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Is agricultural digitization a reality among smallholder farmers in Africa? Unpacking farmers' lived realities of engagement with digital tools and services in rural Northern Ghana

Abdul-Rahim Abdulai[1,3*], Philip Tetteh Quarshie[1], Emily Duncan[1] and Evan Fraser[1,2]

Abstract

Background Digital technologies are promoted as transformational for smallholders in Africa through the potential to enhance access to knowledge, increase productivity and food security. Despite the anticipations for agricultural digitalization in Africa, smallholders' engagement with digitalization is empirically underexplored. Hence, we surveyed 1565 rural farmers in Northern Ghana to explore how farmers interact with digital tools and services, and the variations in their engagements.

Results We found that despite the growing array of digital opportunities (with diverse tools and services available to farmers), farmers are mainly confined to simple devices (mobile phones, radio, and TV) as access to digital resources, including the internet remains limited. Meanwhile, the main sources of digitalization services for smallholders remain largely the highly subisidized, development-orieted. NGOs and private-sector projects, which generally leverage SMS, Interactive Voice Response (IVR), radio, or field agents to reach farmers. Nonetheless, participation in digitalization services remains limited, unimpressive at best, and often fades over time because of weak building blocks evident in low literacies, lack of digital competencies and the limited access to digital resources.

Conclusions 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 current and future structural limitations of smallholder agriculture, including low literacy and limited access to digital tools, to make agriculture digitalization reach its full potential in Africa.

Keywords Digitalization, Rural, Smallholders, Digital services, Digital agriculture, Africa

*Correspondence:
Abdul-Rahim Abdulai
aabdulai@uoguelph.ca
[1] Department of Geography, Environment and Geomatics, University of Guelph, Guelph, ON, Canada
[2] Arrell Food Institute at the University of Guelph, University of Guelph, Guelph, ON, Canada
[3] The Alliance Bioversity and International Centre for Tropical Agriculture, Cali, Colombia

Introduction

Africa's agriculture sector is underdeveloped in varied ways, including low level of productivity partly influenced limited adoption and use of innovations and technologies. For example, information and communication technologies (ICTs) noted as instrumental to the next phase of agricultural development, remain low in Africa [8, 32]); sub-Sahara Africa had the lowest percentage of population with internet access in 2020, at 30.04% compared 38.54 in South Asia or 91.52% in North America [31]. The levels of technological proliferations are also disproportional between rural and urban areas, with rural communities and smallholders always at the lower end of access [19, 27]. Meanwhile, there exist so much potential for agricultural growth and development by ending technologies inequities of varied forms for and among smallholders.

In fact, digitalization—the application of varied forms of digital tools and services to aid agriculture processes— is proclaimed as a "game-changer" pathway to transformation for farmers and communities in Sub-Sahara Africa [6, 7, 15, 18]. Particularly, digitalization could increase access to information, enhance productivity, profitability, and strengthen resilience for smallholders and communities, as well as climate change responses [3]. 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 [25, 32]. As at early 2020 over 437 digital services were tracked by the Groupe Speciale Mobile Association (GSMA) AgriTech (GSMAssociation, 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. In addition, the reach increased to 515 million (46% of population) by end of 2021 with an anticipated 50% penetration by 2025. Likewise, smartphone adoption reached 49% of total connections at end of 2021.[1] 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 [22, 32], the full extent of digital penetration and engagements, specifically regarding food and farming, is unknown.

[1] Data can be tracked from GSMA website https://www.gsma.com/mobileeconomy/sub-saharan-africa/.

This paper offers insight into rural farmers' experiences and attitudes toward digital tools and services in Northern 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 Northern 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.

Background

Digitalization for agriculture in Africa

Digitalization of agriculture encompasses applying digital tools and systems to aid agriculture practices and processes [15, 20, 32]. 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 means that new tools are being integrated into farming systems [10, 34]. 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) [14]. 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 [13]. Digitalization may include direct or indirect use of *simple digital devices* (e.g., phones, computers, radios, tablets, etc.) and more *advanced digital hardware* (drone,

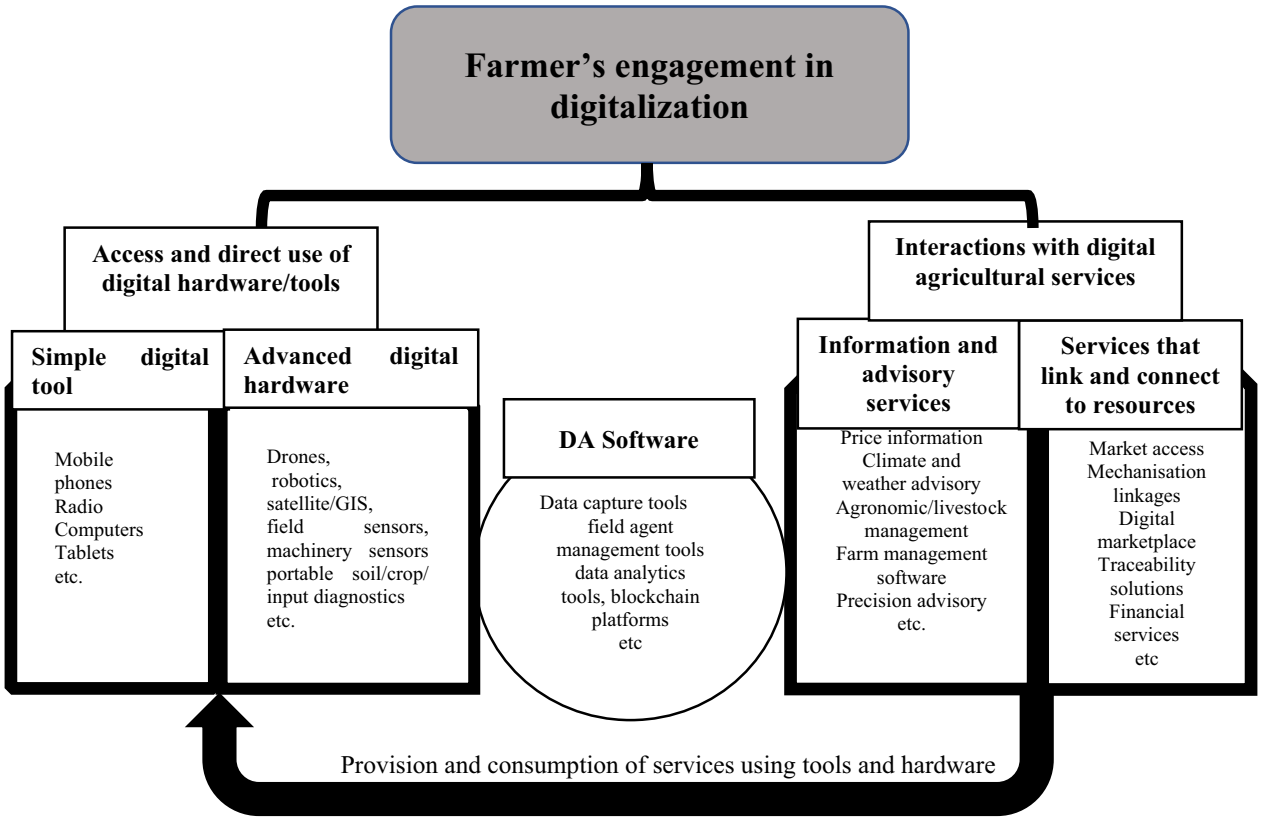

Fig. 1 Framework for farmers' engagement with digitalization in smallholder systems

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 and disease surveillance) to create solutions/services that enhance agri-food processes [9, 14, 21, 32]. The services and solutions are mainly in two areas: *information or advisories* and *connection/linkages to resources* (input and outputs) (see Fig. 1).

From Fig. 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. In addition, the trend is only expected to grow as access to the internet, and mobile technologies continue to develop [21]. 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 space [5, 13]. 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*.

Research setting

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 km^2, 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 [1, 2, 24, 28, 29, 33]. Likewise, Northern

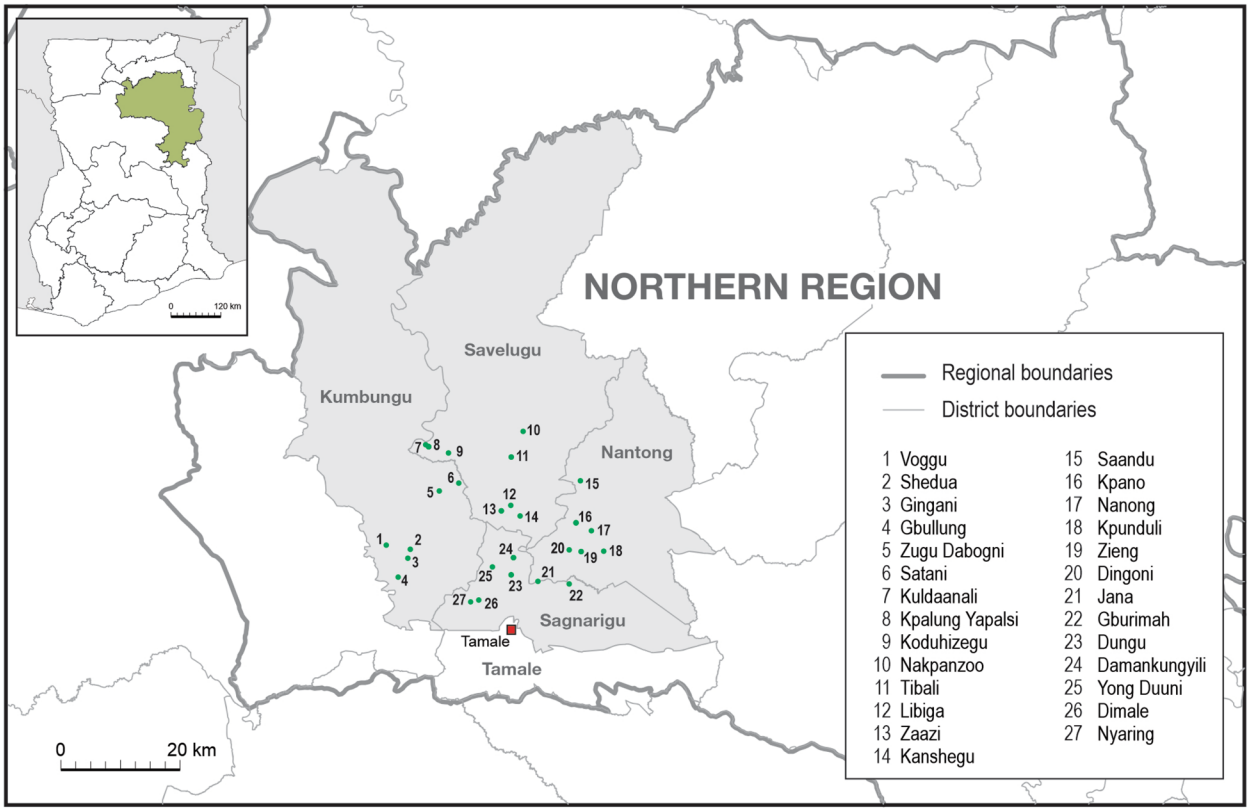

Fig. 2 Map of study communities

Ghana has been a testing ground for digital agriculture start-ups and service providers in recent years (see [18, 23, 27]. 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.

Methods

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 [24, 29]. 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 (see Fig. 2).

Within communities, the data were collected digitally with the help of trained research enumerators. The survey was conducted with a structured questionnaire (see Additional file 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 1).

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

Table 1 Household and farm-level characteristics of participants

Variable (n = 1565)	Mean	Standard deviation
Age	38.8	12.98
Household Size	15.06	8.69
Farm Size (in acres)	5.81	5.91
Duration in Farming (in years)	16.61	13.44

Variable	Options	Frequency	Percentage %
Gender	Female	617	39.42
	Male	948	60.58
Age	15–24	121	7.73
	25–40	891	56.93
	41–60	440	28.12
	60 +	113	7.22
Level of education	No education	1080	69.01
	Basic education (incomplete)	243	15.53
	Basic education (complete)	106	6.77
	High school	104	6.65
	Certificates/vocational	12	0.77
	Higher education	20	1.28
Farm Ownership	Community lands	148	9.45
	Family Land	386	24.65
	Family property (Livestock)	310	19.80
	Own private land	311	19.86
	Own private (livestock)	402	25.67
	Rented land	3	0.19
	Caretaking for someone (Livestock)	4	0.26
	Others	1	0.13
Farming system	Livestock only	2	0.13
	Mixed cropping (more than one crop)	575	36.74
	Mixed farming (both crop and livestock/fishing)	905	57.83
	Monocropping (just one crop)	83	5.30
Farming model	Only feeding the family (subsistence)	474	30.29
	Only For sale (commercial)	14	0.89
	Part for family and part for sales (Semi-commercial)	1077	68.82
Income In GHC (GHC means Ghana Cedis. USD 1 = GHC5.9 at the time of the research, June-July 2021.)	> GHC 1000	1090	69.65
	GHC 1001–2000	248	15.85
	GHC 2001–3000	108	6.90
	GHC 3001–4000	62	3.96
	GHC 4001–5000	30	1.92
	GHC 5001–6000	11	0.70
	GHC 6001–7000	5	0.32
	GHC 7001–8000	5	0.32
	GHC 8001–9000	2	0.13
	GHC 9001–10,000	0	0
	GHC 10,000 +	4	0.26
Business status	Fulltime	1085	69.33
	Part-time	480	30.67
Membership of association	No	511	32.65
	Yes	1054	67.35

Table 1 (continued)

Variable	Options	Frequency	Percentage %
Access to extension	No	479	30.61
	Yes	1086	69.39

Table 2 Overview of other variables used in analysis

Variable	Description	Measurement
Participation in digital services	Measured farmers experience with digital services of any kind in the last five years	Yes if farmer has participated in service No if farmer has no experience with any service
Retention and activeness	Measured current usage of farmers who have indicated prior usage	Yes if farmer is currently an active user No if farmers has discontinued usage
Awareness	Measured farmers self assessed awareness of digital services in their area	Yes if farmer indicated being aware No if farmer indicated not being aware
Ownership and access	Measured if a farmer owned a particular digital tool or had access to it in any way to benefit from it. This could be benefitting from a tool owned by another household member	Measured 6 digital tools (Table 6) Yes if farmer had access to the tool No if farmer had no access to tool
Ability to use	Utilized farmers self-assessments of abilities to undertake specific digital task	Measured self-reported abilities in digital competences (Table 6) Yes if farmer said they can do task No if farmer said they could do task
Willingness to Join	Measured farmers view of joining digital services	Yes if farmer indicated willingness to use in future No if farmer indicated non-willingness
Perception of services	Measured farmers perceptions of digital services across specific statements (whether digital services as good; whether services has a future in smallholder systems)	True- if farmer agreed to statement False if farmer disagreed Not sure—if farmer was uncertain or could not arrive at a firm decision
Use of phone	Self-reported use of phone by farmers	Yes if farmer indicated using phone for farming activity in last one year No if farmer indicated not using phone for farming activity in last one year

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 there 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 (Table 2).

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.

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,

Table 3 Chi-square for farmers participation in digital services

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

χ^2 tests indicate differences are statistically significant at 95% when $p < 0.05$

Participation in digital services measured with the question: has your farm participated in any program related to digital technologies in the last 5 years or currently use any service? (1) Yes (2) No

*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$

Table 4 Chi-square for farmers retention and activeness

Variable (n = 1099)	χ^2	p	Cramers V
Gender	0.761	0.383	0.026
Age	3.448	0.328	0.056
Duration in Farming	0.338	0.845	0.18
Householdsize	4.854	0.183	0.066
Farm Size	1.086	0.896	0.031
Level of education	8.492	0.131	0.088
Farming system	22.948	< 0.001**	0.145
Commercial status	0.779	0.678	0.027
Income	22.384	0.02**	0.143
Business status	0.052	0.820	0.007
Membership of association	2.069	0.150	0.043
Access to extension/Vert services	1.147	0.284	0.032
Phone ownership	0.001	0.980	0.001

χ^2 tests indicate differences are statistically significant at 95% when $p < 0.05$

Retention measured with the question: If yes to prior participation, do you currently actively participate in the service? (1) Yes (2) No.

*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$

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).

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 4 and Additional file 1).

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. In addition, 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.

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, Interactive Voice Response (IVR), and

Table 5 Chi-square for awareness about digital services

Variable *(n = 1565)*	χ^2	*p*	Cramers V
Gender	0.935	0.334	0.024
Age	24.849	< 0.001**	0.126
Duration in Farming	5.751	0.056	0.061
Householdsize	13.988	0.003**	0.095
Farm Size	28.662	< 0.001**	0.135
Level of education	18.307	0.003**	0.108
Farming system	219.903	< 0.001**	0.375
Commercial status	19.383	< 0.001**	0.111
Income	42.055	< 0.001**	0.164
Business status	21.290	< 0.001**	0.117
Membership of association	354.969	< 0.001**	0.467
Access to extension/Vert services	335.550	< 0.001**	0.463

χ^2 tests indicate differences are statistically significant at 95% when $p < 0.05$

Awareness of services: Are you aware of digital technology services and solutions related to your farming activities? (1) Yes (2) No

*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$

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 1), and consequent inability to read SMS, follow IVRs or use the internet independently (see Table 6).

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'

Table 6 Farmers' ownership, access and abilities to use digital tools

Access and ownership of digital resources *(n = 1565)*		
Digital resource	**Farmers WITHOUT access**	**% Farmers WITH access**
Mobile phone	2.2	97.8
Radio	19.0	81.0
TV	33.2	66.8
Cellular internet	87.0	13.0
Computer	97.2	2.8
Wifi	97.3	2.7
Tablet	98.9	1.1
Farmer's competencies in a digital task *(n = 1565)*		
Farmers with the ability to:	**% of farmers who CANNOT**	**% of farmers who CAN**
Answer calls on phone independently	4.9	95.1
Place calls on phone	10.1	89.6
Receive and read SMS on phone	66.5	33.5
Send SMS messages	68.8	31.2
Access audio messages sent to phone	69.5	30.5
Send audio messages on phone	77.5	22.5
Follow IVR on phone	79.2	20.2
Browse the internet for information	82.7	17.3
Use social media	82.4	17.6
Use an independent phone app for activities	82.6	17.4
Use a computer	86.4	13.6

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.

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 (Table 5). 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 5 and Additional file 1). 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.

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 Fig. 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 6).

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.

Table 7 Chi-square for farmers use of phones

Variable (n = 1565)	χ^2	*p*	*Cramers V*
Gender	6.670	0.010**	0.066
Age	21.323	< 0.001**	0.118
Duration in Farming	16.857	< 0.001**	0.105
Householdsize	20.812	< 0.001**	0.117
Farm Size	43.576	< 0.001**	0.169
Level of education	15.779	0.008**	0.102
Farming system	163.237	0.001**	0.327
Commercial status	0.613	0.736	0.02
Income	56.101	0.001**	0.191
Business status	0.003	0.954	0.001
Membership of association	107.303	< 0.001**	0.265
Access to extension/Vert services	139.530	< 0.001**	0.302

χ^2 tests indicate differences are statistically significant at 95% when $p < 0.05$

Use of Phone: In the last farming season did you use your phone to engage in farm related activity? (1) Yes (2) No

*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$

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 7 and Additional file 1).

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 Fig. 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

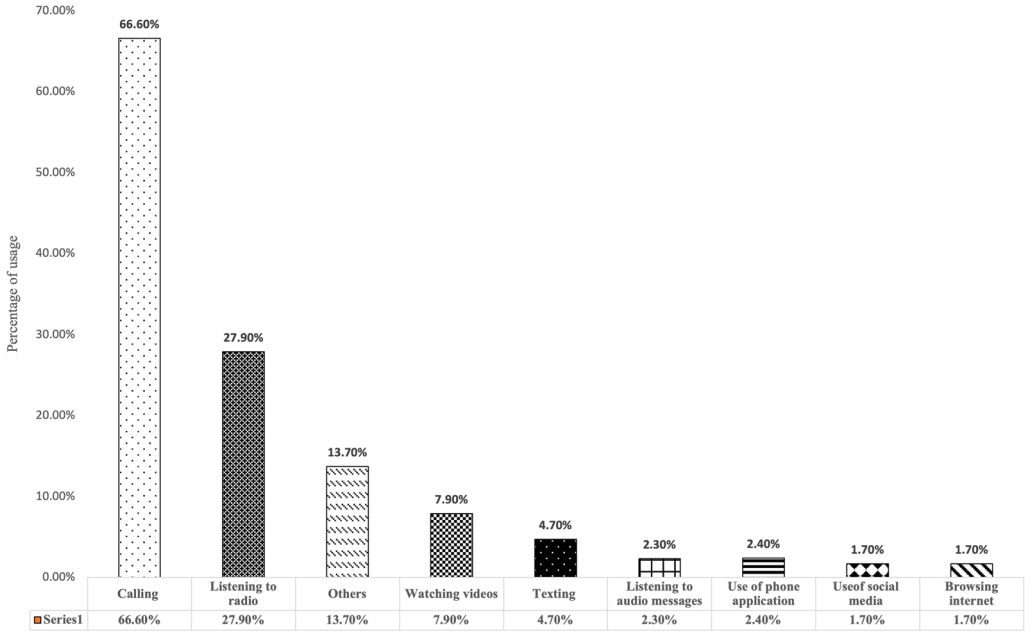

Fig. 3 Ways farmers use mobile phones for farming activities

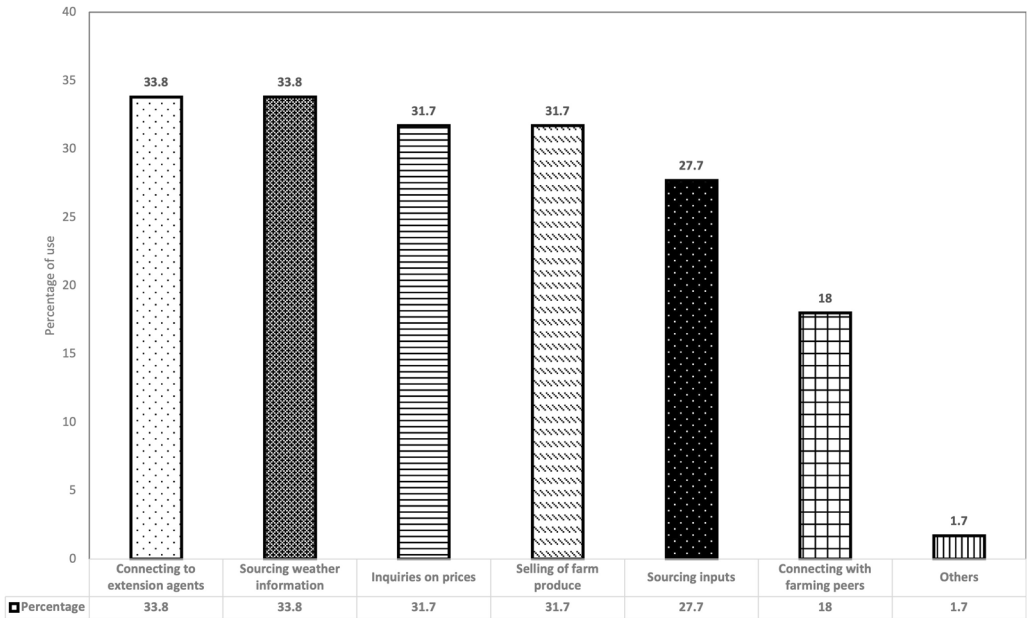

Fig. 4 Farming purposes and tasks farmers use mobile phones to accomplish

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 6).

The common purpose of use were mobile money transactions, connection with extension agents, sourcing weather information, inquiries on prices and selling of farm produce (Fig. 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

Table 8 Chi-square for farmers perceptions about digital services

Variable (n = 1565)	χ^2	*p*	*Cramers V*
Gender	21.504	< 0.001**	0.117
Age	6.375	0.383	0.045
Duration in Farming	11.33	0.023**	0.060
Household size	6.132	0.409	0.044
Farm Size	8.482	0.388	0.052
Level of education	25.134	0.005**	0.090
Farming system	9.487	0.148	0.055
Commercial status	1.648	0.800	0.023
Income	66.203	< 0.001**	0.145
Business status	0.190	0.910	0.011
Membership of association	8.301	0.016**	0.073
Access to extension/Vert services	10.401	0.006**	0.082
Phone ownership	0.283	0. 868	0.013

χ^2 tests indicate differences are statistically significant at 95% when $p < 0.05$

Perception about service: I belief digital technologies and services are good for our farming practices 1. True 2. False 3. Not sure

Digital tools and services are the way forward for my farming activities 1. True 2. False 3. Not sure

*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$

Table 9 Chi-square for farmers willingness to join digital services

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

χ^2 tests indicate differences are statistically significant at 95% when $p < 0.05$

I will accept and use newer digital technologies and services if the right conditions are in place 1. True 2. False 3. Not sure

*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$

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.

How do farmers perceive digitalization?

Farmers generally held positive perceptions around digitalization. Perceptions were measured through a five-point agree-disagree Likert 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 8). 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.

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 9). 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.

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[2] 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 farmer 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 also 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 or pilot 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.

In general, farmers' engagement with digitalization is low in terms of tools and services use. The ubiquity of mobile phones makes them the most accessible and hence commonly used tool [16, 17, 22, 32], while 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 remain part of pro-poor interventions [3, 11, 25, 32], the retention and activeness beyond the project's timeframe are low: of 70.22% who had participated in digital services, only 31.6% were still actively interacting with services, but this number 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. [23] and Palloni et al. [30], 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. [23] and Etwire et al. [18], 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. [17] and Kim et al. [25]. Farmers' general lack of interest emanating from perceived more urgent of other demanding challenges (including climate change risk and lack of access to inputs), low capabilities to sustain engagements, and the long-term experiences and expectations of receiving free support from developmental interventions partly account for this challenge.

The low engagement explored in this paper, we argue, mean that full-scale digitalization that encompasses the vast array of tools and services shown in Fig. 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. Discussion of swarms of mini tractors powered by tablets and uber-like rental services in smallholder systems shows a disconnect from farmers' lived realities, because usage is confined to low technology devices such as mobile phone, radio, and TV (Ayim et al., 2022). The results showed most smallholders could not 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 [26] 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. The basic building blocks, which also include access to digital tools, enabling digital infrastructure, supporting social infrastructure, digital literacy among farmers and extension officers, and shared meanings [4] are too lacking at present for any meaningful engagement nor transformative impacts. Hence, our discussion underscores the need for the critical exploration of the contextual realities of smallholders to inform the discourses and practices of digitalization better.

Conclusion and reflections

Digitalization of agriculture is unfolding for farmers in Africa, but proliferation and engagements are constrained and limited at best. Farmers are not just limited in their use of digital tools and devices [8], but

[2] GHC6001-7000 = USD 1017–1186 at time of the research June–July 2021.

they are also constrained by the low (digital) literacies of varied forms. Hence, farmers' experiences are not established enough to match claims of widespread digitalization or any potential anticipated revolutionary, disruptive, and "game-changing" transformations [7, 32] from digitalization. Therefore, the anticipated digital revolution discourses in African agriculture cannot be limited to the technicalities of creating such innovations and their idealistic impacts, they must be re-focused on sensitivity to farmers' contextual social realities [24], including inequities in access to digital tools, services and competencies.

If digital agriculture has any chance of having an impact amongst smallholder farmers—including reducing food insecurity and poverty—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 [4]. Only by understanding and building 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, and can we also better appreciate how to leverage these tools and service for widespread impacts for farmers and rural communities.

Hence, we call for the creation of "digitalization for smallholders" or a "digitalization for Africa," which is different yet contextually relevant to the structural lived conditions of rural farmers, and situated in the areas of operation. 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 [12] 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. In addition, 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 may be 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.

Supplementary Information

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Additional file 1. Crosstabs and chi-squares for farmers engagement

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A-RA conceptualized the idea, collected data, and prepared the first draft. ED, PQT and EF provided feedback, comments, and inputs on later versions. All authors read and approved the final manuscript.

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Declarations

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The studies involving human participants were reviewed and approved by University of Guelph Research Ethics Board. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

Consent for publication
The authors offer consent for publication.

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