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Beyond transformations: Zooming in on agricultural digitalization and the changing social practices of rural farming in Northern Ghana, West Africa

Abdul-Rahim Abdulai^{a,d,*}, Ryan Gibson^b, Evan D.G. Fraser^{a,c}

^a Department of Geography, Environment and Geomatics, University of Guelph, Guelph, Ontario, Canada

^b School of Environmental Design and Rural Development, University of Guelph, Guelph, Ontario, Canada

^c Arrell Food Institute at the University of Guelph, Ontario, Canada

^d The Alliance of Bioversity and International Centre for Tropical Agriculture, Cali, Colombia

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ABSTRACT

Digitalization of agriculture (DA) has emerged as a powerful rural transformative force. However, the dynamics of how digitalization is changing smallholder farming practices at the heart of rural life remain underexplored. Here, we employ a mixed-method approach (1565 survey respondents, 16 focus group discussions, and 22 interviews) to examine farmers' experiences with digital agriculture services in Northern Ghana through a social practice theory (SPT) lens. We found that farmers perceive digitalization as transitioning their everyday activities across the farming spectrum, including decisions and activities related to season planning, planting, husbandry, harvesting, post-harvest management, and sales. Notably, 1) new materials of phones and digital platforms redefine farmers' knowledge and competencies, ultimately 2) temporary re-patterning their routines and rhythms. Therefore, we argue that, beyond the contested claims of digital transformations, a pertinent dimension of DA and rural social change is the transitions in the everyday practices of farmers and rural living. Our paper, as we know, is among the early attempts to theoretically and empirically examine agriculture digitalization through an explicit practice lens, and more so in the context of African smallholder systems. We contribute to the scholarship on DA and rural change by (re)framing the dynamics of the phenomenon through everyday practices. By this approach we aim to steer the DA discourse and policy from the optimistic rural transformations towards the often-overlooked yet critical gradual changes and transitions in the day-to-day life of farmers.

1. Introduction

Technological innovations, including digitalization, are transforming society in many domains (Duncan et al., 2021; Hilbert, 2022). In particular, digitalization of agriculture (DA) is presented as a pathway to transformation—radical and mostly structural change—in food systems and rural landscapes (Atanga, 2020). However, despite growing interest and research on the impacts of digitalization on agriculture (Carolan, 2020a; Fielke et al., 2022; Klerkx et al., 2019) and rural lives (Lin et al., 2016; Rolandi et al., 2021), further exploration is needed to appreciate the heterogeneous changes and transitions—gradual, pervasive shift from one condition to something different (Hinrichs, 2014)—in farmer's day to day life across different rural landscapes

(Abdulai, 2022b). Because, many empirical and theoretical questions remain on the social dynamics of agricultural digitalization, especially in smallholder systems. For example, 1) how do rural smallholders perceive and experience changes in their farming activities through engagements with DA? And 2) through which mechanism(s) do DA cause change to smallholder living at the basic level? We use the social practice' approach—dynamics in the unfolding constellations of everyday actions and activities (Reckwitz, 2002; Schatzki, 2002)—to explore these questions in the context of DA use cases in Northern Ghana. It is documented that previous technological breakthroughs disrupted and transformed farming activities, such as the automation of previously manual tasks and creation of new life forms (Bear and Holloway, 2015). Consequently, emerging digital tools, such as robots, drones, mobile

Abbreviations: DA, Digital agriculture; AI, Artificial Intelligence; GSMA, Global System for Mobile Communications Association; FAO, Food and Agriculture Organization of the United Nations.

* Corresponding author. Department of Geography, Environment and Geomatics/ The Alliance of Bioversity and International Centre for Tropical Agriculture, Cali, Colombia.

E-mail address: aabdulai@uoguelph.ca (A.-R. Abdulai).

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phones, and AI, are following suit in changing farming activities (Carolan, 2017b, 2020a; Holloway and Bear, 2017; Vasconez et al., 2019). Yet, there is a little attempt in the literature to understand how digital innovations alter the day to day practices of farmers, especially in rural smallholder systems.

Meanwhile, digitalization efforts have become mainstay interventions in rural smallholder agriculture. The *Digital technologies in agriculture and rural areas - Status report* (FAO, 2019) emphasized the growing application of mobile 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 et al., 2021*) also furthered observations of DA embedment in and changing rural activities in Africa. These, together with similar reports (GSMA, 2020; Kim et al., 2020) all speak to the emergence of new transformative technologies rapidly penetrating and changing the fibre of farming and rural communities. In smallholder system in particular, digital services, defined as the leveraging of digital tools, hardware, and software, to create services that aid agriculture activities and processes, are at the heart of this transformation. Meanwhile, mobile advisories that digitally deliver information on topics such as weather and market prices to farmers' mobile phones is the commonest of such services in sub-Saharan Africa (GSMA, 2020). Whether these technologies would become truly transformative is still in question, but we do know they are already altering the dynamics of smallholders (Fabregas et al., 2019; Tsan et al., 2019). Thus, rural scholars must explore how such alterations are manifesting across geographies. Notably, the need for social theoretical explanations of the mechanisms of change underscores the essence of rural scholars' engagements on the subject.

This paper contributes to a nascent work on *agricultural digitalization and rural (social) change* (Carolan, 2020b; Rotz et al., 2019) through a social practice exploration. We draw on smallholders' experiences with mobile-based agronomic, climate information and market connection services to show how digitalization introduces new competencies in digital materialities and temporarily reorganize routines. We show that digitalization's discourses need to move beyond transformation to pay attention to changes to social practices. The paper proceeds as follows. In the next section, we review literature on digitalization and rural change to show the growing interest in the subject. We then introduce social practice as a candidate theory to further scholars' engagement with digitalization. The materials and methods section outlines our study area, cases and the activities of our mixed-method approach while reflecting on our data analysis and limitations. Our results and findings are presented through farmer perceptions and experiences with digital information and services. The discussion draws out the mechanism(s) of agriculture digitalization-induced rural change through new materialities, competencies and routines. We end with a conclusion and reflection on our work's novel practical and theoretical contributions, and highlight areas for further research.

2. Background

2.1. Digitalization and changing rural practices

Social science perspectives on agricultural digitalization are growing, primarily interrogating their socio-cultural implications (see, for example; Carolan, 2017a, 2020b; Rotz et al., 2019). According to Klerkx et al. (2019), the social science research on digitalization converges around five key areas: 1) On-farm adoption, uses and adaptation of digital technologies; 2) Effects of digitalization on farmer identity, farmer skills, and farm work; 3) Power, ownership, privacy and ethics in digitalizing agriculture; 4) Digitalization and agricultural knowledge and innovation systems, and 5) Economics and management of DA. These and many more on the social implications of DA have been thoroughly explored in the existing literature and in this journal (see, for examples, Alam et al., 2018; Carolan, 2020c; Fraser, 2021; Lin et al.,

2016; Rotz et al., 2019). These papers, though primarily reflect the Global North's experiences, lay the foundations on the interrogating interactions of DA in rural spaces. However, our interest in this literature is understanding how digitalization shapes performances and social life in the often-neglected spaces of rural smallholder Africa.

The literature is emphatic that digitalization is already changing farming, rural dynamics and subjectivities in myriad ways (Carolan, 2020b; Holloway and Bear, 2017; Sam and Grobbelaar, 2021; Vasconez et al., 2019). For example, automated systems such as robots and drones drastically alters the basic activities humans and 'other things' do in farming spaces. This change involves the shifts from hands-on farming practices to data-driven and/or (semi)autonomous (Carolan, 2017a; Driessen and Heutinck, 2015; Holloway and 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; Vasconez et al., 2019). These processes not only (re)produce human-robot interactions but also alter farming's very 'performances'. Likewise, these tools 'discipline' farmers' work routines in specific ways (Carolan, 2020a), including making farming operations more predictable and streamlined along preset ways (Wittman et al., 2020). Meanwhile, these tools results in collecting big data, increasingly converging with earlier mechanical tools and biological materials—substances in living organisms—to reshape labour dynamics in farming (Ajates, 2022).

However, as Sam and Grobbelaar (2021) note in their review of the current field, there is still limited research on the changing farmer routines emanating from digitalization—some exceptions being Abdulai (2022b); Lin et al. (2016). Meanwhile, different tools and services would engender variegated and heterogeneous changes across systems, scales, and geographies. For example, while robotics could make farming less hands-on, mobile advisories may reduce time spent on the farm without necessarily providing similar labour-shedding dynamics. Similarly, the effects of different digital tools will differ through place-based socio-economic and cultural dynamics dictates.

In smallholder systems, for example, digitalization, including mobile advisories and market platforms are reportedly helping farmers 'upgrade' the way they farm (Kliemann, 2020) in ways which may alter their routines. Salkovic et al. (2015) showed in the case of Ghana that the use of Esoko call and SMS-based weather and market price platform influenced rural culture and how 'interpersonal communications and relationships are enacted, experienced, performed, and even maintained' (p.1). One way to understand these changing dynamics is exploring the constitution of everyday life of farming (cf McMillan, 2017; Schatzki, 2002). Hence, we use conceptions of 'practices of farming' (see next section) to invests in these issues by assessing the digitalization-induced changes to smallholders performances of farming practices.

2.2. Theory: social practices and everyday dynamics

Social practices (or practices) may offer an understanding how digitalization alters agriculture's dynamics in smallholder cultures. Without a unified definition, practices are the unfolding of constellations of everyday activities (Feldman and 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" (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 (e.g. Schatzki, 1996; 2001 2002, 2013, 2019), where practices are described as 'open-ended spatial-temporal manifolds of actions' (2005, p. 77) manifested in sayings and doings spread out over objective space and time (Schatzki, 2019).

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. Examples of such practices include ‘describing, explaining, questioning, 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 focus of the concept throughout the millennium, examples which include farming, cooking, and business practices. In *Sustainable Practices*, Warde, 2013 explained eating as an interconnected and 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. Shove et al. (2012) described this integration as bundles of practices, which 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 and Shove, 2010, p. 12) but can also share materials if ‘things’ are considered at non-element parts of practices.

Following the descriptions of practices, we are interested in how digital technologies cause social change. We draw on the descriptions on ICTs and social change through practices (Abdulai, 2022b; Lin et al., 2016; Ropke and Christensen, 2013; Schatzki, 2019). In situating materiality in practice, Schatzki draws our attention to how WELL online community integrated into its users’ everyday lives to enable new practices, new forms and means of interaction. The introduction of the new materials in ICTs bounded into other bundles they participated in at work, at home, or in their free time to create new forms of socializing (Schatzki, 2019). As Ropke 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 allows people to combine practices of reading news and other activities, such as waiting to board a bus (Ropke and Christensen, 2013).

Building on these conceptions of practices and digital materialities, we conceive practices in multiple folds. First, we contend that social life is constituted by arrangements of practices; therefore, every activity is either a practice or a constituent of a practice (Schatzki, 2019). In this sense, farming is a practice. The constituent processes of planning, planting, husbandry, harvesting, and marketing/sale are sub-practices and activities that bundle into an ‘integrated farming practice’. Hence, any change in how (and what, where, when) of any of these sub-practices or their formational activities is broadly an alteration to the basic unit of social life. Second, following Shove et al. (2012) work, and Abdulai’s (2022b) conception of digitalization in smallholder systems, (digital) farming is a practice that comes together through the integration of material stuff of life, knowhow, understandings and knowledge and symbolic aspirations (see Abdulai, 2022b). In that case, digital tools, services, and software are new materials in the fibre of farming, which alter how other elements are brought together over time and space in performances. Thirdly, practices entail patterning daily lives and how actions and activities are arranged to fill the time vacuum (Southerton, 2020). Following these three conceptual aspects to practices, we are interested in how the introduction of digital services affects the performance of farming and/or the constituent actions. We are also interested in how DA alters the key elements in practices, as well as the temporal re-organization of farming and rural spaces.

3. Materials and methods

We employed a mixed-method approach (Clark and Ivankova, 2015; Creswell and Creswell, 2017), simultaneously combining (see Morse, 2010) surveys (from July to September 2021), interviews and focus group discussions (February to October 2021) to explore changing practices within three use cases of digital solutions in Northern

Ghana—Esoko, Farmradio and Agrocenta (See Fig. 1 and Table 1). The cases were selected because of being most widely used of the different types digital services in the region. The focus on services delivered through mobile was also informed by it being the commonest form of DA usage among smallholder in Africa (see Tsan et al., 2019; Abdulai, 2023). The use of mixed methods to explore practices was further informed by Sargant (2014) practiced-based approach to sustainable consumption.

Northern Ghana has a strong rural agricultural system that draws the interest of researchers (see Nyantakyi-Frimpong and Bezner Kerr, 2017; Vercillo and Hird-Younger, 2019). The region is home to many developmental NGOs and programs that offer farmers experiences with pro-poor interventions in agriculture, including the diverse digital agricultural innovations (see Etwire et al., 2017; Hidrobo et al., 2021 for examples). These characteristics make the setting an excellent socio-technical environment for understanding digitalization’s social interactions.

To collect data in this region we followed the cultural ethos of the area, including prior information and announcements before visits through chiefs and religious leaders and paying homage to chiefs with colanut. These procedures were in line with ethics approval granted by the University of Guelph Research Ethics Board. All research activities were in Dagbani and Mumpruli, the local languages in the area—and conducted or supervised by the lead author.

The data collection was pragmatic in approach as we relied mainly on experiences in the field to inform the methods and timeline of activities. We started with preliminary interviews and a few focus group discussions. After a few months of qualitative data, insights and key themes on farming change were built into the survey that examined farmers’ perceptions and experiences. For example, our preliminary data showed that farmers viewed digitalization in relation to the services and changes perceived changes relative to specific aspects of activities. So the survey included a section to assess the percentages of farmers that experienced changes in planning, husbandry, marketing and so on (see results). The data collection then ended with additional interviews and focus group discussions that allowed us to follow up and clarify higher level insights from the surveys. Below we outline the details of each method.

3.1. Survey

We administered a survey to assess engagement with DA, experiences and perceptions. Following prior works on a survey of rural smallholders in Africa (for example, Baiyegunhi et al., 2018; Kansanga et al., 2018), we surveyed 1565 farmers across four districts in the Northern region —Savelugu, Nantong, Kumbungu, and Sagnarigu—between May to August 2021.

A multistage sampling method was used for participating smallholder farmer selection. First, four districts were selected due to their proximity to the regional capital, Tamale Metropolis. Their closeness to the regional capital makes them accessible to the many NGOs that operate from the city and provide services to rural smallholders. Secondly, 28 communities 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 other third house selection criteria was used within communities after field assistants were assigned to segments in communities (Kansanga et al., 2018). Enumerators had to skip two houses after each survey before selecting another household. The survey participants were randomly chosen at their homes based on availability at the time of data collection and a set pattern of the first household in the house or third household if there were more than three households in a house. The household heads were the primary target, but in the absence of the household head, the wife or other senior household members were surveyed.

The data were collected digitally through kobo toolbox with the help

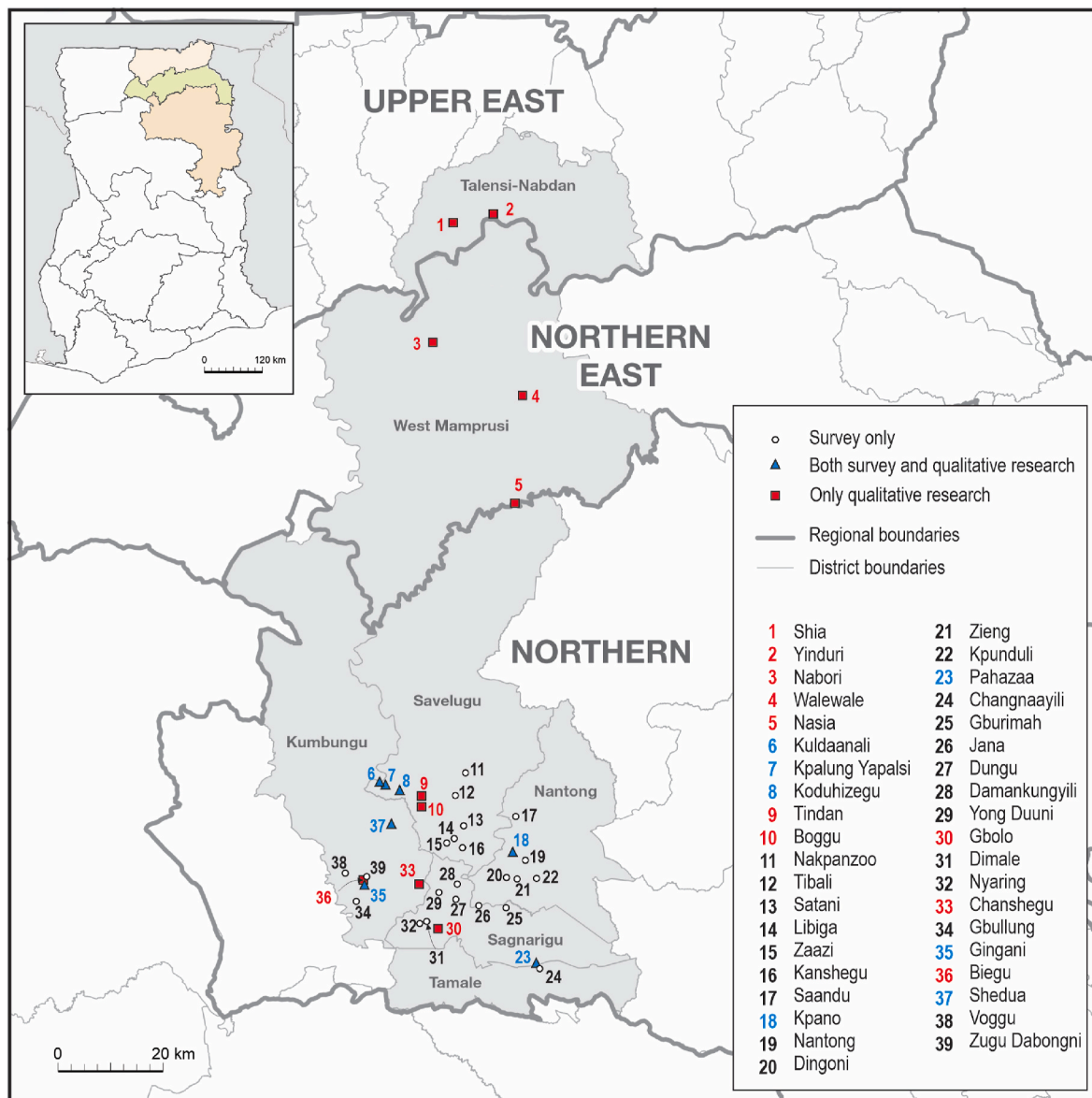


Fig. 1. Research setting and communities
Source: Map prepared by Marie Puddister, University of Guelph.

of twenty-five trained research assistants. Regarding design, questionnaires included open- and closed-ended questions (Nardi, 2018). The survey focused on understanding respondents’ characteristics, perceptions of the impacts of DA, challenges, and adoption. Our choice of the survey was because of its ability to reach large number of participants and capture a broad scope of a phenomenon while enhancing the validity of study findings (Moser et al., 2017).

3.2. Interviews

We adopted face-to-face interviews to assess the changes individuals using digital services experience. Specifically, semi-structured interviews were used, allowing the researcher to seek clarification (McIntosh and Morse, 2015; Paine, 2015). Twenty-two (22) farmers were interviewed through purposive sampling in relation to 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 an attempt to ensure we cover the diversity of smallholder agriculture, interviews included farmers

with different systems (see supplementary material-Table 2).

Generally, the number of farmers interviewed was also 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 min and 90 min. 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 the topics of interest (Rowley, 2012). Topics were from the nature of engagement with digital tools to the changes 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.

Table 1
Case services.

Technology service provider	Description of service(s)	Methods applied to cases
Esoko Ghana (E)	Farmers specifically received weather information and market price alerts through SMS. They also accessed services by calling a helpline. It started as an NGO-sponsored project that provided free services to farmers and later became a farmer subscription service after project completion.	Surveys, interviews, focus groups
Farm Radio International (F)	The communities covered were beneficiaries of Farm radio Uliza services . Farmers helped create radio programs while utilizing digital services-calls, SMS- to engage and receive information on weather, particular crops, or agronomic advice. This is an NGO-sponsored project. Farmers did not pay for services at the time of research.	Surveys, interviews, and focus groups
Agrocenta (A)	Using the digital app, agents profiled and provided agronomic advice to farmers during the farming season while offering them an assured market place after harvest. Started as NGO project with free services to registered farmers. Some currently pay for services from sales transacted by the company.	Interviews and focus groups

3.3. Focus group discussions

We conducted sixteen focus group discussions across thirteen communities to assess how digitalization changes practices in their communities. These involved interaction between the lead researcher and six to twelve purposefully selected informants (Carey et al., 2016; Krueger, 2014; Stewart and Shamdasani, 2014). To capture the diversity in smallholder groups, we conducted 14 mixed groups, one male-only and one female-only. Mixed groups were conducted in communities where females felt free to speak in the presence of males. The mixed groups were majority male dominated (8 groups), while six were balanced with equal numbers between men and women. Participants were different in most focus groups, except in the one community of the female-only focus where three of the participants also participated in the mixed group. However, having participants speak freely when brought together was still an issue, especially for women, which may undermine gendered nuances in the results—but individualized interviews and the sex-specific focus group discussion would have minimized this concern. Discussions took place at locations desired by participants, mainly at community centres, the chief’s house, the home of a lead farmer, or communal seating places.

The focused group discussions, guided by a guide, covered smallholder experiences of changes in their communities. The guide, included prompts on agricultural transformation issues, motivations of engagement with digital tools, experiences with services, impacts, challenges, and expectations.

For analysis, the survey data were exported from Kobo Toolbox into XLS and CSV files and later into SPSS and R-Statistics to create relevant tables and statistics. For interviews and focus group data, thematic and content analysis were 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 Essoko(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). We then uploaded the files to Nvivo for audio coding at the first stage. The lead author and research

assistant independently listened to the files and coded them based on pre-determined and emergent themes. Each coder transcribed the resulting translated quotations and stories corresponding to the identified themes. The lead author corroborated these themes after the audios were fully transcribed in *Expres Scribe* before thematic and content analysis. We described what was said to ensure content stayed close to respondents’ words, which adds validity to qualitative information. However, we also acknowledge that translations may have affected the quality of extracts.

Before we present the results and further discussions, we must further clarify some issues readers must be mindful of. First, the respondents’ across the methods were predominantly male. Because the cultural setting of the area makes for majority male household heads, the current poor targeting by digital interventions turns to exclude female in registrations (Abdulai et al. 2023; Tsan et al, 2019;). This situation may obscure the nuances women’s experiences could have enriched our discussions. However, some of the generic experiences discussed included both sexes, making the results generalizable. Second, snapshotting farming in time potentially debarred changes experienced in other seasons. This limitation certainly has theoretical implications because practices are temporal (Pantzar and Shove, 2010; Schatzki, 2013). Finally, our data is based on specific cases of digital services and their interactions with practices within the research settings. But we appreciate that digitalization is broader than the case covered and practices are contextual (McMillan, 2017); hence the data must be interpreted within this theoretical assumption—without necessarily undermining the broader insights.

4. Results and findings

4.1. Smallholders’ perceptions on digitalization changing farming and livelihoods

We assessed farmers’ perceptions on digitalization impacts on rural livelihood activities and farming practices. Of 1271 that responded to the perception questions, as expected, the majority (72.15% and 83.2%) affirmed digitalization changed livelihoods and farming practices, respectively. Those that perceived digitalization as changing livelihoods referenced the many impacts experienced in their interaction, as we expand later sections. Surprisingly, about 6.1% and 4.6% did not believe services altered their livelihoods or farming practices, and 21.72%,12.3% respectively were unsure. Considering the apparent effects of these services (as a reviewer pointed out), we attribute the lingering uncertainties to skepticism on the part of some farmers, low engagement due to low literacy and other barriers (Abdulai et al. forthcoming), and a general lack of understanding by some farmers on what impacts may be attributed to the services.

Chi-square analysis at a 95% confidence level showed farmers’ perceptions of livelihood changes from digital services varied significantly across districts ($P < 0.001$) and sex ($P = 0.030$), while perceptions of farming practice changes were significant across sex ($P < 0.001$), age ($P = 0.008$); and districts ($P < 0.001$) (see [Supplementary materials-Table 3](#)). Farmers in Nantong and female farmers were likelier to perceive that digitalization changes livelihoods in rural communities. However, farmers in the Sagnarigu District (89.9%), male (89.7%) and 60+ years farmers (89.7%) were likely to attribute digital services to changing farming (see [Table 3](#),Supplementary materials). The reasons for such variations were unclear at the time of the research, and must be explored further.

Despite some variations in perceptions among groups, farmers generally believed that changes to farming practices. Because rural livelihood activities are primarily connected to agriculture, such as agrifood trade and the sale of labour time on farms, farmers perceived any changes to farming practices as reflective of collective social dynamics.

4.2. Farmers’ experiences of agricultural digitalization services changes to farming and rural life

Using the three use cases outlined in [Table 1](#), we explored the

changes experienced by farmers in their interaction with four types of digital services: digital agronomic advice; weather information; market/price information; and market connections. Farmers viewed 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 benefit from the information” (F4–F). Hence, farmers constantly referred to receiving information through the phone as the anchor to engaging with the world of digitalization. Smallholders are, therefore, currently interested in the

Table 2
Farmer experiences of changes from digital services.

Digitalization service and solution use case	Some change mechanisms noted	Corresponding quotes
Agronomic advice	Alterations of time spent on on-farm practices. E.g., Planting Reduction in overall time spent on farm care Quick decisions on what and when to do on-farm in specific cases Changes on choice of crops to grow Altering planting periods	“When I beep [call], I know what to do, you know. I don’t waste time on things I don’t.” F4–F “Because of the advice, I know when to go to the farm, not every day now. F5–F “They tell us what we can grow, so sometimes I listen to them and follow. I mean, change things.”FG7-F “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
Weather information	Times of planting informed by alerts Decisions on crops to plant-based on information received Times of fertilizer application informed by weather alerts Decisions on when to spray fields based on weather information Post-harvest activities informed by weather alerts	“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
Market/price information	Changes to market visits Changes in market farmers access Price information influences who farmers sell Changes in when farmers decide to sell	“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
Market connections	Opening new markets for farmers Decisions on what to cultivate based on market information New markets at farmers’ doorsteps Size of production based on available connected market Elimination of the sourcing of market from farmer’s task	“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

services and less about knowing the technologies behind those services. Nonetheless, farmers were still particular about how the new technologies, particularly phones, and the information received affects their longstanding practices (Table 2).

4.2.1. Agronomic advice and changing practices

Farmers viewed the delivery of agronomic advice through innovative digital-enhanced radio programmings,¹ SMS and calls as integral to how they farm. Mobile agronomic advice was critical to what, when and how to plant and careed for farms. 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.” FG7-F.

Farmers emphasized how the digital delivery of agronomic information has allowed them to introduce newly cultivated rice in the community. Others switched crops in some seasons based on their interactive radio programming and calling to ask the experts. The ability of digital information to open them to knowledge quickly was crucial in farmers deciding on what they do on their farms throughout the season and how. Reaching agronomic information faster also meant that they could respond to emergent issues quickly and in varied ways, as a lead farmer also 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.

4.2.2. Weather information and changing practices

Weather and climate information was a common form of digitalization with apparent routine altering potentials. Farm radio and Esoko services incorporated climate and weather information via SMS, phone calls, and radio. A respondent who actively received both services talked about how it informed the family’s farming activities:

.... . They tell me the forecast, so I plan my planting and spray based on it. Before that, we just spray; 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 and ensure they don’t waste time bringing things out and rushing to store again because of unexpected rain. F4–F

Specifically, we found this information to change planting, crop management and post-harvest activities. When farmers receive weather alerts, they apply the knowledge to inform farming activities rather than past uncertainties. This information thus allow them to plan and execute specific tasks based on weather predictions efficiently. Specifically, farmers plan when to plant, produce, spray, and undertake certain post-harvest management activities, such as when to dry their crops and, for some, when to even travel to market centres. The mechanism of change is

¹ Development interventions classify radio as part of digitalization, partly due to digital innovations now enhancing radio programmings. We studied Farm-radio ULIZA project, which combine radio, mobile phones and, often, IVR to enable listeners to communicate and exchange information with their radio station quickly, easily and free of charge (<https://farmradio.org/uliza-services/>).

thus time use and efforts put into specific farming tasks. However, some respondents were also critical of these services, alluding to the occasional unreliability of the information which undermine their planning.

4.2.3. Market (price and connections) information and changing practices

Farmers employed market price alerts and connections to alter their marketing activities. Many farmers traditionally sell at low prices at nearby open markets due in part to limited information. Others sell through intermediaries coming to communities to buy produce at their set, yet farmer-unfavourable, prices. However, knowing prices at different markets allowed farmers to make good decisions and “choose where and when to go and sell” (F8-E). Likewise, market price information influenced negotiation practices. Knowing prices beforehand, farmers’ marketing strategies incorporates the added knowledge, as a 60 years old farmer described: “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 ...” (F8-E). The added knowledge advantage creates new modalities of farmers’ interaction with other value chain actors like middlemen and wholesalers. However, as in the case of F8-E, she referred to when everything is good, meaning the ability for marketing changes is circumstantial on poverty and emerging financial needs.

We also found that new digital services that connect farmers to markers by buying produces also cause a different kind of change for smallholders. In a conversation with a young farmer participating digital-enabled market connection, he quickly pointed to 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 farming?

F4-A: so many ways, I think it’s 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 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 in market connection programs shared this sense of peace with the certainty of sales. Changes that come with that within farming activities or broader social life were considered instrumental in solving market and financial problems they faced. Farmers viewed changes to sourcing markets as time-saving and task-reducing. For example, the typical person will describe African rural farming as struggling to find buyers for produce after harvest. However, experiences with emerging digital markets solutions pointed to the shifting of this long-held belief as 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”. By concentrating on just activities on the farm, these solution are offering pathways to changing farmer livelihood routines.

4.3. Aspects of smallholder farming arrangements reshaped by digital services

We further assessed perceptions among those who had used digital services regarding seven non-exhaustive areas of potential changes to farming activities (see [Table 3](#) and [supplementary materials](#)). These

Table 3
Farmers’ perceptions of changes to components of farming.

Area of practice	Description of change
Planning season	Digital climate forecasting helps farmers decide what and when to plant, minimizing time spent planning
Choosing planting crops	Digital agronomic and climate information aid farmers in choosing which specific crops to plant. Farmers also choose crops based on digital market price information.
Planting decisions and activities	Climate and forecast alerts help farmers decide what time to plant.
Everyday farm care practices	Weather information allows farmers to decide when to visit farms for fertilizer application, weeding, and pest control
Harvesting activities	Price and market connections also affect when a smallholder decides to harvest and transport produce.
Post-harvest management activities	Farmers using weather alerts to decide when to dry farm produce
Marketing and sale activities	Farmers decide where and when to sell using market connection services. Burden of moving products taken from farmers to digital platforms.

areas were derived from the initial qualitative interviews and focus groups and built into the survey.

Among all seven areas, season’s planning was the highest change reported by farmers (91.1%), followed by modifications to harvesting (89.6%) and post-harvest management activities (85.8%). 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 actively engage them at the start of the season, allowing them to use more information to inform planning for the season. Likewise, farmers’ desperation to find markets after harvest meant they paid attention and applied digital information to their activities. The experiences showed that rural farmers are experiencing digitalization-induced changes from pre-to post-production activities. However, certain farmers were still adamant about whether these services resulted in any changes for them. Changes to everyday farm practices had the highest percentage of disagreement of change (10.2%), followed by decisions on the choice of crops (7.8%). These reported lack of changes and uncertainties reveal important yet surprising insights into farmers’ engagement with these innovations. Low literacies, among many other challenges, still hinder some farmers from using the innovations, even if they are regularly provided with services (Abdulai et al. 2023). However, these require further investigations to understand the issues hindering services from impacting some farmers.

5. Discussion: Mechanism(s) of agriculture digitalization induced rural change

The DA discourses among smallholders, though contested (Abdulai 2022c; Duncan et al., 2021), optimistically and uncritically anticipate transformational impacts (Atanga, 2020; FAO, 2019; An et al., 2021) at the macro structural levels, framed on anticipatory potentials rather than current lived realities. Such analysis, as Motta and Martín (2021) argue, has severe limitations for understanding how transformations take place in the individual’s life course; because, they obscure the micro-level changes in daily rural life. Meanwhile, practice scholars (see Shove et al., 2012) have emphasized that analysis of individual everyday actions has unique nuances for social change and how phenomenon like digitalization could become established in society.

The results show that digital information and services are reshaping farmers’ long-held understandings of rural farming. Following Warde’s description of eating as an interconnected and 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 and Schatzki, 1996). It comprises constituent activities and sub-practices like planning, land preparation, planting,

weeding, fertilizing, harvesting, husbandry activities, marketing, sales, and judgments of good agriculture, all of which our results points to digitalization-induced changes. Hence, we contend that farming is a social practice(s) (Reckwitz, 2002; Schatzki, 2019) is being transitioned into a new digital agriculture practice. This new DA practice is a digitally enabled farming. It differs from the older ways of smallholder farming through the new materials (digital tools and services) and competencies introduced into the everyday activities of farmers. And these changes, in turn, reflect in reshaping smallholder livelihoods and causing rural social change. Two main observations inform our argument: I) Digitalization is introducing new (digital) materiality that are altering understandings of farming, which ultimately is II) temporally re-patterning of rural farming routines. We expand these two observations in the next sections.

5.1. (Digital) materialities altering 'understandings' in smallholder farming

The first mechanism that digitalization is changing the farming is introducing new material elements with competence-altering abilities into its processes. Though we do not wish to engage in the debates on materials and their agencies in practice (see, for example, Arcari, 2019; Schatzki, 2010, 2019; Shove et al., 2012 for extensive discussions), we are interested in how digitalization through their material services reconstitutes the make-up and doings of farming activities. According to Schatzki (2019), "veritable cascades of new and improved hardware and software, in conjunction with evolving and repeatedly upgraded electronic infrastructures, have made significant contributions to the emergence, development, persistence, and dissolution of social phenomena" (p.19) Likewise, Abdulai (2022b), drawing from Shove et al. (2012) argue that the introduction of digital innovations represents new material stuff into the fibre agriculture, which are altering the constitution and performance of farming. Building on these positions, our results show that digital innovations are introducing new materials—phones, radio, and *the information delivered through them*—into what is generally required to do farming. However, our results extends that, materiality is beyond the physical hardware and the software, as it includes new informational elements by way of digital platforms and information services. The role of digital materiality is therefore evident in the new ways farmers undertake their activities by drawing on digital devices and information alerts. Also salient in these observations is how these material elements influence farmers' practical understandings and knowledge.

It is well established that a critical element of social practices is understanding (Reckwitz, 2002; Schatzki, 2010; Shove et al., 2012; Warde, 2013) or what Shove and colleagues (2014; 2012; 2010) simplified as competence—skills, knowhow and techniques of action. The informational services affect knowhows among smallholders: most farmers confirmed that they used the advisories to inform activities such as when to go to the farm, when to plant, what crops to plant and undertaking marketing activities. Hence, these advisories (re)define the understanding of how *to do* various farming activities to follow the dictates of 'digital things,' moving them away from older methods, such as solely depending on experiences and guessing. Understandably, farmers perceived these changes as emergence of new knowledge that complements old ways of decision making. Considering that competencies are central to the formation and performance of practices, the injections of new understandings, and by extension, the consciousness of farming actions by digital mediums engenders different farming agencies. These knowledge changes confirm the claims that agencies and competencies are distributed between things and people (Latour, 2007; Reckwitz, 2002; Shove et al., 2012). Certainly, these developments raise questions on the autonomy and subjectivities of smallholder farmers with their actions increasingly dictated by the digital artifacts and the agencies they carry. These practice-altering mechanisms of mobile-based digital services enrich our understanding

of how the digitalization is reshaping rural subjectivities (Rose and Chilvers, 2018) and, in the process, either strengthening and undermining certain rustic elements (Carolan, 2020a). These changes, as we will show in what follows, triggers new mechanisms of social change through the temporality and pace of rural rhythms.

5.2. Digitalization and temporal (re)patterning of farming rhythms

The second mechanism we observe in digitalization changing rural social life is the temporal re-patterning of farmers' activities. Practices are spatial-temporal because they entail assemblages of acts filling space and time (Schatzki et al., 2005 2005; Southerton, 2020). Practices and their constituent activities take place in or over time. Hence, how human activities are temporary organized is a central mechanisms of change (Southerton, 2020). Our results confirm Lin et al. (2016) observations of digital services shifting rural life to follow the rhythms of the information era: In our case, changes were evident in the amount of time spent on various activities and how different activities were patterned across the time vacuum. Digital services and solutions allow farmers to alter the frequency, duration and sequence of planting activities, crop care, harvesting and marketing strategies. Likewise, planning daily activities based on the information means that the rhythms of farmers' livelihood activities increasingly rely on digital technologies (cf Ropke and 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. For instance, we found that on a typical day in the start of the farming season, a rural farmer in Northern Ghana undertakes the following routine: wakes up, takes breakfast, walk or rides bicycle-/motorcycle to the farm, does field preparation or planting, returns back home, talk to peers enroute home or at community grounds and visits family. However, on days of an alert indicating rain, the routines are reshaped to exclude, for example, visiting the farm and planting, as well as the interactions with people to and from the farm. Instead, the time is used to do other activities, such as spending time with children. These tidal movements in the performance of everyday farming experiences constitute the 'softening' of farming time and space (cf Ropke and Christensen, 2013). Hence, we argue, and in consonant to practice theory (cf McMillan, 2017), that the ability of digital tools and services to alter rural communities also lies in how they reshape the temporary routines and rhythms of farming life and the connections to other activities.

6. Conclusion and reflections

We have drawn on the social practice theory to discuss digitalization-driven changes in smallholder rural farming life in Northern Ghana. We established that digital innovations are redefining agriculture and rural life through 1) new digital materials that carry competence-altering agencies ,which 2) restructures the temporary routines and rhythms of farmers'. Our paper responded to calls for "partial, contextualized and empirically-based analysis of social change" (Motta and Martín, 2021, p. 504) and empirically backed earlier assertions that digital technologies may rescript rural farming and communities (Carolan, 2020b; Rose and Chilvers, 2018). In so doing, we have also redirected the DA discourse in smallholder systems from current obsession with transformations towards a much needed, but often neglected micro changes and transitions occurring in day to day activities of farmers.

The discussions are critical in policy and practice circles for understanding and managing social change emanating from DA. Without discounting the relevance of development/policy interventions broadly engaging interests in structural changes on rural employment, incomes, and other indices, we contend a shift to practices provides nuances for management of the DA processes as they are more visible and relatable at the individual level. We recommend that policy stakeholders use

these day-to-day changes as the focus of interventions. Doing so would require re-targeting digital innovations and public policy towards positive, desirable enhancement of farmers' lived experiences. Similarly, public policy needs to enable and facilitate micro changes among farmers through place-based policies that are farmer-centred and promote local capacity building. Likewise, the competence altering mechanism of digital innovation must be leveraged by extension actors to aid knowledge transfers and facilitate rural behavior changes.

However, we do not expect the changing practices to be taken uncritically. Other theoretical lenses, such as political economy and responsible innovations, must be employed to attain a fuller picture of the power, equity and inclusivity implications in these rural spaces. Furthermore, we do not claim to provide an exhaustive stock of how DA change farming activities and communities, nor have we claimed such changes are universal—for example, nuanced sex and gender dimensions are not adequately captured. Third, we have not evaluated the normative directionality of the changing practices, i.e., related to power, wealth, ecological feedback, and other issues that are critical to rural sustainability and resilience. Instead, we have outlined and, by extension, extended understandings of how these technologies redefine what farming means and how it is done. We acknowledge that digital changes can be a transition in the wrong direction (Ropke and Christensen, 2013), especially in agriculture, where anxieties about potential undesirable consequences on rural labour, farmer autonomy and dependence, and power imbalances has come under scrutiny (Bronson and Knezevic, 2016; Carolan, 2017a, 2020b; Rose and Chilvers, 2018; Rotz et al., 2019). Hence, further research on the inclusiveness and sustainability of the observed patterns is critical to avoid undesirable consequences on farming and rural social life. Future research must also assess the kind of world views digital services project on farmers and rural communities.

Credit author statement

Abdul-Rahim Abdulai: Conceptualization; Data curation; Formal analysis; Funding acquisition; Methodology; Project administration; Resources; Software; Supervision; Visualization; Roles/Writing - original draft; Writing - review & editing. **Evan D. G. Fraser:** Conceptualization; Funding acquisition; Supervision; Validation; Writing - review & editing. **Ryan Gibson:** Conceptualization; Supervision; Writing - review & editing.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

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