, and 3) creating services that target farmers at the collective level rather than the individual. For example, since the core foundations for smallholder digitalization are currently fragile, the successful future of digital
innovations requires shifting attention from transformative goals to the building of digital practices from the primary level, where incremental changes to everyday life become the core focus. I have indicated that digitalization can be considered a new practice (Chapter Six) and a phenomenon that changes farmers' livelihood practices (Chapter Five). Focusing on the formation of digitalization at the basic level, where the contextual tools and competencies of farmers become the foundations, would be critical to overcoming any structural deficiencies and keeping the goals of the phenomenon realistic. Such focus would require creating and integrating materials, competencies, and associated meanings to form the basic blocks of smallholders' digital practices (cf Shove et al., 2012).

The conclusions underscore that smallholder digitalization is essentially overstressed and overstated, and the phenomenon's (transformative) future is uncertain at best. The claims of transformation and disruptions, which I have futuristic technocratic outlook to changing smallholder conditions, are certainly unrealistic within current structures. However, it is essential to note that the digitalization of smallholder agriculture is already underway, and will certainly continue into the future. Hence, the key question to reflect is how phenomenon will look like in the future. Will the future of digitalization in smallholder Africa be constrained to the current limited status or will there be widespread and fully flourishing phenomenon. The futuristic status is very much dependent on how the phenomenon is approached now. Certainly, digitalization must not uncritically be treated as a saviour of smallholder agriculture and rural livelihoods without considering the contextual political-economic conditions and implications across scales. Any measures that remotely impose such innovations would likely result in low interest and engagement, and ultimate failures to make meaningful impacts on farmers and other food systems actors in Africa. In fact, such impositions will only be further entrenchment of neoliberal values that have held current food system hostage, and by extension has drawn digitalization under it's whims. Farmers perceive many pressing challenges, including climate change and access to inputs, which cannot be overcome by technical solutions such as digitalization-at least not entirely. These issues mean that farmers are unlikely to find value in newer technologies within their current reality. Though digitalization is presented as a solution to lingering smallholder challenges (See Chapters Two and Three), there cannot be the desired adoption and use or transformations if the phenomenon were not situated in smallholders' specific contexts and lived experiences. Hence, progressive changes rooted in the socio-cultural context of smallholders and targeting solutions to the many challenges outlined in this dissertation are critical. These measures are necessary because earlier technological advancements (e.g. Green Revolution
innovations) in Africa have shown that promise does not always translate to impact (Amanor, 2011; Bates & Block, 2009; Vercillo et al., 2015b).

7.3 Scholarly Contributions of Research

In my theoretical and empirical exploration of the dynamics of digital agriculture in Africa and Ghana, I contribute to the collection of literature and scholarly works in multiple intersecting fields that are beginning to engage the topic of agricultural digitalization, including the geography of food and agriculture, rural geography, science and technology studies, food studies, and political-economy of food (see Bronson & Knezevic, 2016b; Carolan, 2018; Klerkx et al., 2019; Rotz et al., 2019). Specifically, I draw on political economy, rural development, and social practices theory to explore digital agriculture in Africa to make three crucial scholarly contributions.

First, this research has critically brought the digital lived realities of smallholders to light to underscore the need for political-economic consideration of digitalization. While I do not claim to be the first to engage smallholder digitalization from the political economy point of view (as that will do injustice to the wonderful works such as Béné 2022; Carolan, 2018; Rotz et al., 2019), this is the most extensive effort yet to explore the subject across multiple dimensions empirically. For example, I have shown that digitalization is a hype by development actors and corporations with neoliberal ideals without adequate attention to potential inequalities (Béné 2022); Hence, they are likely to entrench power imbalances and create newer classes in rural smallholder systems. Likewise, I have argued that the digital transformations may not happen if we try to “run before walk” by imposing innovations on systems with weak foundations, such as illiteracy, low digital competencies and limited internet access. Hence, whether through my assessment of farmers’ constrained capacities to engage or the potential uneven access and impacts of digitalization or unfair power outcomes, this dissertation directly and powerfully makes a case for political-economic assessment of digitalization. This hypothesis is a critical contribution that opens spaces for further scholarly engagements and enriches the discourse of digitalization.

Secondly, I make novel contributions to the literature on digitalization by being the first, to the best of my knowledge, to propose and apply social practices to agricultural digitalization and the smallholder digital future. In Chapters Five and Six, I use different strands of social practice theories to explain how emergence and integration of digital innovations and offer directions for the future of digitalization in Africa. These critical scholarly engagements make significant contributions that enrich the literature in many ways. As noted, some researchers have argued that social practices
should be the focus of social science research on understanding the constitutions of everyday societal activities and change (see, for example, McMillan, 2017; Schatzki, 2001; Shove et al., 2012), because practices are the building blocks of society. This call means that practices could be the unit of inquiry and analysis in how innovations emerge, take hold, and disappear over time and space (Shove et al., 2012; Shove & Walker, 2014). I find merit in that argument, thus informing my decision to apply and propose that approach to studying, inquiring, and guiding the emergence and persistence of digitalization of rural smallholder farming systems. The approach centers on a flat ontology that social phenomena, such as farming, occur within and form part of practices (Shove et al., 2012; Shove & Walker, 2010), which are very context-driven (McMillan, 2017). Hence, the practice approach could reshape the questions we ask about the digital revolution, from what digital tools are to inquiring about what purposes we use digital tools to serve (cf Shove and Walker, 2014). By this approach, I have laid the foundation for researchers of digital agriculture to focus on understanding the building blocks that bring digital practices to life, which this study has shown are sooo lacking in smallholder systems.

Finally, by situating this study in Africa and Ghana, I have injected much-needed diverse empirical experiences from the Global South and smallholder systems that are generally missing in an otherwise highly Global North-focused field. As noted in this dissertation, the limited empirical research on agricultural digitalization is apparent in many contexts, especially in Africa and rural smallholder systems (FAO, 2019). A recent report by FAO on the status of digitalization in Sub-Saharan Africa underscores this need for diverse place-specific explorations of digitalization (Food and Agriculture Organization of the United Nations & the International Telecommunication Union, 2022) because much of what we know is limited to reports and documents produced by development entities and corporations (see Chapter 2). Hence, the empirical exploration of the nature of smallholder digitalization, determinants of farmers' participation, and mechanisms of change emanating from digitalization have not only extended empirics for these themes, but I have further injected a more place-based understanding of how the phenomena unfold. So, whether through a critique of the narratives of actors or factors that determine farmers' participation or the potential impacts mechanism of changing practices, I have laid the foundation for future research to explore in specificity, across context, some of the issues presented in each chapter.
7.4 Practical Implications and Lessons of Research and Way Forward

The findings from this study have practical implications for the digitalization of agriculture and rural communities in Africa. The research highlights the experiences of farmers with digital technologies and their expectations of future changes. The empirical data can potentially enable an informed public debate relating to the differentiated roles of digital agriculture technology in the Global South. Hence, I highlight the following practical implications of the findings of this research.

7.4.1 The need for material and infrastructural support

This research has emphasized the critical role of diverse infrastructures and tools in unfolding digitalization. Telecommunication, internet, roads, and electricity are needed across the continent, especially in rural areas where most smallholders are based. Likewise, digitalization requires access to digital resources, including mobile phones and the internet. Meanwhile, I have also shown that the digital divide and other material inequalities are entrenched within current structures, undermining any potential impacts from digital innovations. Hence, governments and private sectors must work to bridge the divide in access to perquisite materials and services for currently disadvantaged groups, including rural communities, women, and digital illiterate populations. At this point, governments and private sectors should work to create the needed market environment that eases farmers' access to these resources.

7.4.2 Beyond technologies, embedded social contexts matter

Beyond the development of the material technologies and accompanying services, this study has underscored the socio-cultural environment in the development and operations of technologies. Development actors and private service providers must strive to understand the socio-cultural context of their beneficiaries and incorporate that into the design and implementation of digitalization services because every technology is inherently socio-cultural. It is essential to centre smallholder cultures and value in technology development processes. One way of achieving this goal complementing technological innovations with social innovations. For example, innovative solutions that develop local language-based digitalization services could allow for finding common grounds for these digital tools and local methods of doing things. Likewise, low literacy among farmers makes providing information via phone or SMS counterintuitive since they cannot adequately utilize it; using face-to-face to complement digital services would be ideal in these cases. Also, while
digitalization generally favours individualized services, I have noted in this research that the cultural setup of most rural smallholder systems in Africa favours group-based services and knowledge exchange, which also means that digitalization should be adapted to fit such requirements. So, all actors must assess and understand these dynamics to ensure digitalization is implemented within the social frame of beneficiaries to attain buy-ins.

7.4.3 Centering farmers in the digitalization process

Another important implication of this research is the essence of centring farmers in the digitalization process. Digitalization is currently disconnected from farmers' live experiences through individualized digital services or SMS to illiterate farmers. Meanwhile, I have shown that digitalization is an emerging practice that sits within and changes farmers' everyday livelihoods. The gap between current views of digitalization and the core everyday practices conception proposed in this work must be bridged for meaningful progress in establishing the phenomenon in smallholder systems. One way to achieve this goal is ensuring interventions to promote digitalization are deliberately created and situated in specific socio-cultural settings to benefit diverse groups of farmers. Centring farmers would also mean assessing and identifying the make-up of farmers and their needs before interventions are created and implemented. This approach would ensure that digital services cater to different groups' needs within smallholder systems to minimize the potential for entrenching inequities.

7.4.4 Enabling policy and regulatory environment

Since digitalization is nascent in smallholder systems, an enabling policy environment is critical for the phenomenon to thrive contextually in smallholder systems and Africa. Many actors are engaged in digitalization, including governments, private sector start-ups, multinational corporations, international development organizations, NGOs, and farmer groups. The multi-actor nature of the space requires effective policies and regulatory frameworks to guide the activities of stakeholders and make farmers the centre of digitalization. Hence, governments and decision-makers across all scales in Africa must work with all the stakeholders to design and institute legal documents, policies, and regulations for digitalization. Such policies and regulations would enhance the confidence of all actors in the digital ecosystems and draw more participation in the future.
7.5 Some Limitations and Areas for Future Research

Like in any research, this dissertation has practical and empirical limitations. However, instead of seeing the limitations as weaknesses, I prefer to present them as openings for future research. Hence, I outline some limitations and propose how future research could engage these gaps.

Firstly, the goal of the research from the onset was to explore digitalization in Africa and Ghana, focusing on the social dimensions of the phenomena. Like any exploratory study (Swedberg, 2020), this research is limited by the depth of engaging issues emerging from the data and raises more questions than answers. While highlighting a wide range of topics throughout this work, there are many instances I could have delved deeper into each case to offer solutions. Instead, I choose to open spaces for further inquiries while raising interest in the many topics. For example, while I show some of the determinants or factors that significantly affect farmers' participation in digital services in Chapter Three, the study did not delve into the reasons for each variable included in the modelling. Hence, I position this study as a point of bringing the themes to life, piquing curiosity for future research, and where further research could explore each of these issues in detail to ascertain how they interact with digitalization. To better understand the social context of digital agriculture in Africa, future research must examine how and why various socio-economic characteristics, different digital competencies, and access to digital resources influence the participation of farmers in the digitalization of agriculture. Likewise, a placed-based understanding of digitalization dynamics and directions is essential.

Secondly, this dissertation was limited in including some diverse voices within African smallholder systems. Specifically, communities included in the on-field empirics were those with known digital agriculture services, which reinforce some power imbalances in which voices I have captured. This approach meant that the experiences of communities (which are the majority) who are in the unknown or have had no experience in digitalization were relegated. The decision for this approach was both logistical and methodological. Since digitalization is currently limited in scope, including communities with no experience in my sampling could have resulted in a skew towards communities that will offer little to my goal of understanding the dynamics of change emanating from digitalization. Such an approach would have also required much more logistical and time commitments than I could accomplish within the frame of this research. I consider this an essential omission since it partly reinforces some rural development bias noted by Chambers by excluding some voices, especially those who probably do not have the institutional connections to benefit from the early pilots of the digitalization agenda. Future research must examine the extent of penetration
and engagement beyond communities with digitalization experiences. By including all forms of communities, research would offer a different but fuller insight into Africa's phenomena in ways that bring the affairs of the have-nots or those Chambers (1984) refer to as the last into the conversations.

Thirdly, this research has not explicitly measured the impacts of digitalization beyond farmers' perceptions of change. Across this work, I have referred to anticipated transformative expectations of the digitalization of agriculture, with much of it covered in Chapter Two. However, the current study has not established whether and how digitalization engenders such impacts. The change mechanisms of farming practices discussed in Chapter Five came close to addressing this limitation but did not, by design. Mainly, I have not established if the changes reported in Chapter Five positively or negatively impact income, employment, productivity, environmental sustainability, and rural empowerment. My experiences informed this limitation in the field: the projects were pilots running for a few years without real continuity to measure impacts, and farmers' engagements were limited for any real assessments of impacts. However, as the phenomenon expands and grows and private sector entities adapt to finding ways for long-term sustainability, future research should seek to assess empirically assess these impact pathways through place-based and service-type-based inquiries.

Beyond the research opportunities emanating from the limitations in this study, it is crucial to understand that more areas for further research are revealed in this study.

As noted in Chapter Two, digital agriculture in Africa is at a nascent stage, but it opens a research space in desperate need of critical engagements that explore the implications of digitalization for inequalities and power dynamics with smallholder systems. While I engaged the political-economic considerations of agriculture digitalization across this dissertation and Chapter Two, there is still a need for critical scholarships from political economy, political ecology, and critical science and technology studies on who benefits or loose from digitalization. While there already exists some level of engagement, as noted throughout this dissertation, there is an urgent need to move beyond the current concentration on Global North understandings of digitalization to engage the specifics within smallholder systems and within the unique, rich, and diverse farming context of Africa.

Also, further research is needed on the placeness of digitalization. Throughout this thesis, I have implicitly and explicitly revealed findings that speak to the place dynamics of digitalization. For
example, I have noted the need for contextualizing digitalization for smallholders, considering their unique characteristics. I also stated in Chapter Six that practices are performed variedly across places. Meanwhile, there is still little research to understand how digitalization is developed and manifested across spaces. Hence, future research must examine the place dynamics of agricultural digitalization. Some place-related areas for exploration may include rural-urban interlinkages in digitalization, (dis)connections between places of development and places of use of digital services, and how place defines the creation and utilization of digital tools and services.

Finally, more research on ethics and responsible innovations in the smallholder digitalization space are needed. There is a growing research interest from the responsible innovation scholars in the ethical implications of agricultural digitalization, especially around big data (Bronson, 2018, 2019; Bronson & Knezevic, 2016a; Bruynseels, 2020; Klerkx & Rose, 2020; McCampbell et al., 2021; Rose & Chilvers, 2018). However, much of the current literature has focused on studies in the Global North, where the dynamics of the phenomena are highly different from the Global South and smallholder systems. For example, considering the low literacy and awareness regarding data and digitalization processes issues in general in my case areas, context-specific research is needed on the deployment and use of big data systems within such spaces. Hence, future research must engage with the ethical implications in the design, implementation, and use of digital tools and services by smallholders in diverse contexts in Africa and beyond. The work of McCampbell et al. (2021) takes some critical steps in filling this gap. However, more research is still essential across smallholder food sectors, solutions, services, and geographical areas.
7.6 References


Bronson, K., & Knezevic, I. (2016a). Big Data in food and agriculture. *Big Data & Society, 3*(1), 1-5. https://doi.org/10/gcd2g5


Appendix I: Crosstabs and chi-squares for farmers engagement

Respondents’ awareness of digital services

<table>
<thead>
<tr>
<th>Variable</th>
<th>% Aware</th>
<th>% Unaware</th>
<th>Total</th>
<th>Chi-Square (X²)</th>
<th>Significance (p)</th>
<th>Cramer (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N=1565</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>81.4</td>
<td>18.6</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td></td>
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</tr>
<tr>
<td>Female</td>
<td>80.2</td>
<td>19.8</td>
<td>39.4</td>
<td>X²=0.935</td>
<td>p=0.334</td>
<td>V= 0.024</td>
</tr>
<tr>
<td>Male</td>
<td>82.2</td>
<td>17.8</td>
<td>60.6</td>
<td></td>
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<td></td>
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<tr>
<td>Age</td>
<td></td>
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<tr>
<td>15-24</td>
<td>66.9</td>
<td>33.1</td>
<td>7.7</td>
<td>X²=24.849</td>
<td>p&lt;0.001</td>
<td>V= 0.126</td>
</tr>
<tr>
<td>25-40</td>
<td>84.6</td>
<td>15.4</td>
<td>56.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>41-60</td>
<td>80.0</td>
<td>20.0</td>
<td>28.1</td>
<td></td>
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<tr>
<td>60+</td>
<td>77.0</td>
<td>23.0</td>
<td>7.2</td>
<td></td>
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<tr>
<td>Duration in Farming</td>
<td></td>
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<tr>
<td>0-5</td>
<td>84.4</td>
<td>15.6</td>
<td>25.0</td>
<td>X²=5.751</td>
<td>p=0.056</td>
<td>V= 0.061</td>
</tr>
<tr>
<td>6-10</td>
<td>83.4</td>
<td>16.6</td>
<td>20.4</td>
<td></td>
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<tr>
<td>11+</td>
<td>79.3</td>
<td>20.7</td>
<td>54.6</td>
<td></td>
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<tr>
<td>Household size</td>
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<tr>
<td>1-10</td>
<td>72.4</td>
<td>27.6</td>
<td>9.3</td>
<td>X²=13.988</td>
<td>p=0.003</td>
<td>V= 0.095</td>
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<tr>
<td>6-10</td>
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<td>19.8</td>
<td>28.1</td>
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<tr>
<td>11-15</td>
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<td>13.8</td>
<td>24.9</td>
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<td></td>
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</tr>
<tr>
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### Respondents participation in digital services

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<th>Non-participation in service (%)</th>
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Business status:
- Fulltime: 72.0% 28.0% 69.3% \( \chi^2 = 5.228 \), \( p = 0.026 \)
- Part-time: 66.3% 33.8% 30.7% 

Membership of association:
- No: 31.1% 68.9% 32.7% \( \chi^2 = 554.977 \), \( p < 0.001 \)
- Yes: 89.2% 10.8% 67.3% 

Access to extension/Vert services:
- No: 33.6% 66.4% 30.6% \( \chi^2 = 442.488 \), \( p < 0.001 \)
- Yes: 86.4% 13.6% 69.4% 

Phone ownership:
- No: 62.9% 37.1% 2.2% \( \chi^2 = 0.929 \), \( p = 0.335 \)
- Yes: 70.4% 26.6% 97.7%
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## Perceptions on whether digitalization is good for farmers

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V=0.013
Respondents willingness to join digital services

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<th>Unwilling (%)</th>
<th>Total</th>
<th>Chi-Square (X^2)</th>
<th>Significance (p)</th>
<th>Cramer (V)</th>
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<td>GHC 10000+</td>
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| Business status | Fulltime | 91.8 | 5.7 | 2.5 | 69.3 | X²=2.368 | p=0.306 | V= 0.039 |
|                | Part-time| 91.5 | 4.8 | 3.8 | 30.7 |          |         |          |
| Membership of association | No | 84.0 | 8.4 | 7.6 | 32.7 | X²=77.097 | p<0.001 | V= 0.222 |
|                | Yes | 95.4 | 4.0 | 0.6 | 67.3 |          |         |          |
| Access to extension/Vertical services | No | 86.4 | 7.1 | 6.5 | 30.6 | X²=36.666 | p<0.001 | V= 0.153 |
|                | Yes | 94.0 | 4.7 | 1.3 | 69.4 |          |         |          |
| Phone ownership | No | 94.3 | 5.7 | 0.0 | 18.6 | X²=1.061 | p=0.588 | V= 0.026 |
|                | Yes | 91.6 | 5.4 | 2.9 | 81.4 |          |         |          |
### Phone usage among groups

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<th>Total</th>
<th>Chi-Square (X²)</th>
<th>Significance (p)</th>
<th>Cramer (V)</th>
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<td>Livestock only</td>
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<td>Monocropping (just one crop)</td>
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<td></td>
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<td>V= 0.265</td>
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</table>

V= 0.302
The members of the University of Guelph Research Ethics Board have examined the protocol which describes the participation of the human participants in the above-named research project and considers the procedures, as described by the applicant, to conform to the University’s ethical standards and the Tri-Council Policy Statement, 2nd Edition.

The REB requires that researchers:

- Adhere to the protocol as last reviewed and approved by the REB.
- Receive approval from the REB for any modifications before they can be implemented.
- Report any change in the source of funding.
- Report unexpected events or incidental findings to the REB as soon as possible with an indication of how these events affect, in the view of the Principal Investigator, the safety of the participants, and the continuation of the protocol.
- Are responsible for ascertaining and complying with all applicable legal and regulatory requirements with respect to consent and the protection of privacy of participants in the jurisdiction of the research project.

The Principal Investigator must:

- Ensure that the ethical guidelines and approvals of facilities or institutions involved in the research are obtained and filed with the REB prior to the initiation of any research protocols.
• Submit an **Annual Renewal** to the REB upon completion of the project. If the research is a multiyear project, a status report must be submitted annually prior to the expiry date. Failure to submit an annual status report will lead to your study being suspended and potentially terminated.

The approval for this protocol terminates on the **EXPIRY DATE**, or the term of your appointment or employment at the University of Guelph whichever comes first.

Signature:                                                                                           Date: March 20, 2020

Stephen P. Lewis
Chair, Research Ethics Board-General
The members of the University of Guelph Research Ethics Board have examined the protocol which describes the participation of the human participants in the above-named research project and considers the procedures, as described by the applicant, to conform to the University's ethical standards and the Tri-Council Policy Statement, 2nd Edition.

The REB requires that researchers:

- Adhere to the protocol as last reviewed and approved by the REB.
- Receive approval from the REB for any modifications before they can be implemented.
- Report any change in the source of funding.
- Report unexpected events or incidental findings to the REB as soon as possible with an indication of how these events affect, in the view of the Principal Investigator, the safety of the participants, and the continuation of the protocol.
- Are responsible for ascertaining and complying with all applicable legal and regulatory requirements with respect to consent and the protection of privacy of participants in the jurisdiction of the research project.

The Principal Investigator must:

- Ensure that the ethical guidelines and approvals of facilities or institutions involved in the research are obtained and filed with the REB prior to the initiation of any research protocols.
- Submit an Annual Renewal to the REB upon completion of the project. If the research is a multiyear project, a status report must be submitted annually prior to the expiry date. Failure to submit an annual status report will lead to your study being suspended and potentially terminated.
The approval for this protocol terminates on the **EXPIRY DATE**, or the term of your appointment or employment at the University of Guelph whichever comes first.

Signature: 

Date: November 9, 2020

Stephen P. Lewis  
Chair, Research Ethics Board-General
Research Ethics Board (REB)

Amendment Request Form

DIRECTIONS

Step 1: Forms and Other Documents
Please complete and submit this form if you wish to make a change or an addition to any part of an approved REB Application package.
Once you have noted the changes in item 4 below, prepare your other documents.
For every document which is changing:

- Start with a clean copy of the previously approved documents (i.e., accept all old changes/revisions and remove all highlights BEFORE you make changes).
- Amendments including tracked changes or highlights NOT part of the current submission, will be sent back to the researchers for clean up before review will commence
- Use track changes to indicate the current amendments being proposed for each approved document. Rename the file [file_name]_tracked.
- Accept all the changes so that the document is in its final format. Rename the file [file_name]_clean.

Step 2: Attestation
The Principal Investigator must, in an email from the PI’s @uoguelph.ca account, copy and paste the following wording to certify that:

- I have reviewed this Amendment and the information within is acceptable and ready for REB review.
- If a student has been added to this protocol, their Training Certificate has been included.
- All project personnel have reviewed and are in agreement with the contents of this submission.

Step 3: Submission
Submit to reb@uoguelph.ca
1. Research Ethics Approval number

19-12-027

2. Title of the research project

Social Impacts of Digital Agricultural Technologies in Ghana

3. Investigator Information

<table>
<thead>
<tr>
<th>Name &amp; position</th>
<th>Principal Investigator</th>
<th>Faculty Co-Investigator</th>
<th>Student Investigator</th>
<th>Other Investigator</th>
<th>Department</th>
<th>Phone No.</th>
<th>E-Mail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evan Fraser , Director of Arrell Food Institute, University of Guelph</td>
<td>Yes</td>
<td>Abdul-Rahim Abdulai ; Emily Duncan ; Phillip Tetteh Quarshie</td>
<td>Geography, Environment and Geomatics</td>
<td></td>
<td>519-824-4120 X 5301</td>
<td><a href="mailto:efraser@uoguelph.ca">efraser@uoguelph.ca</a></td>
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</tbody>
</table>

4.

Itemize and summarize the changes you are proposing to make to the previously approved ethics application package.

<table>
<thead>
<tr>
<th>Question Number</th>
<th>Amendment Summary</th>
</tr>
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<tbody>
<tr>
<td>Q4.</td>
<td>Introduction of Covid-19 clause &quot;To ensure appropriate safety precautions when conducting in-person study procedures, the plan for conducting in-person visits outlined in the ‘Research Management Plans’ document will be followed.&quot;</td>
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</table>
6.

Describe the amendments you are proposing to make to the other previously approved documents

<table>
<thead>
<tr>
<th>Document Name</th>
<th>Amendment Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appendix A</td>
<td>Questions restructured to reflect changes to research situation due to COVID-19</td>
</tr>
<tr>
<td>Appendix B</td>
<td>Questions restructured to reflect changes to research situation due to COVID-19</td>
</tr>
<tr>
<td>Appendix C</td>
<td>Questions restructured to reflect changes to research situation due to COVID-19</td>
</tr>
<tr>
<td>Appendix D</td>
<td>Questions restructured to reflect changes to research situation due to COVID-19</td>
</tr>
<tr>
<td>Appendix H</td>
<td>Covid-19 clauses introduced in consent</td>
</tr>
<tr>
<td>Appendix I</td>
<td>Covid-19 clauses introduced in consent</td>
</tr>
<tr>
<td>Appendix J</td>
<td>Covid-19 clauses introduced in consent</td>
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Appendix III: Research Management Plan

Appendix V – Research Management Plan (RMP) – Face-to-Face Human Research
This form is to be completed by each PI to document their health and safety plans to support the return to research activities specifically related to the return of human participant research. Research plans must work to minimize the number of people necessary to undertake the research safely. Where the research necessitates interaction with human participants, additional procedures must be employed and are to be outlined below. This is an example plan and can be modified to capture research specific to different Academic Units.

It is appreciated that many researchers may have a range of research that could fall under different categories of mitigation needs. Please include coverage of the main procedures that take place at the study location that involve face-to-face human research, where there may be increased risk of COVID-19 exposure. Specifically, consider proximity to participants, and duration of proximity, in addition to the nature of the research and the risks this may impose.

1. Are you currently completing your human participant research remotely or transitioning research remotely and still require access to campus to fulfill these requirements? If so, explain any changes that have been made to protocols. See Level 1 of return to face-to-face human research document for guidelines.

Briefly explain aspects of research with COVID-19 concerns. Identify protocol or procedure changes for each concern.

The research involves interviews, survey, and focus group discussions, which all require close contact between researchers and participants.

All methods involve talking between researchers and participants, thus posing a risk of droplet exchange in interactions.
<table>
<thead>
<tr>
<th>Action</th>
<th>Comments/Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐ Changes have been made to protocols to maintain remote research or transition research remotely</td>
<td></td>
</tr>
<tr>
<td>☒ Changes have been made to REB documents and COVID specific language has been added</td>
<td>Covid-19 clauses introduced in consent documents. Questions adjusted to reflect current changes, and measures instituted in RMP to minimize risk.</td>
</tr>
<tr>
<td>☐ Research at this level is Not Applicable – see further details below</td>
<td></td>
</tr>
</tbody>
</table>

2. If research requires face-to-face interaction, but physical distancing can be maintained, what engineering and administrative controls have been implemented to maintain two metres distance? If research also requires use of PPE for aspects of research that will involve periods of time within two metres, administrative and engineering controls can still be listed here. See Level 2 of return to face-to-face human research document for guidelines.

**Briefly explain aspects of research with COVID-19 concerns. Identify administrative and engineering controls being proposed to mitigate risk for each concern.**

The research involves interviews, surveys and focus groups, which could be in indoor or outdoor locations.

- When telephone interviews are impossible to administer, surveys and interviews will be conducted in outdoor spaces (tree sheds outside homes/ common sitting areas in homes/ on farms)– engaging in small groups, social distancing, and mask wearing practices. The social life and daily practices in many rural communities will allow for this open-air data collection at all times as people normally hold conversations outside homes and in community spaces. Hence, no data collection will be done in indoor spaces at this points, except for exceptional cases outlined in Level 3.

- Data collectors will follow the Ghana Ministry of Health guidelines to maintain the two metres distance between people, wear mask, and use sanitizers (https://www.ghanahealthservice.org/covid19/downloads/covid_19_nose_mas
(k.pdf). To attain this, all group-based methods, like focused groups, will be limited to the minimal participants possible to minimise human contacts. In line with the culture and traditions of the place, group-based activities will be conducted in open spaces, mostly community grounds or outside home.

- Part of the research budget will be allocated to purchase protective equipment’s (including mask, gloves, sanitizers, and face shields) to protect participants and data collectors alike. Data collectors will be provided with mask (to be worn at all time) and sanitizers and required to use it as frequently as possible during the field activities. In addition, each research participant will be provided with a mask prior to survey, focus group or interview interactions.

- Data collection will be switched from paper to digital means to reduce potential exposure. The researchers will employ Kobo toolbox (a secure field data collection app) to allow data collection on smartphones and tablets. Hence, each data collector will stick to one devise throughout the field work, to minimise contact and potential exposure associated with handling paper.

- Consent process will be amended from paper signed to verbal consent, whenever possible. Hence, data collectors will use phones/tablets to obtain consent orally rather than having participants sign them. The use of the tablets/phones and Kobo toolbox will allow for collection of oral consent as part of the surveys.

- The use of digital data collection with gps coordinates will allow for effective contact tracing if needed. Kobo toolbox allow for collection of location data and other vital information needed for contact tracing when necessary.

- In-country transportation for research purposes will be carried entirely with private means, to minimize any potential exposure through public transport. A van will be rented to transport the researchers to field communities at all time.

- During periods of fieldwork in remote communities, researchers and assistants will be provided with accommodation with proven COVID-19 preparedness. When that is not possible, arrangements will be made to find separate and safe accommodation within communities.

- Food and accommodation will be provided in ways that are sensitive to COVID-19 exposure. Researchers will have separate accommodation wherever possible. We will also reduce exposure by providing food in bulk from one source at each time to avoid a situation wherein researchers have to find food for themselves during the data collection in communities.

<table>
<thead>
<tr>
<th>Action</th>
<th>Comments/Description</th>
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</thead>
<tbody>
<tr>
<td>☐ Items at location have been relocated where possible to support minimum physical distancing with participant</td>
<td></td>
</tr>
<tr>
<td>☒ Engineering controls have been implemented using change in location</td>
<td></td>
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</tbody>
</table>
where possible, for example from inside to outside

☐ If more than one researcher is required to perform an activity, research members are paired up to minimize the number of discrete contacts with different individuals, thus limiting potential exposure to a potential positive case of COVID-19.

☐ Consent forms (and other documents) are administered online.

☒ Changes have been made to REB documents, and COVID specific language has been added.

3. If it is not possible to maintain two metres distance from human participants, list engineering and administrative controls (listed above or here) in addition to specific PPE required to mitigate risk during close proximity (<two metres). Include consideration of duration and nature of testing. See Level 3 of return to face-to-face human research document for guidelines.

Briefly explain aspects of research with COVID-19 concerns. Identify administrative and engineering controls (describe here or above) as well as PPE being proposed to mitigate risk for each concern.

- Since there will be close contacts among the research team, if possible local arrangements will be made to vaccinate members of the research team prior to start of the project. (Note: This is not a far-reaching goal in Ghana’s Covid-19 vaccination plan since no-risk members of the population are already receiving shots).
- , if vaccination is possible before the start, members will be tested prior to collective activities like travelling together in van. (This is practically possible within Ghana’s free COVID-19 testing readily available to citizens).
- Researchers and participants will continue to adhere to the use of PPEs when social distancing is not possible.
- In case of a research activity undertaken on a rainy day or participant choose a closed space for interview or survey, researchers will as much as possible ensure two meters distance with participant(s) wherever possible in those closed spaces.
- In case two meters distance cannot be possible in indoor spaces, researchers and participants will wear PPE and will limit contact time at the location to 30 minutes each time, with five minutes breaks to allow for
air flow. It must however be noted that cultural and physical experiences at the field sites shows this situation is unlikely to ever occur.

- Also, vulnerable and at-risk populations will not be included in activities involving close contacts.

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<tr>
<th>Action</th>
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<tr>
<td>☒ PPE has been sourced and will be available to researchers and participants, if required.</td>
<td></td>
</tr>
<tr>
<td>☐ All personnel working with participants have reviewed this form and it will be posted somewhere in the lab</td>
<td></td>
</tr>
<tr>
<td>☒ Changes have been made to REB documents, and COVID specific language has been added.</td>
<td></td>
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<tr>
<td>☐ Other (explain)</td>
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4. If your study takes place outside of Ontario, please describe how the current health standards and practices of this research location compare to health standards and practices in Ontario (and the University of Guelph). In your view, which location has the more stringent requirements and why?

5. The research is situated in the context of Northern Ghana. The COVID-19 situation in Ghana can be described as mild, compared to many parts of the world. The first two cases were recorded on 13th March, 2020. The government instituted a nationwide lockdown a few weeks after, which lasted for about a month. Ghana is touted as a model for doublehanding of the pandemic in Africa. Currently, Ghana has confirmed more than over 90,000 COVID-19 cases and 740 death within its borders since March, 2020. The latest information can be accessed here. And as can be seen from the link, the Northern regions are the least affected areas in the country, with the few cases largely concentrated in urban areas.

- Within the country, the Ministry of Health has mandated the use of facemasks in public.

https://www.ghanhealthservice.org/covid19/downloads/covid_19_nose_mask.pdf Restaurants are operating with appropriate social distancing precautions. Conferences, workshops, weddings, and private burials are permitted with a maximum attendance of 100 persons. Religious services
may operate at full capacity for up to two hours per service. Large sporting events, political rallies, and festivals have resumed. Open-air drinking establishments and Ghana’s national tourists sites/attractions are open. Domestic airplanes, taxis, and buses are permitted to operate at full capacity. Face coverings are required in public spaces. All schools in the country reopened in January 2021 for in-person classes. Life in Ghana is back to close to normal, with mostly only the use of PPE being the visible measures.

The measures in Ontario are more stringent than in Ghana. This is because the COVID-19 situation in Ghana and Northern Ghana in particular has mostly been under control. With an average of less than 100 cases daily now, the entirety of Ghana records lower numbers than Ontario.

6. If travel to a research site is required, are there anticipated issues for researchers travelling to this location? Or issues for researchers and participants if travel within a research context is required (e.g. car travel)? If so, please detail plan for managing these challenges.

In-country transportation for research purposes will be carried entirely with private means, to minimize any potential exposure through public transport. A van will be rented to transport the researchers to field communities at all time.

7. Please outline your plan in the case of incidental close contact (less than two metres) with a participant, in the event of an Emergency (e.g. participant faints during exercise).

No incidental contact is anticipated. However, in case, for example, a participant faints during a survey or interview-, the right medical personal will be sought to attend to the person. However, if any research team member is in a position to provide first aid, the person will do while using the right PPEs, including mask, gloves, etc.

8. Does the nature of the research impose additional risk (aerosol producing procedures, prolonged close contact)? Please explain below and document what mitigation strategies are being implemented to reduce risk specific to those concerns.

No
9. Does your target research population include high-risk/vulnerable populations in COVID-19 context, per Appendix III? If YES, please describe additional protection measures that will be utilized. Consideration of exceptional cases to work with higher risk populations can be requested, provided there are effective protection measures to reduce risk to these individuals (e.g., COVID-19 vaccination).

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10. Would you like your RMP to be reviewed at an additional tier to provide guidance for appropriate mitigation strategies for procedures with additional risk? If you choose NO, it does not mean your RMP won’t be reviewed at the second tier if questions remain that require additional expertise prior to clearance.

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Appendix IV: Research Information and Advertisements

Recruitment – Email to Organisations

Recruitment Email - Agency Centred

Research Ethics Number – [#########]
Hello [Specific names will be inserted]

We are writing to invite your participation in our research project. We are researchers at the Department of Geography, Environment and Geomatics, University of Guelph, and we are interested in learning about Ghanaian farmers’ engagement with digital technologies in agriculture and how that influences their practices and communities. As part of the study, we will be meeting for short interviews with farmers and other people interested in farming in Ghana on their views and experiences with the use of digital technologies in agriculture. We will ask questions about some of the technologies used on farms, how those have or may change farming practices and daily farm routines over time, and the impacts on farmers and communities. We will also be asking about the management and future of digital technologies and the data they collect.

This is academic research and participation is voluntary, however, we hope to get people to share their views as a way of developing the agricultural industry and rural communities. We are available to speak to interested people in person or via phone at their convenience for a period between 30-1:30 minutes.

We have attached a one-page information sheet about the study and if you are interested in participating in this research, please reply to this email or contact me on:

Email: aabdulai@uoguelph.ca    Phone: 0541161538

Yours sincerely

Abdul-Rahim

Recruitment – Email for Farmers

Research Ethics Number – [#########]
Hello [Specific names will be inserted]

We are writing to invite your participation in our research project. We are researchers at the Department of Geography, Environment and Geomatics, University of Guelph, and we are interested in learning about Ghanaian farmers’ engagement with digital technologies in agriculture and how that influences their practices and communities.

As part of the study, we will be meeting for short interviews with farmers, and other people interested in farming in Ghana on experiences with the use of new technologies in agriculture. We will ask questions about some of the technologies you use on your farm, how those have changed farming practices and daily farm routines over time, and views on the future of those technologies in shaping communities.
We hope to be granted an opportunity to speak to you on these important issues of relevance to farmers and their communities to help provide directions that can make farming systems and rural communities resilient.

This is academic research and participation is voluntary, however, we hope to get people to share their views as a way of developing the agricultural industry in your area. We will be available to speak to you in person or via phone at your convenience for a period between 30-1:30 minutes.

We have attached a one-page information sheet about the study and if you are interested in participating in this research, please reply to this email or contact me on:
Email: aabdulai@uoguelph.ca   Phone: 0541161538

If you have any questions regarding your rights and welfare as a research participant in this study (REB #18-11-028), please contact: Director, Research Ethics; University of Guelph; reb@uoguelph.ca; 519-824-4120 ext. 56606.

We are excited about the potential for this project to help understand how we can better support farmers to build resilient farms and communities!

Yours sincerely
Abdul-Rahim

Advertisement/ Social Media Add for Interviews

Researchers at the Department of Geography, Environment and Geomatics, University of Guelph are seeking participants for a research project on “The Social Impacts of Digital Agricultural Technologies in Ghana”.

The goal of the project is to understand how farmers are engaging with diverse digital agricultural technologies and big data, and how that may in turn impact practices and power dynamics among actors in agriculture and in rural communities.

Participants are invited to take part in a 45 minutes interview and/or Survey to discuss issues around some of the digital technologies farmers use on their farms, how those have changed their farming practices and daily farm routines over time, and their views on the future of those technologies in shaping their communities.

This is an academic research and participation is voluntary, however, the researcher hopes to get many participants as possible as he explores issues around the growing disruptions in agriculture and agricultural settings.

We are available to speak to you in person or via phone at the convenience of participants:
Email: aabdulai@uoguelph.ca   Phone: 0541161538

If you have any questions regarding your rights and welfare as a research participant in this study (REB ####) please contact Director, Research Ethics; University of Guelph; reb@uoguelph.ca; 519-824-4120 ext. 56606.

We are excited about the potential for this project to help us understand how we can better support farmers to build resilient farms and communities!
Researchers at the Department of Geography, Environment and Geomatics, University of Guelph are seeking participants for a research project on “The Social Impacts of Digital Agricultural Technologies in Ghana.”

The goal of the project is to understand how farmers are engaging with diverse digital agricultural technologies and big data, and how those may impact practices and power dynamics among stakeholders in agriculture.

Participants are invited to take part in a survey of about 45 minutes to highlight issues around some of the digital technologies farmers use on their farms, how those have changed their farming practices and daily farm routines over time, and their views on the future of those technologies in shaping their communities.

This is an academic research and participation is voluntary, however, the researcher hopes to get many participants as possible as he explores issues around the growing disruptions in agriculture and agricultural settings.

If you are interested in this, we are available to speak to you in person or via phone at the convenience of participants: Email: aabdulai@uoguelph.ca  Phone: 0541161538

If you have any questions regarding your rights and welfare as a research participant in this study (REB ####) please contact Director, Research Ethics; University of Guelph; reb@uoguelph.ca; 519-824-4120 ext. 56606.

We are excited about the potential for this project to help us understand how we can better support farmers to build resilient farms and communities!
Appendix V: Interview Guides

Farmer Participant Semi-Structured Interview Questions

The farmer and farming life
1. Please tell me a little bit about your farm operation — probe on what is cultivated, production methods, seasonal operations, marketing of produce, etc.
2. How has your farming changed in the past ten years?
3. What type of digital technology services have you used in the past or at present?
4. Now let’s talk of a specific service. Mention types available in the area, ask how long the service has been used.
5. What has motivated you to adopt certain technologies and not others?
6. How has the digital technology service(s) altered the daily activities and routines on your farm? You can use any digital technology service to illustrate your experience.
7. In which ways have digital farmer services helped your farming activity?
8. Probe on income, efficiency, time, outputs, climate change resilience, household food security, etc.

Rural, smallholder livelihoods resilience and food security
9. In which ways do you see digital agriculture impacting rural people and communities in general? Probe about diverse socio-economic impacts.
10. How did the implementation of these technologies help you cope with shocks and changes?
   • Ask for specific climate change resilience stories
   • Ask for Covid-19 response and recovery examples
11. In which ways does digital technologies help promote food security in your community?

Data and Service dynamics
12. Describe your relationship to the company that provides the digital farmer service.
13. Who gains the most from using digital agricultural data? And why?
14. How do you use the digital agricultural data that is generated through technologies on your farm?
15. Does this data have an impact on your farming decisions? If so, how? What challenges do you face in using digital services?

Towards inclusive and responsible digital agriculture
16. What kinds of technologies do you see yourself adopting in the next 5 years? Why?
17. What types of processes, rules or incentives might help manage or reduce the risks of using digital tools? (e.g. protocols, practices, partnerships, support, etc.)?

18. Who do you think should be responsible for managing information or data flows that are generated by digital agriculture technologies? Ex. Governments, corporations, farmer groups or farmers?

19. What role can farmers play to ensure digital technologies help the farm community?

20. What new knowledge and competences should be promoted to ensure you are included in digital technology usage on your farm, and who should take responsibility for that?

21. What role could these entities play in promoting socially sustainable digital agriculture?
   - Farmers
   - Local government/municipalities
   - Farming communities, rural area
   - Government
   - Education institutions-universities
   - Private sector-agricultural/technology companies

22. If there was an opportunity to make a specific change, what do you see as the most essential strategy or policy needed to support digital technologies?
Key Informant Participant Semi-Structured Interview Questions

1. Describe your role/position in [company/organization]?
2. What is your understanding of the role that digital agriculture technology plays in Ghanian agriculture?
3. How do you see digital agriculture technology (and the companies that sell these technologies) changing the ways people farm?

Multi-Scale Drivers

4. What are the broader drivers to the emergence of digital technologies in agriculture in the country? *Probe on what motivates the company (or organisation) to supply the service(s) they offer or why the organization promote digitization.*
5. What do you see as the farm level drivers that nudge farmers to adopt and use digital technologies? (Service providers: *Why do you think farmers adopt your service?*)
6. In which ways do existing rules or regulations facilitate the use of digital services in agriculture? *Probe about farmers' conditions, legislations, market dynamics, institutional, environmental, cultural etc.*
7. How do current structures undermine the integration of digital technologies in the country? *Probe about farmers' conditions, legislations, market dynamics, institutional, environmental, cultural etc.*

Data

8. What forms of data are collected from farmers?
9. How is the data collected from farmers being managed?
10. Who is responsible for managing information or data flows in agriculture and why? Example. Governments, corporations, farmer groups or farmers?
11. What are the rules guiding the collection and management of agricultural data in the country?
12. What types of processes, rules or incentives might help to manage or reduce some of the risks associated with agricultural Big Data in the country (e.g. protocols, practices, partnerships, support etc.)?

Farming practices and change

13. In what specific ways do the technologies change or improve the act of farming for your clients?
14. What aspects of farm activities are technologies mostly applicable?
15. Are there new demands for farmer’s use of your technologies? if yes, what are the demands? What can be done to meet these demands? *Probe on attitudes, knowledge, legislation, institutions, etc.*
16. What aspects of farm activities and practices could these technologies make obsolete?

Rural, smallholder livelihoods resilience and food security
17. Based on your interactions with farmers, what are the socio-economic impacts of these services for farmers and rural communities?
18. How are these technologies helping enhance smallholder farmers and their livelihoods against shocks/changes? Any examples?
   - Ask for specific climate change resilience stories
   - Ask for covid-19 response and recovery examples
19. In which ways does digital technologies help promote food security in the region?
20. How do you see farmers being impacted in the future by digital agriculture technologies and the agricultural Big Data that they generate?

Towards inclusive transition to digital agriculture

21. How do we ensure digital agriculture benefit all forms of farmers (small and large)?
22. Considering the nature of services, how can farmers be prepared in terms of knowledge and competences to transition into digital farming?
23. What are the institutional changes required to aid farmers in adopting and using digital technologies?
   - Ask of potential institutional changes
   - Ask of cultural changes required
   - Ask of regulatory changes needed

24. What role can each of these entities play in promoting socially sustainable digital agriculture?
   - Government
   - Local government/district assemblies
   - Educational institutions
   - Farmers
   - Farming communities
   - Private sector
   - Technology service providers
   - Agricultural companies
   - Extension agencies

25. If there was an opportunity to make a specific change, what do you see as the most crucial strategy or policy needed to support digital technologies in Ghana
Key Informant Participant Semi-Structured Interview Questions

1. Describe your role/position in [company/organization] and how you are engaged in the digital agriculture ecosystem in Africa?
2. What is your understanding of the role that digital agriculture technology plays in African agriculture? Or Why are we promoting these technologies on the continent?

Multi-Scale Drivers

3. What are the broader drivers to the emergence of digital technologies in agriculture on the continent? Probe on what motivates the company or organisations to supply the service(s) they offer or why the organization promote digitization.
4. What do you see as the farm level/local drivers that nudge farmers to adopt and use digital technologies? (Service providers: Why do you think farmers adopt your service?)
5. In which ways do existing rules or regulations facilitate the use of digital services in agriculture? Probe about farmers' conditions, legislations, market dynamics, institutional, environmental, cultural etc.
6. How do current structures in African countries undermine the integration of digital technologies? Probe about farmers' conditions, legislations, market dynamics, institutional, environmental, cultural etc
7. As a retailer or service provider, what factors do you perceive as instrumental in supporting farmers with your services? What has helped? What may have challenged the process?

Impacts ---TECHNOLOGY AS THE ENABLER

8. Based on your interactions with farmers, which ways have these technologies been helpful in the region?
9. What aspects of farm activities are technologies mostly applicable?
10. In what specific ways do the technologies change or improve the act of farming for your clients?
11. Are there new demands for farmer’s use of your technologies? if yes, what are the demands? What can be done to meet these demands? Probe on attitudes, knowledge, legislation, institutions, etc.
12. What aspects of farm activities and practices could these technologies make obsolete?

Rural, smallholder livelihoods resilience and food security

13. In which ways do you see digital agriculture impacting rural people and communities? Probe about diverse socio-economic impacts
14. How are these technologies helping enhance smallholder farmers and their livelihoods against shocks/changes? Any examples?
15. How did the implementation of these technologies help rural Africa cope with shocks?
   Ask for specific climate change resilience stories
   Ask for covid-19 response and recovery examples
16. In which ways does digital technologies help promote food security in the region?
17. How do you see farmers being impacted in the future by digital agriculture technologies and the agricultural Big Data that they generate?

Data
1. What forms of data are collected from farmers?
2. How is the data collected from farmers being managed?
3. Who is responsible for managing information or data flows in agriculture and why? Example. Governments, corporations, farmer groups or farmers?
4. What are the rules guiding the collection and management of agricultural data in the country?
5. What types of processes, rules or incentives might help to manage or reduce some of the risks associated with agricultural Big Data on the continent (e.g. protocols, practices, partnerships, support etc.)?

Towards inclusive transition to digital agriculture
6. How do we ensure digital agriculture benefit all forms of farmers (small and large)?
7. Considering the nature of services, how can farmers be prepared in terms of knowledge and competences to transition into digital farming?
8. What are the institutional changes required to aid farmers in adopting and using digital technologies?
9. How can cultural values and practices in Africa be leveraged to enhance digitization?
10. Which ways must current regulations be changed to support digital technologies in agriculture?
11. What role can various entities play in promoting socially sustainable digital agriculture?
   • Government
   • Farmers and farming communities
   • Private sector
   • Technology service providers and agricultural companies
12. If there was an opportunity to make a specific change, what do you see as the most crucial strategy or policy needed to support digital technologies in Africa?
Appendix VI: Focus Group Discussion Guide

Focus Group Discussion Guide

Consent Process
Consent forms for focus group participants are completed in advance by all those seeking to participate.

Thank you for agreeing to participate in our discussion. We want to know your experiences with digital agriculture services.

- The purpose of this is to understand how the adoption of digital technologies will impact society, specifically farming households and rural communities. We are interested in understanding changes to practices of farming, issues of access, and power dynamics altered by digital technologies. We will make recommendations to government and private actors based on our findings, to try to positively develop digital agriculture in socially sustainable and inclusive ways.

- The information we collect is completely confidential, and we will not associate your name with anything you say in this focus group.

- We would like to tape the discussions to allow us to capture the thoughts, opinions, and ideas we hear from everyone here. No names will be attached to the focus groups and the tapes will be destroyed after the project is complete. If there is not consensus about the discussion being recorded, then it will not be recorded and the researchers will take written notes instead.

- You may refuse to respond to any question you wish without any consequences

- You can withdraw from the study at any time during the discussion.

- We understand how important privacy is to many of us here, so we entreat all participants to ensure the privacy and confidentiality of discussions. We will ask participants to respect each other’s confidentiality.

- Please feel to ask us if you have any questions now or later and we will be happy to respond.

- Please check the boxes on the consent form to show you freely agree to participate in this discussion.

Introduction:

1. Welcome
   Researchers introduce themselves and note takers to participants. Key points in introduction include:
   - Who we are and what we’re trying to do.
   - What will be done with this information
   - Why we asked you to participate

2. Explanation of the process
   Group will be asked if anyone has participated in a focus group before. The group will then be talked through the key points for discussions.
**Key points to note**
- We learn from you (positive and negative)
- Not trying to achieve consensus, we’re gathering information
- No virtue in long lists: we’re looking for priorities
- In this project, we are doing both questionnaires, interviews and focus group discussions. The reason is to obtain more in-depth and diverse information from a smaller group of people in focus groups. This allows us to understand the context behind the answers given in the written survey and helps us explore topics in more detail than we can do in a written survey.

**Logistics**
- Focus group will last about one hour to one and a half hour
- Feel free to move around
- Help yourself to refreshments

3. **Ground Rules**
   Ask the group to suggest some ground rules. After they brainstorm some, make sure the following are on the list.
   - Everyone should participate.
   - Information provided in the focus group must be kept confidential
   - Stay with the group and please don’t have side conversations
   - Turn off cell phones if possible
   - Enjoy the conversations we are having

4. **Turn on Tape Recorder**

5. **Group to be asked if there are any questions before we get started, and address those questions.**
6. **Introductions**
   - Who participants are, what they grow and their interaction with digital technologies.

**Questions:**

1. Let’s start the discussion by talking about what makes people use digital farmer services. Why do people here find digital services useful? What specific services or aspects of the services do people find useful?
2. What kind of changes have people experienced since they started using digital services?
3. What are some challenges people here face in accessing or using digital farmer services?
4. Have you considered not using digital farmer services? If so, why? What factors contributed to your decision to continue usage?
5. In what ways do people anticipate digital technologies to help you? What do you wish to see in the future? What suggestions do you have to improve the services to ensure everyone benefits from them?

*Probes for Discussion:*
• Types of services
• Benefits
• Challenges
  □ Social and economic
• Impacts
  □ Everyday farm practices
  □ Changes in community farming systems
  □ Changes to power dynamics in communities
• Decision Making and Practices
  o Everyday farming practices in community
  • Planting decisions and practices
  • Harvesting decisions and practices
  • Market decisions and practices
• Specific impacts
  □ Access to markets
  □ Access to inputs
  □ Incomes
  □ Farmer knowledge exchange
  □ Social capital
  □ Decision making
  □ Household role
  □ Food security
  □ Climate change resilience
  □ Community resilience (experiences with Covid)
• Big Data
  • Knowledge on data collected
  • Purpose and use of the data
  • Privacy and transparency in data

That concludes our focus group. Thank you so much for coming and sharing your thoughts and opinions with us. Please feel free to come talk to us later if you have any further information to share.

Materials and supplies for focus groups
• Sign-in sheet
• Consent forms (one copy for participants, one copy for the team)
• Evaluation sheets, one for each participant
• Name tents
• Focus Group Discussion Guide for Facilitator
• 1 recording device
• Batteries for recording device
• Notebook for note-taking
• Refreshments
Appendix VII: Surveys

Digital Agriculture use Cases in Ghana

Survey Identifiers
Record your current

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accuracy

Name of Community

- [ ] Saandu

District

- [ ] Tamale
- [ ] Savelugu
- [ ] Kumbungu
- [ ] Tolon
- [ ] Gushegu
- [ ] Sagnarigu
- [ ] Nantong

Farmer Characteristics and Background

Gender of Respondent

- [ ] Male
- [ ] Female

Household status
○ Household head
○ Farm wife
○ Member of farm household
○ Others

**Marital Status**
○ Never Married
○ Married
○ Widowed
○ Separated
○ Divorced
○ Others

**Household Size**

---

**Are you the household member registered for digital service?**
○ Yes
○ No

**What is the age of the farmer**

---

**How long have you been farming?**
Answer in years

---

**What is the highest level of education of the farmer?**
Farm and Farming Characteristics and Experiences

What is the size of your farm?
Write answer in approximate acres

What is the ownership status of your land?
- Own private land
- Family Land
- Community lands
- Rented land
- Others

What type of farming system do you practice?
- Monocropping (just one crop)
- Mixed cropping (more than one crop)
- Mixed farming (both crop and livestock)
- Only Livestock
- Outgrower

What type of crops do you grow? Tick all that apply
Tick all that apply
- Cereals
- Legumes
- Tubers
- Fruits and vegetables
- Others

If livestock, please provide details
Tick all that apply
How many different crops does the farmer/household cultivate in a season?

What type of farming do you do?
- Only feeding the family (subsistence)
- Only For sale (commercial)
- Part for family and part for sales (Semi-commercial)
- Others

What is the annual income from farming activities?
- >GHC 1000
- GHC 1001-2000
- GHC 2001-3000
- GHC 3001-4,000
- GHC 4001-5000
- GHC 5001-6000
- GHC6001-7000
- GHC7001-8000
- GHC8001-9000
- GHC9001-10000
- GHC10000+

Do you operate this farm as a fulltime business or part-time?
- Fulltime
- Part-time

If part-time, what other jobs do you do?
How many people does your farm employ/engage in a season?

Are you a member of any farm association?
- Yes
- No

Do you access extension/vertinary services?
- Yes
- No

If yes to extension agents, which type of extension do you access?
- Government extension agents
- Private extension
- Both

Mobile technology awareness and usage

Do you/your household own/have the following? [items which have been functioning within the last 12 months]
- Radio
- Television
- Mobile Phone (Feature Phone)
- Mobile Phone (Smartphone)
- Computer
- Tablet
- Internet access (Cellular)
Internet access (Wifi)  
Electricity

If you own a phone, what type of phone does the farmer use?

- Feature phone
- Smart phone
- Both
- No phone

In the last farming season did you use your phone to engage in farm related activity?

- Yes
- No

If yes, what form of usage did you apply?

- Calls for farm related activities
- Texting messages related to farm activities
- Use of an application for farm activity (company specific app)
- Use of application for farm activity (e.g. watsup, facebook, etc)
- Browsing the internet for farm activities
- Listening to audio messages on phone for farm practices
- Watching videos on farm
- activities Listening to radio for
- farming purposes others

If yes, which specific farm activities did you use the phone to help undertake? Tick all that apply

- Inquiring about agronomic practices
- Seeking extension from agents/verts
- Sourcing weather/meteorological information
- Seeking/sourcing inputs
- Inquiries about prices
- Marketing/selling of farm produce/animals
- Connecting with farming peers
- Mobile money activities
- Others
Did farmer use mobile money for farm and produce trading activities?

- Yes
- No

Please indicate whether participants have the ability to perform the following digital activities:

- I can receive and read SMS on my phone
- I can send SMS messages
- I can answer call on my phone independently
- I can place calls on my phone
- I can access audio messages sent to my phone
- I can send audio messages on my phone
- I can follow IVR on my phone
- I can browse the internet for information
- I can use social media

I am able to use an independent phone apps for my activities I can use a computer

How competent are you with using your phone/internet for farm related activities?

- Not competent
- Somewhat competent
- Neutral
- Competent
- Highly competent

Digital technology solutions/services experiences

Are you aware of digital technology services and solutions related to your farming activities?

- Yes
- No
» Potential adoption
Now let's discuss the possibility of adoption

Would you be willing to join a digital service or solution if they were made available here? Yes

If yes, what will make you adopt these technologies?

- When they are made free
- When I am convinced of their benefits
- When I see my peers using them
- When they become widespread in this area
- When I have the competence to use them
- When the network is good around here
- Others

If others please specify

If no, why?

- I just don't think we need these technologies
- I trust my old farming ways
- I don't trust digital technologies
- I don't trust the people providing the solutions
- I have had bad experiences with other technologies/services
- I am just not interested in change
- We are not ready for that system
- Others

If others please specify

Has your farm participated in any program related to digital technologies in the last five years or currently use any service?

- Yes
- No
If yes, do you currently actively participate in the service?

- Yes
- No

» Non-adoption of solutions/services

What are the main reasons for not having tried any digital solutions?
[Spontaneous response only. Mark all that apply.]

- No interest in trying something new
- Unable to afford the technology/service
- Don't know where to get the technology/service
- Don't have enough/type of land/animals to join
- Don't have the skills to use technologies
- I don't trust the providers of the technologies
- No other farmer in my area uses these technologies/services
- I trust my old ways of farming
- I was not here when they were registering
- Others

If others please provide details

If you have ever used these technologies but no longer, why did you stop using them?

- They were expensive
- I did not understand how to get the best out of them
- I was in a program that ended
- I just don't care about them anymore
- I just feel my old ways were better than them
- The service is no longer available
- I did not gain any benefits
- I was part of a program that ended
- Others

Do you see yourself adopting these solutions in the future?

- Yes
- No
If yes, what will make you adopt these technologies?

- When they are made free
- When I am convinced of their benefits
- When I see my peers using them
- When they become widespread in this area
- When I have the competence to use them
- When the network is good around here
- Others If others, please specify

If no, why?

- I just don't think we need these technologies
- I trust my old farming ways
- I don't trust digital technologies
- I don't trust the people providing the solutions
- I have had bad experiences with other technologies/services
- I am just not interested in change
- We are not ready for that system
- Others

If others provide details

Perceptions of farmers

» Farm and farming perceptions

Let's talk about perception on farming and smallholder systems

Digital services will make farming in the area productive and efficient

- Strongly Disagree
- Disagree
- So-so
- Agree
- Strongly Agree
Digital technologies will allow farmers to explore different farming models

- Strongly Disagree
- Disagree
- So-so
- Agree
- Strongly Agree

Digital technologies will change cropping patterns of smallholders

- Strongly Disagree
- Disagree
- So-so
- Agree
- Strongly Agree

New technologies would lead to farms becoming bigger

- Strongly Disagree
- Disagree
- So-so
- Agree
- Strongly Agree

Technologies will make farming profitable again

- Strongly Disagree
- Disagree
- So-so
- Agree
- Strongly Agree

Digital technologies will make smallholder farming practices environmentally sustainable

- Strongly Disagree
- Disagree
- So-so
- Agree
- Strongly Agree

245
Digital technologies would make smallholders resilient to climate change

- Strongly Disagree
- Disagree
- So-so
- Agree
- Strongly Agree

Digital technologies may bring undesirable changes to farmer livelihoods

- Strongly Disagree
- Disagree
- So-so
- Agree
- Strongly Agree

The technologies will force out smallholder farmers

- Strongly Disagree
- Disagree
- So-so
- Agree
- Strongly Agree

Digital technologies will reduce the agency and innovation of farmers to deal with emergent issues

- Strongly Disagree
- Disagree
- So-so
- Agree
- Strongly Agree

Digital technologies will make farmers dependent on external knowledge

- Strongly Disagree
- Disagree
- So-so
- Agree
- Strongly Agree
Digital technologies will reduce the agency and innovation of farmers to deal with emergent issues
- Strongly Disagree
- Disagree
- So-so
- Agree
- Strongly Agree

» » Rural impacts perceptions

The technologies would make agriculture attractive to the youth in this area
- Strongly Disagree
- Disagree
- So-so
- Agree
- Strongly Agree

Digital technologies would attract more people into rural communities
- Strongly Disagree
- Disagree
- So-so
- Agree
- Strongly Agree

Digital technologies will increase employment diversity in rural areas
- Strongly Disagree
- Disagree
- So-so
- Agree
- Strongly Agree

Digital technologies will create new livelihood opportunities for rural people
Digital technologies will reduce rural poverty

- Strongly Disagree
- Disagree
- So-so
- Agree
- Strongly Agree

Digital technologies will bring food security to rural people

- Strongly Disagree
- Disagree
- So-so
- Agree
- Strongly Agree

Digital technologies could open more opportunities for women to engage in farming

- Strongly Disagree
- Disagree
- So-so
- Agree
- Strongly Agree

Digital technologies to enhance resilience of in rural areas

- Strongly Disagree
- Disagree
- So-so
- Agree
- Strongly Agree

Digital technologies could open more opportunities for women to engage in farming
» Digital Technology Platform Usage

Which of these services have you or a member of your household use?

- Agrocenta
- Cowtribe
- Esoko
- Farmradio
- Farmerline
- Trotro Tractor
- Agromyx
- QualiTrace
- AcquahMeyer Drone Tech
- AgroInnova
- Complete Farmer
- Farmwallet
- Vodafon Farmers Club
- Iska
- Others
What type of solutions do you receive from your main provider?

Tick all that apply

- Market price information
- Market linkages
- Climate and weather information
- Agronomic advise
- Linkage to agri-inputs (seeds, fertilisers, veterinary products)
- Linkage to mechanization (tractors, irrigation, etc)
- Farm management software
- Livestock management
- Veterinary services
- Precision advisory
- Financial access
- Insurance
- Payment solutions and wallets
- Credits to farmers
- Crowdfunding
- Supply chain management
- Farm community building (peer to peer connections)
- Traceability services
- Nutrition advise
- Others

What was the main source you learnt about the service(s)?
<table>
<thead>
<tr>
<th>Digital service provider outreach</th>
<th>NGO</th>
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<tbody>
<tr>
<td>Neighbour/relative</td>
<td></td>
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<tr>
<td>Radio program</td>
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<tr>
<td>TV program</td>
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<tr>
<td>ICT/Internet search</td>
<td></td>
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<tr>
<td>Community events</td>
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<td>Government extension agent</td>
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<tr>
<td>Agricultural Show</td>
<td></td>
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<tr>
<td>Others</td>
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</tbody>
</table>

**What was your main motivation that persuaded you to adopt this digital technology service?**

- I wanted to make more money with my farming
- I wanted to increase my productivity
- I wanted to be resilient to changing the weather
- I just happen to be in a program that provided the service
- I just wanted to give new technologies/services a try
- I was convinced by an agent or by a friend
- I wanted to become a modern farmer
- I was really convinced it will bring me many benefits
- I wanted to reduce the time and stress of farm activities/practices
- The technology was affordable or free for me to give a try
- I was influenced by my peers who adopted or recommended the services
- I wanted to be up to date with farming information and knowledge

If others specify

________________________________________________________________________

**How do you receive information from the service/solution?**
Radio
Voice messages
SMS
Independent phone app
Social media app
Webservice platform
Interactive Voice Response (IVR)
Field agents
Phone calls
Peer farmers
Others

How long have you used the digital solution(s)?

In the last farming season, how often did you receive information from your service provider?

- Daily
- Weekly
- Bi-weekly
- Monthly
- When the situation requires

How often did you use the advise to inform your practices?

- Never
- Sometimes
- Always

» Impacts of digital solutions
Now lets talk about some of the Impacts you have experienced in using the digital solutions (Please focus on one solution received by respondent)

Have you seen benefits in using the digital solution?
Do you feel these technologies are changing the way you or people here farm?

- Yes
- No
- Not sure

Do you feel these technologies are changing the way you or people in this community go about your livelihood activities?

- Yes
- No
- Maybe

How has the technologies changed farming?

My participation and use of digital tools and services influences how I plan my season.

My participation and use of digital tools and services has changed my choice of crop.

<table>
<thead>
<tr>
<th>Disagree</th>
<th>Agree.</th>
<th>Not sure</th>
</tr>
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</tbody>
</table>
My participation and use of digital tools and services has changed my planting decisions

My participation and use of digital tools and services has changed my everyday farm care practices

My participation and use of digital tools and services has changed my harvesting activities

My participation and use of digital tools and services has changed my postharvest management activities

My participation and use of digital tools and services has changed my marketing and sale activities

If these technologies are changing the way you or people here farm, are you excited about the changes?

- Yes
- No
- Not sure

To what extent has digital services impacted your operations in the following areas?

Advisory and information services

The farm has experienced increased income as we use these services

We have been able to increase our production

We have been able to reduce postharvest losses

We are able to make good and informed decisions about our farm activities quicker

We are able to make effective use of labour time as we spend less time on the farm

Farming has become less stressful and tiring for us

Strongly disagree  Disagree  So-so  Agree  Strongly agree
We are able to make sales/marketing decisions with more certainty
We are able to reduce our vulnerability to changing weather patterns
Our operations have become better for the local environment (soil, water)
We are able to produce more and different crops
We are able to make timely decisions on farm practices
We have not seen any change from these services

To what extent has digital services impacted your operations in the following areas?

Strongly disagree  Disagree  Neutral  Agree  Strongly agree

The farm has experienced increased income as we use these services
We have been able to increase our production
We have been able to reduce postharvest losses
We are able to make good and informed decisions about our farm activities quicker
We are able to make effective use of labour time as we spend less time seeking inputs
Farming has become less stressful and tiring for us
We are able to make timely decisions on farm practices
We are able to reduce our vulnerability to changing weather patterns
Our operations have become better for the local environment (soil, water)
We are able to produce more and different crops because of the ease for accessing inputs
We now worry less about finding the right inputs on time
We have not seen any change from these services

To what extent has digital services impacted your operations in the following areas?
Post-Harvest markets and sales solutions
The farm has experienced increased income as we use these services
We have been able to increase our production due to certainty of market
We have been able to reduce postharvest losses
We are able to make effective use of labour time as we spend less time seeking markets
Farming has become less stressful and tiring for us
We are able to make decisions with more certainty
We are able to bring more land into production due to ready market

Strongly disagree
Disagree
Neutral
Agree
Strongly agree
We are able to access new markets

We now get good prices for products compared to before

We have not seen any any change from these services

To what extent has digital services impacted your operations in the following areas?

Financial solutions

The farm has experienced increased income as we use these services

We have been able to increase our production

We have been able to reduce postharvest losses

We are able to make effective use of labour time as we spend less time on the farm

Farming has become less stressful and tiring for us

We are able to make decisions with more certainty

We are able to reduce our dependence on other farmers for information and services

We are able to make decisions with more certainty

We have not seen any any change from these services

We are able to easily access credit for farming activities

We have not seen any any change from these services

Now lets talk about your assessment of change in regards to the following areas, in the last five years

We have become more aware of changes affecting our farming practices

We have been able to adapt our farming practices to emerging changes (e.g. climate change, fall army worm, etc)

We have been able to reduce losses emanating from unknown changes

We have been able to maintain or increase my farming activities despite emerging shocks
On a scale of 1-10, how will you rate your ability to cope with shocks?

0 | | | | | | | | | | 10

During the last 12 months, was there a time when, because of lack of money or other resources:

You were worried you would not have enough food to eat? ○ ○
You were unable to eat healthy and nutritious food? ○ ○
You ate only a few kinds of foods? You had to skip a meal? ○ ○
You ate less than you thought you should? ○ ○
Your household ran out of food? ○ ○
You were hungry but did not eat? ○ ○
You went without eating for a whole day?

Now let’s talk about your potential use of digital technologies

True False Not sure

I will accept and use newer digital technologies and services if the right conditions are in place
I believe digital technologies and services are good for our farming practices
I believe in my old farming ways and won’t use digital technologies and services
My cultural beliefs and services are sometimes incompatible with digital tools and services
Digital tools and services are the way forward for my farming activities
What have been the biggest challenge to adopting digital solutions?

- Expensive to purchase
- Services not readily available
- Not fitted for all smallholders
- Don't have the expertise to turn advice into action
- Not locally accessible (e.g. language)
- Poor network in this community
- Others

If others please specify

What have been the main challenge of using digital solutions?

- Expensive to maintain
- Services not readily available
- Services are not well suited for my needs
- No proven benefits to me
- Difficult to trust the information provided
- Don't have the expertise to turn advice into action
- Not locally accessible (e.g. language)
- Non reliability of services
- Poor internet in the area
- Others

If others, please specify

Towards Inclusive and Sustainable Digitisation

What aspects of farming will you like to see further digitisation efforts in?
On-farm practices
Input access
Market linkages and access
Finances and payment
Supply chains enhancements
Climate and weather information
Precision advisories
Insurance schemes
Others

What kind of change can service providers make to help you fully utilise the potentials of digital tools?

- Involve farmers in creating solutions
- Use local languages
- Provide more diverse options for farmers
- Make subscriptions cheap
- More marketing of solutions
- Demonstrate value to farmers
- Others

Others please specify

How can digital agriculture be made useful for you?

How can digital agriculture be made useful for your community?

Contact number of respondent
Appendix VIII: Consent Forms

Consent Form
You are being invited to participate in a research project entitled “The Social Impacts of Digital Agricultural Technologies in Ghana”. The study is being conducted by Abdul-Rahim Abdulai and Emily Duncan, under the supervision of Dr. Evan Fraser at the Department of Geography, Environment and Geomatics, University of Guelph. The research is funded by the Canadian First Research Excellence Fund. 

Contact: Abdul-Rahim Abdulai (aabdulai@uoguelph.ca); Emily Duncan (edunca01@uoguelph.ca); Evan Fraser (frasere@uoguelph.ca)

Purpose of the Research:
The purpose of this is to understand how the adoption, use of digital technologies will impact society, specifically farming households and rural communities. We are interested in understanding changes to practices of farming, issues of access, and power dynamics altered by digital technologies and big data in agriculture. Data will be used to inform improve data governance and management structures. Data will also provide insights on how to develop socially inclusive digital agricultural technologies for improved farming outcomes.

COVID-19 and Face-to-Face Research
COVID-19 refers to the virus being spread in communities across the globe. We are providing you with important information about COVID-19 and we ask that you consider the following information to determine if study participation is right for you at this time.

COVID-19 is a respiratory condition caused by SARS-CoV2, which can be spread by respiratory droplets, mainly from person-to-person. This can happen between people who are in close contact with one another (less than 2 metres). It is also possible that a person can get COVID-19 by touching a surface or object (such as a doorknob or counter surface) that has the virus on it, then touching their mouth, nose or eyes. As new vaccines emerge and the public has access, it is important to remain vigilant in all safety precautions until Public health deems it appropriate to change our behaviour.

This study requires in-person visits and it is important to understand that this may increase your exposure to COVID-19. However, the University of Guelph and researchers have taken certain precautions to reduce the risk for you, the research staff, and their families (among others in the community) safe. The safety plans described below aim to minimize the spread of COVID-19 and are consistent with current Ontario Public Health, the Ghana Ministry of Health and University of Guelph Environmental Health and Safety guidelines.

Participant Screening
Due to the peculiar social structures of this research location, participants will be screened on the day of the interview. The following questions will be asked before any further research interaction continues:

1. Do you currently (and/or recently) have a cough, fever or any other symptoms of COVID-19?
2. Have you travelled outside of Ghana in the past 14 days?
3. Have you ever tested positive for COVID-19 or had close contact with anyone that has tested positive for COVID-19?

If you answer YES to any of these questions, it is important to stay self-isolate. Call local health care provider to find a test.

Where will the study take place?
The study will take place at a location chosen by the respondent or at a convenient point where the researcher is able to meet the respondent. This will normally consist of homes of respondents, farms or offices. Outdoor spaces in these locations will be prioritized.

What will happen the day of the study visit?
1. Researchers will use screening questions to assess respondents prior to research activities.
2. Participants are encouraged to travel to [campus/research location] in their own vehicles rather than public transportation, if possible. You are also encouraged to attend [campus/research location] alone.
3. All research participants are asked to wait outside until called to enter [research location].
4. A local representative will distribute mask and sanitisers in communities a day before our visit. You are required to wear a mask prior to and following entry into the building. Once your mask is on, you are asked to try not to touch your face or eyes with your hands.

5. You will be asked to wash or sanitize your hands prior to our encounter.

6. Participants will follow the research personnel to the designated study space and asked to follow their instructions once inside.

7. Once the study visit is complete, the research team member will exit to their mode of transportation.

8. If you are unable or unwilling to follow these guidelines, please notify the local representatives at the time of distribution of mask and sanitisers.

Safety Precautions
In addition to participant screening, you will find the following additional measures have been put in place to help reduce the risk of spreading or contracting COVID-19:

- Personal Protective Equipment (PPE) – masks, gloves and/or face shields
- Handwashing and sanitizing
- Physical distancing
- Minimized time of contact
- Open windows or increased ventilation when necessary
- Hygiene and disinfection protocols and materials

You have been invited to participate based on the following criteria:

- You are a farmer, a technology service provider, or an agricultural official in Ghana.
- You have experience and expertise to speak to digitization efforts in Ghana.
- You are an adult (18+)

What You Will Be Asked to do in the Research: As a participant, you will be asked to participate in an interview of about 45 minutes, sharing your opinions on how digital technologies are impacting farming practices and rural areas broadly. You will also be asked about your specific experiences with the use of digital agricultural technologies, either directly or indirectly.

Risks and Discomforts: There are minimal perceived risks or discomforts associated with this research. Some risks include possible risk to reputation if information about farming practices or livelihoods is revealed and the risk of possible discomfort of disclosing socio-economic information. The researchers will be anonymizing identifying information and storing the data securely. Questions and observations are not intended to be prejudiced or presumptuous, you may decline to answer any questions or disclose specific information in the interview or specify what should not be included in the research.

Also, there is a possibility that during this research activity you could encounter someone with COVID-19. If this were to happen, the University of Guelph and the research team is required by Ministry of Health to collect and retain on file your email of phone number to share with them for contact tracing purposes. As such, anonymity as a research participant cannot be maintained. Should you choose to withdraw from participation in this research, this personal information cannot be withdrawn from University of Guelph or Ministry of Health records. Please be assured that the Ministry of Health will not have access to any other data collected for this research study.

Vulnerable Populations
If you fall within the following categories, you may be vulnerable:

- Above 65 years of age
- Has pre-existing medical conditions (e.g. immunocompromised, diabetes, heart disease, etc)
- Experiencing socio-economic disadvantages such as inadequate or overcrowded housing.
Face to face research involving vulnerable populations will require additional considerations, and measures for safety, and in some instances, participation in the research may not be advisable. Therefore, if you self-identify as a vulnerable or are unsure if you fall within the vulnerable population, it is imperative that you inform the research team and ask for further guidance.

**Safety Precautions**

Due to the risk of COVID-19, the following precautions are put in place:

- Data collectors will follow the Ghana Ministry of Health guidelines to maintain the two metres distance between people, wear mask, and use sanitizers
- Surveys and interviews will be conducted in outdoor spaces as much as possible – engaging in small groups, social distancing, and mask wearing practices.
- You are provided with a mask prior to this interaction, and survey, focus group or interview interactions.
- You will be required to provide consent orally rather than writing to reduce potential exposure.

**Benefits of the Research and Benefits to You:** By participating in this study, you learn about what the conversations around digital technologies are within your region and beyond and share your own experiences and interactions with these new technologies. This will help facilitate policy actions that can make farming better and keep rural communities socially sustainable.

**Voluntary Participation:** Your participation in the study is completely voluntary and you may choose to stop participating at any time. Your decision not to participate will not influence the way you may be relating with the researcher, with the University of Guelph or its community in any way either now, or in the future.

**Confidentiality:** Participation in this research is entirely voluntary and all information shared will be anonymized. Data will be anonymized and will be stored without any identifying information. If the results of this study are published, *no information that discloses your identity will be released.* The interview will be recorded with a digital voice recorder with your consent. Your words may be used directly as quotes; however, your name will not be attributed to it in any way. Direct quotes will only be used if the number of participants is large enough, more than 10 people, so that direct quotes will not reveal the identity of the speaker, and direct quotes will only be used with your express consent. Your data will be safely stored in a locked facility and only the researchers and people directly related to the study or the Ministry of Health in the event COVID-19 contact tracing is necessary will have access to this information. The data will be kept for five years after the end of the project and will subsequently be destroyed through deletion from the harddrive. All notes taken during observation will be transcribed and stored on an encrypted harddrive that will be stored in a locked location and all paper copies will be shredded. Recorded information from the audio recorded will be transferred to be stored on an encrypted harddrive. that will be stored in a locked locations and files will be deleted off the audio recorder immediately after the file transfer. All computers that will be used for data processing will also be password protected.

**Withdrawal from the Study:** You can stop participating in the study at any time, for any reason, if you so decide *up until data has been mixed with others that it cannot be differentiated.* Your decision to stop participating, or to refuse to answer particular questions in the interview, will not affect your relationship with the researchers, University of Guelph, or any other group associated with this study. In the event you withdraw from the study, all associated data collected will be immediately destroyed wherever possible, as long as the researcher can still trace specific information related to you.

**Dissemination of Findings:** Where appropriate, a report of the findings will be emailed to participants. The findings will also be presented to communities in their own language during a Knowledge Mobilization research trip by the researchers in 2021. Results will be reported in aggregate form.

**Questions About the Research?** This project has been reviewed by the Research Ethics Board for compliance with federal guidelines for research involving human participants. If you have questions, concerns or want to speak to the study team for any reason, please contact [Evan Fraser (frasere@uoguelph.ca)](mailto:frasere@uoguelph.ca). If you
have questions regarding your rights and welfare as a research participant in this study (REB#......), please contact: Manager, Research Ethics; University of Guelph; reb@uoguelph.ca; (519) 824-4120 (ext. 56606)
You do not waive any legal rights by agreeing to take part in this study.

Your consent to this interview means that: (*Please tick on boxes that apply to the consent being given*)
☐ You have full understanding of this research as provided in the information sheet
☐ You have had the opportunity to ask questions about this study, which have been clarified to your satisfaction
☐ You understand that you are free to withdraw the study within six months of your interview date, without having to give a reason, and that doing so will not affect you now or in the future.
Additionally, the researcher may use specific techniques in this study. Please consent to the nature you will like your information to be collected and used.
☐ I agree to be audio-recorded during the interview [ ]
☐ I wish to be identified by my job title or agency affiliation or name [ ]
☐ I agree with the use of quotations [ ], but do not want my title to be identified in any publication resulting from this study [ ]
☐ I do not agree to quotations and do not use my occupation or work position [ ]
☐ I consent to have my farming operations observed [ ]

**Legal Rights and Signatures:**
I _____________________________________________________________consent to participate in “The Social Impacts of Digital Agricultural Technologies” conducted by Abdul-Rahim Abdulai and Emily Duncan. I have understood the nature of this study and wish to participate.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Signature/Thumbprint</th>
<th>Date</th>
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<table>
<thead>
<tr>
<th>Researcher</th>
<th>Signature</th>
<th>Date</th>
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Consent was obtained orally
I have explained this study to the best of my ability, and invited questions and gave answers. I believe that the participant fully understands what is involved in participating in this study, any potential risks of the study and that he or she has freely chosen to be in the study.

<table>
<thead>
<tr>
<th>Signature of Investigator</th>
<th>Date</th>
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Consent Form focus groups
You are being invited to participate in a research project entitled “The Social Impacts of Digital Agricultural Technologies in Ghana”. The study is being conducted by Abdul-Rahim Abdulai and Emily Duncan, under the supervision of Dr. Evan Fraser at the Department of Geography, Environment and Geomatics, University of Guelph. The research is funded by the Canadian First Research Excellence Fund.

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Participant Screening
Participants will be screened a day before the focus group. The following questions will be asked before any further research interaction continues:

4. Do you currently (and/or recently) have a cough, fever or any other symptoms of COVID-19?
5. Have you travelled outside of Ghana in the past 14 days?
6. Have you ever tested positive for COVID-19 or had close contact with anyone that has tested positive for COVID-19?

If you answer YES to any of these questions, it is important to stay self-isolate. Call local health care provider to find a test.

Where will the study take place?
The study will take place at a location chosen by the respondent or at a convenient point where the researcher is able to meet the respondent. This will normally take place outside homes or community meeting grounds.

What will happen the day of the study visit?
9. Researchers will use screening questions to assess respondents prior to research activities.

10. Participants are encouraged to travel to [campus/research location] in their own vehicles rather than public transportation, if possible. You are also encouraged to attend [campus/research location] alone.

11. All research participants are asked to wait outside until called to enter [research location].

12. A local representative will distribute masks and sanitizers in communities a day before our visit. You are required to wear a mask prior to and following entry into the building. Once your mask is on, you are asked to try not to touch your face or eyes with your hands.

13. You will be asked to wash or sanitize your hands prior to our encounter.

14. Participants will follow the research personnel to the designated study space and asked to follow their instructions once inside.

15. Once the study visit is complete, the research team member will exit to their mode of transportation.

16. If you are unable or unwilling to follow these guidelines, please notify the local representatives at the time of distribution of mask and sanitizers.

Safety Precautions
In addition to participant screening, you will find the following additional measures have been put in place to help reduce the risk of spreading or contracting COVID-19:

- Personal Protective Equipment (PPE) – masks, gloves and/or face shields
- Handwashing and sanitizing
- Physical distancing
- Minimized time of contact
- Open windows or increased ventilation when necessary
- Hygiene and disinfection protocols and materials

You have been invited to participate based on the following criteria:

- You are a farmer in an agricultural community in Ghana.
- You have engaged with digital technology services in Ghana.
- You are an adult (18+)

What You Will Be Asked to do in the Research: As a participant, you would be asked to participate in a focus group discussion of about 1 hour 30 minutes, sharing your opinions on how digital technologies are impacting farming practices and rural areas broadly. You may also be asked about your specific experiences with the use of digital agricultural technologies, either directly or indirectly, during the discussions. Your participation will involve openly sharing your perspectives with your peers.

Risks and Discomforts: There are minimal perceived risks or discomforts associated with this research. Some risks include possible risk to reputation if information about farming practices or livelihoods is revealed and the risk of possible discomfort of disclosing socio-economic information. The researchers will be anonymizing identifying information and storing the data securely. Questions and observations are not intended to be prejudiced or presumptuous, you may decline to answer any questions or disclose specific information in the interview or specify what should not be included in the research. There is also a risk because other focus group participants cannot be compelled to keep answers discussed in the focus group private.

Also, there is a possibility that during this research activity you could come in contact with someone with COVID-19. If this were to happen, the University of Guelph and the research team is required by Ministry of Health to collect and retain on file your email of phone number to share with them for contact tracing purposes. As such, anonymity as a research participant cannot be maintained. Should you choose to withdraw from participation in this research, this personal information cannot be withdrawn from University of
Guelph or Ministry of Health records. Please be assured that the Ministry of Health will not have access to any other data collected for this research study.

**Vulnerable Populations**

If you fall within the following categories, you may be vulnerable:
- Above 65 years of age
- Has pre-existing medical conditions (e.g. immunocompromised, diabetes, heart disease, etc)
- Experiencing socio-economic disadvantages such as inadequate or overcrowded housing.

Face to face research involving vulnerable populations will require additional considerations, and measures for safety, and in some instances, participation in the research may not be advisable. Therefore, if you self-identify as a vulnerable or are unsure if you fall within the vulnerable population, it is imperative that you inform the research team and ask for further guidance.

**Safety Precautions**

Due to the risk of COVID-19, the following precautions are put in place:
- Data collectors will follow the Ghana Ministry of Health guidelines to maintain the two metres distance between people, wear mask, and use sanitizers
- Surveys and interviews will be conducted in outdoor spaces as much as possible – engaging in small groups, social distancing, and mask wearing practices.
- You are provided with a mask prior to this interaction, and survey, focus group or interview interactions.
- You will be required to provide consent orally rather than writing to reduce potential exposure.

**Benefits of the Research and Benefits to You:** By participating in this study, you learn about what the conversations around digital technologies are within your region and beyond, and share your own experiences and interactions with these new technologies. This will help facilitate policy actions that can make farming better and keep rural communities sustainable.

**Voluntary Participation:** Your participation in the study is completely voluntary and you may choose to stop participating at any time during the session. Your decision not to participate will not influence the way you may be relating with the researcher, with the University of Guelph or its community in any way either now, or in the future.

**Confidentiality:** Participation in this research is entirely voluntary and all information shared will be anonymized. Data will be anonymized and will be stored without any identifying information. If the results of this study are published, *no information that discloses your identity will be released.* The interview will be recorded with a digital voice recorder with your consent. Your words may be used directly as quotes; however, your name will not be attributed to it in any way. Direct quotes will only be used if the number of participants is large enough, more than 10 people, so that direct quotes will not reveal the identity of the speaker, and direct quotes will only be used with your express consent. Your data will be safely stored in a locked facility and only the researchers and people directly related to the study or the Ministry of Health in the event COVID-19 contact tracing is necessary will have access to this information. The data will be kept for five years after the end of the project and will subsequently be destroyed through deletion from the harddrive. All notes taken during observation will be transcribed and stored on an encrypted harddrive that will be stored in a locked location and all paper copies will be shredded. Recorded information from the audio recorded will be transferred to be stored on an encrypted harddrive that will be stored in a locked locations and files will be deleted off the audio recorder immediately after the file transfer. The focus group will only be audio recorded provided that all participants consent to being recorded. If participants do not consent, researchers will take notes of the focus group which will be stored on an encrypted harddrive in a locked location and all paper notes will be shredded.

Although the researchers will take every precaution to maintain confidentiality of the data, the nature of focus groups prevents the researchers from guaranteeing total confidentiality. The researchers would like to remind
participants to respect the privacy of your fellow participants and not repeat what is said in the focus group to others. All discussions must stay within the group.

Withdrawal from the Study: You can stop participating in the study at any time, for any reason, if you so decide up until data has been mixed with others that it cannot be differentiated. Your decision to stop participating, or to refuse to answer particular questions in the interview, will not affect your relationship with the researchers, University of Guelph, or any other group associated with this study. In the event you withdraw from the study, all associated data collected will be immediately destroyed wherever possible, as long as the researcher can still trace specific information related to you.

Dissemination of Findings: Where appropriate, a report of the findings will be emailed to participants. The findings will also be presented to communities in their own language during a Knowledge Mobilization research trip by the researchers in 2021. Results will be reported in aggregate form.

Questions About the Research? This project has been reviewed by the Research Ethics Board for compliance with federal guidelines for research involving human participants. If you have questions, concerns or want to speak to the study team for any reason, please contact Evan Fraser (frasere@uoguelph.ca). If you have questions regarding your rights and welfare as a research participant in this study (REB#....), please contact: Manager, Research Ethics; University of Guelph; reb@uoguelph.ca; (519) 824-4120 (ext. 56606)

You do not waive any legal rights by agreeing to take part in this study.

Your consent to this interview means that: (Please tick boxes that apply to the consent being given)
☐ You have a full understanding of this research as provided in the information sheet
☐ You have had the opportunity to ask questions about this study, which have been clarified to your satisfaction
☐ You understand that you are free to withdraw the study within six months of the survey date, without having to give a reason, and that doing so will not affect you now or in the future.

Additionally, the researcher may use specific techniques in this study. Please consent to the nature you will like your information to be collected and used.
☐ I agree to be audio recorded during discussion session []
☐ I agree to the use of quotations [], but do not want my title to be identified in any publication resulting from this study []
☐ I do not agree to quotations and do not to use of occupation or work position []
☐ I consent to have my operations observed []

Legal Rights and Signatures:
I ________________________________ consent to participate in “The Social Impacts of Digital Agricultural Technologies” conducted by Abdul-Rahim Abdulai and Emily Duncan. I have understood the nature of this study and wish to participate.

My signature below indicates my consent.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Signature/Thumbprint</th>
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<table>
<thead>
<tr>
<th>Researcher</th>
<th>Signature</th>
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Consent was obtained orally
I have explained this study to the best of my ability, and invited questions and gave answers. I believe that the participant fully understands what is involved in participating in this study, any potential risks of the study and that he or she has freely chosen to be in the study.

<table>
<thead>
<tr>
<th>Signature of Investigator</th>
<th>Date</th>
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Consent Form Surveys
You are being invited to participate in a research project entitled “The Social Impacts of Digital Agricultural Technologies in Ghana”. The study is being conducted by Abdul-Rahim Abdulai and Emily Duncan, under the supervision of Dr. Evan Fraser at the Department of Geography, Environment and Geomatics, University of Guelph. The research is funded by the Canadian First Research Excellence Fund.

Contact: Abdul-Rahim Abdulai (aabdulai@uoguelph.ca); Emily Duncan (edunca01@uoguelph.ca); Evan Fraser (frasere@uoguelph.ca)

Purpose of the Research:
The purpose of this is to understand how the adoption, use of digital technologies will impact society, specifically farming households and rural communities. We are interested in understanding changes to practices of farming, issues of access, and power dynamics altered by digital technologies and big data in agriculture. Data will be used to inform improve data governance and management structures. Data will also provide insights on how to develop socially inclusive digital agricultural technologies for improved farming outcomes.

COVID-19 and Face-to-Face Research
COVID-19 refers to the virus being spread in communities across the globe. We are providing you with important information about COVID-19 and we ask that you consider the following information to determine if study participation is right for you at this time.

COVID-19 is a respiratory condition caused by SARS-CoV2, which can be spread by respiratory droplets, mainly from person-to-person. This can happen between people who are in close contact with one another (less than 2 metres). It is also possible that a person can get COVID-19 by touching a surface or object (such as a doorknob or counter surface) that has the virus on it, then touching their mouth, nose or eyes. As new vaccines emerge and the public has access, it is important to remain vigilant in all safety precautions until Public health deems it appropriate to change our behaviour.

This study requires in-person visits and it is important to understand that this may increase your exposure to COVID-19. However, the University of Guelph and researchers have taken certain precautions to reduce the risk for you, the research staff, and their families (among others in the community) safe. The safety plans described below aim to minimize the spread of COVID-19 and are consistent with current Ontario Public Health, the Ghana Ministry of Health and University of Guelph Environmental Health and Safety guidelines.

Participant Screening
Participants will be screened on the day of the interview. The following questions will be asked before any further research interaction continues:

7. Do you currently (and/or recently) have a cough, fever or any other symptoms of COVID-19?
8. Have you travelled outside of Ghana in the past 14 days?
9. Have you ever tested positive for COVID-19 or had close contact with anyone that has tested positive for COVID-19?

If you answer YES to any of these questions, it is important to stay self-isolate. Call local health care provider to find a test.

Where will the study take place?
The study will take place at a location chosen by the respondent or at a convenient point where the researcher is able to meet the respondent. This will normally consist of homes of respondents, farms or offices.

What will happen the day of the study visit?
17. Researchers will use screening questions to assess respondents prior to research activities.

18. Participants are encouraged to travel to [campus/research location] in their own vehicles rather than public transportation, if possible. You are also encouraged to attend [campus/research location] alone.

19. All research participants are asked to wait outside until called to enter [research location].

20. A local representative will distribute mask and sanitizers in communities a day before our visit. You are required to wear a mask prior to and following entry into the building. Once your mask is on, you are asked to try not to touch your face or eyes with your hands.

21. You will be asked to wash or sanitize your hands prior to our encounter.

22. Participants will follow the research personnel to the designated study space and asked to follow their instructions once inside.

23. Once the study visit is complete, the research team member will exit to their mode of transportation.

24. If you are unable or unwilling to follow these guidelines, please notify the local representatives at the time of distribution of mask and sanitizers.

Safety Precautions
In addition to participant screening, you will find the following additional measures have been put in place to help reduce the risk of spreading or contracting COVID-19:

• Personal Protective Equipment (PPE) – masks, gloves and/or face shields

• Handwashing and sanitizing

• Physical distancing

• Minimized time of contact

• Open windows or increased ventilation when necessary

Hygiene and disinfection protocols and materials

You have been invited to participate based on the following criteria:

• You are a farmer in an agricultural community in Ghana.

• You are an adult (18+)

What You Will Be Asked to do in the Research: As a participant, you are being asked to participate in a survey of about 30 minutes, sharing your opinions on how digital technologies are impacting your farming practices and your communities. You will also be asked about your specific experiences with the use of particular digital agricultural services, either directly or indirectly. The survey will be administered orally and responses will be recorded by the research team on paper.

Risks and Discomforts: There are minimal perceived risks or discomforts associated with this research. Some risks include possible risk to reputation if information about farming practices or livelihoods is revealed and
the risk of possible discomfort of disclosing socio-economic information. Questions and observations are not intended to be prejudiced or presumptuous, you may decline to answer any questions or disclose specific information in the interview or specify what should not be included in the research. The researchers may also engage in observation to understand how a particular technology is employed on the farm or how people engage with digital tools.

Also, there is a possibility that during this research activity you could come in contact with someone with COVID-19. If this were to happen, the University of Guelph and the research team is required by Ministry of Health to collect and retain on file your email of phone number to share with them for contact tracing purposes. As such, anonymity as a research participant cannot be maintained. Should you choose to withdraw from participation in this research, this personal information cannot be withdrawn from University of Guelph or Ministry of Health records. Please be assured that the Ministry of Health will not have access to any other data collected for this research study.

Vulnerable Populations

If you fall within the following categories, you may be vulnerable:

- Above 65 years of age
- Has pre-existing medical conditions (e.g. immunocompromised, diabetes, heart disease, etc)
- Experiencing socio-economic disadvantages such as inadequate or overcrowded housing.

Face to face research involving vulnerable populations will require additional considerations, and measures for safety, and in some instances, participation in the research may not be advisable. Therefore, if you self-identify as a vulnerable or are unsure if you fall within the vulnerable population, it is imperative that you inform the research team and ask for further guidance.

Safety Precautions

Due to the risk of COVID-19, the following precautions are put in place:

- Data collectors will follow the Ghana Ministry of Health guidelines to maintain the two metres distance between people, wear mask, and use sanitizers
- Surveys and interviews will be conducted in outdoor spaces as much as possible – engaging in small groups, social distancing, and mask wearing practices.
- You are provided with a mask prior to this interaction, and survey, focus group or interview interactions.
- You will be required to provide consent orally rather than writing to reduce potential exposure.

Benefits of the Research and Benefits to You: By participating in this study, you learn about what the conversations around digital technologies are within your region and beyond, and share your own experiences and interactions with these new technologies. This will help facilitate policy actions that can make farming better and keep rural communities sustainable.

Voluntary Participation: Your participation in the study is completely voluntary and you may choose to stop participating at any time. Your decision not to participate will not influence the way you may be relating with the researcher, with University of Guelph or its community in anyway either now, or in the future.

Confidentiality: Participation in this research is entirely voluntary and all information shared will be anonymized. Data will be anonymized and will be stored without any identifying information. If the results of this study are published, no information that discloses your identity will be released. Your data will be safely stored in a locked facility and only the researchers and people directly related to the study or the Ministry of Health in the event COVID-19 contact tracing is necessary will have access to this information. The data will be kept for five years after the end of the project and will subsequently be destroyed through deletion from the harddrive. All notes taken during observation will be transcribed and stored on an encrypted harddrive that will be stored in a locked location and all paper copies will be shredded. Recorded information from the audio recorded will be transferred to be stored to an encrypted harddrive that will be stored in a locked locations and files will be deleted off the audio recorder immediately after the file transfer. All computers that will be used for data processing will be password protected.
Withdrawal from the Study: You can stop participating in the study at any time, for any reason, if you so decide up until data has been mixed with others that it cannot be differentiated. Your decision to stop participating, or to refuse to answer particular questions in the interview, will not affect your relationship with the researchers, University of Guelph, or any other group associated with this study. In the event you withdraw from the study, all associated data collected will be immediately destroyed wherever possible, as long as the researcher can still trace specific information related to you.

Dissemination of Findings: Where appropriate, a report of the findings will be emailed to participants. The findings will also be presented to communities in their own language during a Knowledge Mobilization research trip by the researchers in 2021. Results will be reported in aggregate form.

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If you have questions regarding your rights and welfare as a research participant in this study (REB#....), please contact: Manager, Research Ethics; University of Guelph; reb@uoguelph.ca; (519) 824-4120 (ext. 56606)

You do not waive any legal rights by agreeing to take part in this study.
Your consent to this interview means that: (Please tick on boxes that apply to the consent being given)

- You have a full understanding of this research as provided in the information sheet
- You have had the opportunity to ask questions about this study, which have been clarified to your satisfaction
- You understand that you are free to withdraw the study within six months of the survey date, without having to give a reason, and that doing so will not affect you now or in the future.

Additionally, the researcher may use specific techniques in this study. Please consent to the nature you will like your information to be collected and used.

- I agree with the use of quotations [ ], but do not want my title to be identified in any publication resulting from this study [ ]
- I do not agree to quotations and do not to use of occupation or work position [ ]
- I consent to have my operations observed [ ]

Legal Rights and Signatures:

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Appendix IX: Copywrite Agreements

PUBLISHING AGREEMENT

This is an agreement under which you, the author, assign copyright in your article to Informa UK Limited registered in England under no. 1072954 trading as Taylor & Francis Group, Registered Office: 5 Howick Place, London, SW1P 1WG (hereinafter “Taylor & Francis”) to allow us to publish your article, including abstract, tables, figures, data, and supplemental material hosted by us, as the Version of Record (VoR) in the Journal for the full period of copyright throughout the world, in all forms and all media, subject to the Terms & Conditions below.

**Article (the "Article")**
entitled: A New Green Revolution (GR) or Neoliberal Entrenchment in Agri-Food Systems? Exploring narratives around digital agriculture (DA), food systems, and development in Sub-Sahara Africa

**Article DOI:** 10.1080/00220388.2022.2032673

**Author(s):** Abdul-Rahim Abdulai

**To publish in the Journal:** The Journal of Development Studies

**Journal ISSN:** 1743-9140

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I confirm that I have read and accept the full Terms & Conditions below including my author warranties, and have read and agree to comply with the Journal’s policies on peer review and publishing ethics.

Signed and dated: Abdul-Rahim Abdulai, 24 January 2022 20:01 (UTC Europe/London)  
Taylor & Francis, 24 January 2022 20:01 (UTC Europe/London)

THIS FORM WILL BE RETAINED BY THE PUBLISHER.
Appendix X: Supplementary Materials for Document Review

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