GHANA'S AGRICULTURAL SUSTAINABILITY WITH DIGITALIZATION: THE MOBILE PHONE USE AS A BOUNDARY OBJECT

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ABSTRACT

Purpose- This study explores the role of mobile phone technology as a boundary object in promoting agricultural sustainability among smallholder farmers in rural Ghana. Drawing on Boundary Object Theory, the research investigates how mobile phones facilitate communication, coordination, and knowledge exchange between farmers, policymakers, agronomists, and market actors.

Design/methodology/approach – Through qualitative analysis of interviews conducted with farmers affiliated with Ministry of Food and Agriculture Ghana (MOFA) and ESOKO, six thematic areas were identified: communication and knowledge exchange, decision-making support, sustainable farming practices, socio-cultural adaptability, infrastructure and accessibility, and social dynamics and inclusion.

Findings – The findings reveal that mobile phones enable farmers to access real-time agricultural information, improve market connectivity, and adopt sustainable practices. However, infrastructural limitations, literacy barriers, and gendered access to digital tools constrain their effectiveness. The study highlights the emergence of farmer-led digital innovation and co-production, demonstrating how mobile phones are adapted to local needs and practices. Policy recommendations include enhancing digital literacy, supporting inclusive cooperative structures, and promoting participatory design of mobile-based agricultural tools.

Research limitations/implications – This study is based on qualitative interviews with a purposive sample of smallholder farmers in the Kwahu district of Ghana. While the findings offer rich insights into mobile phone usage and agricultural sustainability, they may not be generalizable to all rural farming contexts across Ghana or sub-Saharan Africa. Additionally, the reliance on self-reported data introduces potential biases related to recall and social desirability. The study also focuses primarily on mobile phone technology, excluding other digital tools such as tablets, drones, or IoT systems that may influence farming practices.

originality/value –The research contributes to understanding how digitalization intersects with entrepreneurial behavior in agriculture, offering insights into the transformative potential of mobile technology in resource-constrained settings. The research provides valuable implications for theory, policy, and practice. Theoretically, it extends Boundary Object Theory into the domain of rural entrepreneurship, demonstrating how mobile phones function as adaptable tools for knowledge exchange and coordination. Practically, the findings highlight the need for inclusive digital literacy programs, participatory design of mobile applications, and infrastructure investment to support sustainable farming. Policymakers and development agencies should consider farmer-led innovation and co-production as key strategies for enhancing digital adoption and resilience in agricultural systems.

Keyword: Digital entrepreneurship; Mobile phone technology; Boundary object theory; Agricultural sustainability; Rural innovation

1. INTRODUCTION

Digitalization has progressed rapidly over the last two decades, altering how individuals, consumers, and businesses interact, operate, and communicate globally. This trend is attributed to the rise of Information and Communication Technologies (ICT), such as internet and mobile phone technologies, which create new products and processes, as well as innovative market channels, in addition to driving technological advancement. The advantages associated with ICT are seen as a vital catalyst for wealth generation. For countries to harness economic growth, they must efficiently utilize ICT (Myovella et al., 2020). The process of digitalization plays a crucial role in fostering economic prosperity across both advanced and emerging economies (Arendt, 2015). Evidence suggests that improvements in telecommunications infrastructure are linked to economic advancement (Mungadi and Argungu, 2024).

However, the extent of this impact may depend on the level of development within a country (Arthur et al., 2024). It has been proposed that the rapid growth of broadband infrastructure has a more pronounced effect on lower-income nations compared to their high-income counterparts (Awad, 2024), although the situation is complex. For instance, Lee and Kang (2024) observe that investments in information and communication technology (ICT) tend to yield greater economic benefits for developed countries than for developing ones, especially in the context of African nations. Nevertheless, several researchers (Arendt, 2015; Dossou and Berhe, 2024) argue that lower-income countries are increasingly closing the gap with high-income nations through leapfrogging effects enabled by the adoption of ICT.

Digitalization of agriculture refers to the use of digital tools and systems to reinforce agricultural practices and procedures (Abbasi et al. in 2022). Because mobile phones, the internet, and new technologies like big data analytics, artificial intelligence (AI), and machine learning are becoming more widely available, farming systems are incorporating new tools (Sulimin et al. in 2019). Digitalization in Africa's smallholder systems is demonstrated by the availability and utilization of a variety of digital tools, software, and services for farming activities by farmers (Izuogu et al. (2023). According to Gabriel and Gandorfer (2023), digitalization can involve the direct or indirect use of basic digital devices like phones, computers, and tablets. Additionally, digital equipment is used to leverage data to offer services and products that enhance agri-food processes (Izuogu et al. (2023).

Agricultural sustainability represents a critical challenge for economies reliant on agriculture, especially in sub-Saharan Africa, where environmental issues and changing market demands necessitate innovative approaches. In 2023, agriculture accounted for approximately 21.1% of Ghana's Gross Domestic Product (GDP), encompassing activities such as crop farming, forestry, hunting, fishing, and livestock rearing. The sector also provided employment for around 35.37% of the workforce, underscoring its vital importance in sustaining the livelihoods of a substantial segment of the population. However, in 2024, the agricultural contribution to GDP declined to about 19%. This sector still included crop cultivation, forestry, fishing, and livestock production. Notably, during the fourth quarter of 2024, agriculture experienced a real growth rate of 2.9%. Employment in the sector fell to approximately 33.9%, reflecting a decrease of 1.47%. Despite this decline, the sector remains crucial in supporting the livelihoods of a significant portion of the population.

This paper aims to explore the role of mobile phones as boundary objects supporting agricultural sustainability in Ghana, particularly among rural farmers in the remote Kwahu district. It seeks to leverage the personal experiences of these farmers in utilizing mobile phones to enhance communication and knowledge exchange with policymakers and agricultural service providers in Ghana. Additionally, the paper assesses the influence of mobile-based digital tools on sustainable agricultural practices and productivity within the country. Furthermore, it identifies the challenges and opportunities that arise from employing mobile phones as boundary objects in the pursuit of agricultural sustainability in Ghana. The study is framed within the theoretical context established by Star and Griesemer (1989), which emphasizes how mobile phone technology serves as a boundary object that accommodates diverse identities and acts as a reference point for coordinating the viewpoints of various users, thereby transcending geographical limitations (Star & Griesemer, 1989).

2. LITERATURE REVIEW

2.1. The Boundary Object Framework

Boundary Object Theory, as presented by Star and Griesemer (1989), examines how objects aid communication and coordination among various social groups while preserving their unique meanings across different contexts (Star & Griesemer, 1989). Boundary objects possess enough flexibility to allow for different interpretations by multiple stakeholders while acting as shared reference points for collaboration. In Ghana's agricultural sector, mobile phones operate as boundary objects, allowing farmers, policymakers, technology developers, and agricultural service providers to connect within the digitalization framework. Although their priorities and expertise may differ, mobile technology bridges the gaps in knowledge sharing, access to resources, and sustainable farming methods.

The mobile phone technology is flexible enough to meet changing user needs. Boundary objects are not dictated by a single group but are appealing to various stakeholders based on how they are used. These objects empower users by giving them knowledge and control as they modify them to fit their needs. Boundary objects enable local coordination without requiring agreement, allowing users to understand the object in the context of broader activities. This affects user behavior, enabling them to engage in different tasks through the skills they develop.

Boundary objects could be objects that enhance capacities and facilitate usage of certain technological objects and help disseminate information across boundaries – for example, between communities of knowledge and practice. The object (mobile phone technology) performs a brokering role involving translations, coordination, communication, and other activities, based on how users want to use it. Hence, mobile phone technology is a boundary object that can be used to address multiple issues. Carlisle (2002) posited that boundary objects can be categorised into information processing level, the interpretive level, and the pragmatic level (Carlisle, 2002).

The information processing level involves storing, processing, and retrieving knowledge. In small farming businesses, mobile phone technology helps owners keep track of customer information, like names and contacts, which is essential for building relationships. The interpretive level is about understanding this information to decide how to use it effectively. The pragmatic level involves various stakeholders, such as policymakers and agricultural service providers in Ghana, who utilise the knowledge from farmers through mobile technology for support and policymaking. Other involved parties include communities, government agencies, mobile companies, and NGOs, all adapting mobile technology to serve their needs.

The Boundary Object framework has been extensively used to understand the complex relationships between these three levels (Totenkopf's et al., 2015) and in studies on technology adoption and implementation inside organizations (Schillings et al., 2023). The importance of mobile phones as boundary objects and digitalization of the agricultural sector in developed countries (Campos, 2022), more broadly throughout Europe (Runhaar, 2021), and in developing economies (Beumer and Swart, 2021) is examined in the literature (Beumer & Swart, 2021).

The framework, for instance, has served as a guide for studies that use the theory to investigate the ways in which digital livestock technologies— such as mobile applications—affect farm management and animal welfare. The research discusses how these technologies serve as boundary objects, facilitating communication and understanding between farmers and researchers, despite differing perspectives and terminologies (Schillings et al., 2023). Together, the studies demonstrate how mobile technologies can help close gaps between different stakeholders in African agriculture, which is consistent with the ideas of boundary object theory. Our research focuses on small farming business entrepreneurs in rural Ghana, taking forward the use of this model into a remote agricultural region of Ghana.

2.2 The Relevance of Digitalization in Agriculture in Sub-Saharan Africa

Digital technologies hold promises for addressing long-standing structural and systemic issues in agriculture, especially in Sub-Saharan Africa (SSA). These issues include low productivity, climate variability, market accessibility, and a lack of agricultural extension services. Rain-fed systems, subsistence farming, and smallholder dominance define the SSA's agricultural sector

(Jayne and Ameyaw, 2016; Jayne & Ameyaw, 2016).

These circumstances present difficulties, but they also present chances for digital interventions. Digital agriculture has been widely promoted as a way to increase incomes, resilience, and productivity. It is broadly defined as the use of information and communication technologies (ICTs) in the agricultural value chain (Aker et al (Aker et al., 2016). World Bank, 2021; 2016) (World Bank, 2021).

Despite being regarded as essential in Western economies, mobile phone technology is still less common in developing nations, despite its increasing use as a business tool (Konte and Tetteh, 2023). Mobile phones are a versatile tool that helps improve business processes and connect urban and rural areas in developing countries. They are essential in regions lacking landline systems or communication infrastructure. Sub-Saharan Africa has low infrastructure investment, with only 29% of roads paved and about 25% of people having electricity. There are fewer than three landline phones per 100 people. However, mobile phone usage has grown faster in this region over the past 20 years compared to developed countries with established telecom systems. In 2021, there were 515 million mobile subscribers in sub-Saharan Africa, representing around 46% of the population. Recent data shows that 40% of adults use mobile internet, while 44% live in areas with mobile coverage but do not use mobile internet services. Mobile phone technology usage varies across Africa. For example, Kenya leads in mobile money usage with 85% of its population using it, while Ghana has 55%, Tanzania 45%, South Africa 8%, and Nigeria 4%. Despite these differences, mobile money services positively impact financial inclusion and development in sub-Saharan Africa. Additionally, agricultural technology has progressed greatly in the past few decades, utilizing tools like GPS, IoT, and AI to enhance farming practices. These technologies help manage production and reduce costs, leading to more sustainable agriculture and addressing uncertainties in the agricultural value chain (Kouladoum et al., 2022).

Digitalization has created new opportunities in agriculture and also on individual level. Emerging digital technologies, including drones, Geographic Information Systems (GIS), and satellite imagery, are increasingly being utilized in high-value or commercial agriculture. These innovations facilitate precision agriculture by optimizing inputs through data-driven insights (Kamilaris et al., 2017). Despite the limited adoption among smallholders due to financial and infrastructural challenges, pilot initiatives in nations such as Nigeria and Rwanda demonstrate a rising interest and potential for implementation.

Agribusiness platforms like Twiga Foods in Kenya and Agri-wallet link farmers directly to buyers, lowering costs and improving transparency. They provide logistical help, aggregation, and traceability, which are crucial for meeting quality standards in local and international markets. Digitalization using mobile phones facilitate connections among individuals, information, markets, and services across urban-rural and socioeconomic divisions (Elom et al., 2024). In Mali, inhabitants of Timbuktu can contact relatives residing in the capital city of Bamako or those in France. In Niger, day labourers and farmers can contact acquaintances in Benin to casual farming job opportunities saving them about US$40 travel expense.

2.3 The Case of Ghana

2.3.1 Digitalization through Mobile Telecommunications

Ghana's economy is one of the most stable and competitive within West Africa, and this has attracted mobile telecommunication companies (Agyeman-Duah, 2019). Deregulation of Ghana's telecommunications took place in 1994 with the Accelerated Development Program (ADP) supported by the World Bank and the International Telecommunications Union came into effect in 2000 (Osei-Owusu, 2015; Sey 2008) (World Bank, 2021). The aim was achieving a density of 1.5 and 2.5 fixed lines per 100 people in rural and urban areas respectively as well as improving mobile services (Arthur and Arthur, 2017). This project was placed under the management of the National Communications Authority and, with government support, Ghana. The Telecommunications Company was established to oversee this initiative. Subsequently, the fixed line operations were privatized, with the contract granted to Telecom Malaysia (Avle, 2020; Sey, 2008). As part of the liberalization and privatization strategy, another consortium known as WESTEL acquired a 10%

share to facilitate the provision of approximately 300,000 fixed telephone lines, addressing the growing demand resulting from the economic liberalization. The disparity in telecommunications access between rural and urban regions was expected to diminish with the increase in telephone lines (Nimako et al., 2012; Overå, 2008). Nevertheless, the installation costs, which could reach $200 per fixed landline, coupled with shifts in government policy, hindered the realization of the objectives set forth by the ADP. Furthermore, many Ghanaians believed that the development of landline infrastructure was a governmental obligation and were unwilling to bear the costs for these services. The belief in individual ownership has played a significant role in the increase of mobile phone ownership (Williams and Kwofie, 2022). The decline in bandwidth costs has motivated both individuals and enterprises to engage with the internet via private mobile telecommunications providers (Mungadi and Argungu, 2024). In Ghana, the mobile telecommunications landscape includes companies such as AirtelTigo, Capital Telecom, Globacom, MTN Ghana, and Telecel Group (Afutu-Kotey and Gough, 2022; Lusha, 2025).

2.3.2 Agriculture Systems and Sustainability

In Ghana, the agriculture sector plays a significant role, contributing approximately 20% to the nation's GDP (Kwakwa et al., 2023) and around 4% to export revenues (FAO, 2023). It employs nearly 45% of the rural population engaged in farming, fishing, and agro-processing, and is vital for the country's economic growth through tax revenues (Dziwornu et al., 2024). The agricultural market in Ghana is projected to reach USD 3.87 billion by 2029 (Mordor Intelligence, 2024). However, despite its importance, the sector's growth has lagged behind other industries (Nyamekye et al., 2021). By the end of 2020, agriculture represented 18.24% of GDP, a decline from 25.2% in 2015 and 28.2% in 2014 (Danso-Abbeam et al., 2021). This stagnation can be attributed to the failure of previous governments to follow through on promised investments in agriculture (Nkansah-Dwamena, 2024). For the sector to thrive, it requires both governmental and private sector investment to stimulate growth, reduce unemployment, and enhance tax and revenue generation. The farming systems used in Ghana are relevant to understanding business practices and the relevance of mobile technology adoption. The tradition of land fallowing is well-established and can vary in duration, being short-term, long-term, or annual. During the fallow phase, farmers relocate to another plot of land designated to them by either their family or the community (Goldstein et al., 2015).

This approach is more suitable for small-scale subsistence farmers rather than large-scale agricultural enterprises (Baah and Kidido, 2020). The multi-cropping technique involves planting two or more crops on the same land. Certain crops, such as cocoa and coffee, require extended growth periods; therefore, to ensure a steady income and provide for their families, farmers incorporate maize, cassava, plantain, and banana based on the planting season.

In this multi-cropping system, one crop typically serves as the primary crop while the others are considered secondary (Owusu-Ansah and Chigbu, 2020). Some rural farmers practice cooperative farming, called 'Nnoboa', where they help each other with planting and farming to manage larger farms more affordably. They now use mobile phones to coordinate efforts, allowing them to see which farms need help. This method fosters community spirit and strengthens social ties. In the 'Abunu and Abusa' systems, landowners give land to farmers to cultivate, and they share the harvest based on their agreement. In 'Abunu', the farmer keeps half of the harvest, while in 'Abusa', the farmer takes two-thirds, and the landowner gets one-third. Since 2022, agriculture and food sustainability have been key focuses in Ghana. In 2022, agriculture made up about 20.3% of the country's GDP, highlighting its importance. However, by 2024, this dropped to 19% due to growth in other sectors like services and industry. Ghana has launched several programs, such as 'Planting for Food and Jobs,' to improve food security and reduce import reliance. Other initiatives like 'Feed Ghana' aim to modernize farming, enhance infrastructure, and strengthen supply chains. The use of local seeds and solar cold storage has helped reduce food spoilage and improve market access. Additionally, climate-smart practices like agroforestry have increased resilience to climate change. These efforts show agriculture's changing role in Ghana's economy and its ongoing quest for food sustainability. However, challenges like post-harvest losses and limited access to modern technology remain. This

research will explore how digitalization through mobile phone technology can help unlock the agricultural sector's potential and support sustainable practices.

3. THE RESEARCH STUDY CONTEXT

In rural areas lacking landline telecommunications and other communications infrastructure, small business owners must use mobile phone technology if they are to grow and improve their business operations. Digitalization is needed to keep pace with economic development, but this raises the question as to how those in remote locations, such as farmers who operate small businesses in rural Ghana, adopt, use and deploy mobile phone technology as a digitalization tool, integrating it into their farming practices. This research was conducted in the Kwahu district in the eastern region of Ghana. The main activities supporting people's livelihoods here are farming and fishing. About 85% of farmers are small business entrepreneurs (SBEs). By employing farm assistants, they contribute to Ghana's job creation and the country's GDP (Alhassan and Owusu, 2023). However, access to markets and customers is a fundamental challenge to farming businesses entrepreneurships in this area given its mountainous terrain and the Volta Lake. Reliable transportation and good telecommunication infrastructure, which support market access, are major problems; hence the need for Kwahu farmers to adopt digitalization using mobile phone to support these farming businesses and sustainability. (Acheampong et al., 2023). In this study we apply the Boundary Object Theory, as presented by Star and Griesemer (1989), in understanding how farmers, policymakers, technology developers, and agricultural service providers connect within the digitalized environment with one another using mobile phone technology in reference to agricultural sustainability (Star & Griesemer, 1989). The research questions are:

1. How do mobile phones facilitate communication and knowledge exchange between farmers and farming stakeholders?
2. In what ways do mobile phone applications and services influence decision-making and sustainable farming practices among smallholder farmers in rural Ghana?

3. What sociocultural and infrastructural factors affect the effectiveness of mobile phones as boundary objects in promoting agricultural sustainability by small holder farmers in the Kwahu District of rural Ghana?

4. METHODOLOGY

The researcher met the executive officers in charge of agricultural activities at the offices of MOFA and ESOKO in Accra. At these meetings the objectives and aims of the research were explained and it was requested that the executives contact the members of the farming community on behalf of the researcher. This was agreed and the executives asked their members to submit a reflection on their willingness to participate in the project. A total of 55 farmers (22 from MOFA and 23 from ESOKO) expressed interest in participating in the workshop. Executive Directors then organised individual face-to-face meetings with all 55 farmers at their local Kwahu district offices to meet the researcher and discuss the project and the conditions for their participation. It was explained that the participation would be anonymous and that each farmer would be given a consent form to take away while they considered whether they wanted to participate. The researcher followed up the face-to-face meetings by calling each farmer after they had had time to consider the proposal carefully and arranging for an interview to be conducted with each farmer. Of the 55 names initially provided by MOFA and ESOKO, 30 decided not to proceed to this stage, leaving 25 who agreed to participate. Of these, 12 were from MOFA and 13 from ESOKO, although one ESOKO farmer later withdrew for personal reasons. The data were collected in the period between 2019 and 2020.

4.1 Participant profile

The range of participants demonstrates heterogeneity in terms of age, gender, educational background, farm size, number of employees, agricultural produce, and number of mobile phones used (Table 1 below).

Table 1: Participant profile   Participant

Participant number	Farming group	Age	Gender	Education	Farm size (acres)	Number of employees	Agricultural produce	Number of phones used
#1	MOFA	55	Male	Secondary	30	8	Peanuts, onions, sweet chilli	2
#2	MOFA	62	Male	Primary	30	6	Maize, poultry	2
#3	MOFA	58	Male	Secondary	30	5	Cocoa, avocado, maize, poultry	3
#4	MOFA	35	Male	University degree	15	3	Maize, ginger	1
#5	MOFA	53	Male	None	60	10	Maize, peanuts	2
#6	MOFA	48	Male	None	50	9	Maize, yams	1
#7	MOFA	47	Male	Secondary	43	9	Maize, yams	2
#8	MOFA	37	Male	University degree	10	2	Piggery, maize, cassava	2
#9	MOFA	35	Male	University degree	5	2	Piggery, maize, cassava	2
#10	MOFA	63	Male	None	5	2	Maize, cassava, plantain	1
#11	MOFA	62	Male	None	10	4	Tigernut, cassava	1
#12	MOFA	58	Male	Secondary	40	10	Maize, peanuts, onions	2
#13	ESOKO	35	Male	Primary	35	7	Maize, yams	2
#14	ESOKO	33	Male	Secondary	50	11	Maize, yams	2
#15	ESOKO	70	Male	Secondary	60	12	Maize, oranges, cattle	2
#16	ESOKO	42	Female	None	43	8	Maize, yams	2
#17	ESOKO	51	Male	Primary	55	10	Maize, yams	2
#18	ESOKO	39	Female	None	45	6	Maize, yams	1
#19	ESOKO	49	Male	None	27	5	Maize and yams	2
#20	ESOKO	52	Male	None	15	2	Plantain, mangoes, avocadoes	1

#21	ESOKO	43	Female	None	20	4	Maize, yams	2
#22	ESOKO	42	Male	Primary	32	4	Poultry, oranges, cattle	2
#23	ESOKO	76	Male	Secondary	35	7	Cocoa, cola, citrus, beekeeping	2
#24	ESOKO	57	Female	None	40	5	Maize, onions, yams	2

As indicated in the table above, the average age of the farmers was 50, with a range of 33 to 76. Because farming is perceived as a man's domain and male farmers are seen as entrepreneurs in the Kwahu area, there were only four female farmers. Women, on the other hand, are seen as peasant farmers who manage the home through their labour (Azumah et al. 2023). Three farmers had university degrees, seven had completed secondary school, four had completed primary school, and ten had no formal education. The average farm size was 33 acres, with a range of 5 to 60 acres. Only five of the farmers had ten or more employees, while the majority had fewer than ten. A total of 151 people were employed by the farmers, with an average of six workers per farming operation. All of the farmer's farmed crops, mainly yams and maize, but two also kept chickens, two ran pig farms, two kept cattle, and one kept bee. Six farmers used only one mobile phone, 17 had two, and one farmer used three.

4.2 Data collection and analysis

The research study employed semi-structured in-depth interviews as part of a qualitative methodology. This method made it possible to (i) leverage the personal experiences of these farmers in utilizing mobile phones to enhance communication and knowledge exchange with policymakers and agricultural service providers in Ghana. (ii) The study made it possible for the understanding of the influence of mobile-based digital tools on sustainable agricultural practices and productivity within the country. (iii) Furthermore, making it possible to identify the challenges and opportunities that arise from employing mobile phones as boundary objects in the pursuit of agricultural sustainability in Ghana, through the use of open-ended questions. The interview questions are attached as (Appendix 1)

The interviews conducted averaged 50 minutes in duration, with a range of 45 to 90 minutes. With the explicit consent of the farmers, these interviews were audio-recorded. The interviewer transcribed the interview data, resulting in an approximate total word count of 50,000 words, which was subsequently saved in a Microsoft Word document before being imported into the qualitative analysis software NVivo 12.

This methodology enabled the interviewer to gain a comprehensive understanding of the issues discussed in Ghana prior to conducting a thematic analysis. Thematic analysis serves as a systematic approach for examining data and identifying emerging patterns (Braun and Clarke, 2006) (Braun & Clarke, 2006). Utilizing NVivo, the interviewer categorized the transcripts by highlighting quotes under thematic nodes, which were assigned concise code titles. These were then shared with the second author based in the UK, and consensus was reached through discussion. The initial coding round revealed some overlapping issues, leading to the identification of redundant nodes. During the second round of coding, overlapping nodes were consolidated, and redundant ones were eliminated. An iterative discussion process was employed to address any coding redundancies. As noted by Saldaña (2021), care was taken to ensure that valuable nodes were not lost during the process of reducing redundancy and streamlining the data (Saldaña, 2021).

The finalized labelled nodes were aligned with the two research questions and defined in mutual agreement by both authors (see Table 3). Table 3 illustrates that ESOKO farmers, who had received training on mobile phone usage from their local agronomists, perceived greater benefits from adopting the technology compared to the less experienced MOFA farmers. Consequently, additional nodes (code titles) were included and defined specifically for the ESOKO farmers. The text quotes were tabulated relating to each code

title by the interviewer such that representative quotations could be easily identified for illustrative purposes within the findings. Both authors then re-read the quotations to ensure correct classification of the quotes. The number of sources (S) who cited issues under each coding theme, with the volume of references (R) they made to them, were noted so that the importance of each could be determined, thereby guiding the presentation of quotations used within the findings. These counts are presented for each theme in Table 3. The authors then discussed the nature of the definition of each coding theme and determined how this fitted within the Boundary Object framework.

5. FINDINGS

Agriculture remains the backbone of Ghana's economy, employing a significant portion of the population, particularly in rural areas. However, the sector faces persistent challenges including climate variability, limited access to markets, and inadequate extension services. In recent years, digitalization—especially through mobile phone technology, has emerged as a transformative force in addressing these challenges. This study explores how mobile phones function as boundary objects, facilitating communication, coordination, and knowledge exchange among diverse stakeholders such as farmers, extension officers, and market actors. Grounded in Boundary Object Theory (Star & Griesemer, 1989), the research investigates how mobile phones, as shared tools, adapt to the needs of different social worlds while maintaining a coherent identity. Through qualitative analysis of transcripts from MOFA and ESOKO programs, six thematic areas were identified: communication and knowledge exchange, decision-making support, sustainable farming practices, socio-cultural adaptability, infrastructure and accessibility, and social dynamics and inclusion.

5.1 Communication and Knowledge Exchange

Mobile phones have revolutionized the way farmers in Ghana communicate with stakeholders. They serve as conducive forms for real-time information exchange, bridging geographical and institutional gaps.

"Mobile phones have revolutionized communication in agriculture. Through phone calls, SMS, and mobile apps, we can easily share information with each other and with experts in the field." Farmer #1

This sentiment was echoed by other farmers indicating has really improved collaboration among farmers because they could quickly ask questions, seek advice, and stay informed about market trends and best practices." Farmers further that mobile phones have made it much easier for us to connect with extension workers and researchers who provide valuable insights and support to improve our farming techniques Farmers emphasized that voice calls were important for discussing more complex issues or seeking urgent assistance, while SMS is great for quick updates and reminders.

5.2 Decision-Making Support

Mobile applications and services play a critical role in supporting farmers' decision-making processes. They provide timely and localized information on weather, pest outbreaks, crop selection, and resource management. The farmers described the impact of mobile apps: for example, "Apps like Esoko, AgroCenta, and Farmerline provided the farmers with real-time weather forecasts, which help us plan our planting and harvesting schedules more effectively. These apps also offer expert farming tips and advice on best practices. For example, they provide information on crop rotation, pest management, and soil conservation techniques. The findings indicated Mobile phones allow for instant communication, which is crucial in addressing challenges like diseases or weather emergencies that require immediate attention. Using the technology enable farmers to access real-time market prices, helping them decide when and where to sell their produce for the best price. Many of these apps offered digital payment solutions, which reduced the risks associated with cash transactions. This made it easier for farmers to save and invest in quality inputs like seeds and fertilizers. As indicated by one of the farmers.

"Internet access in rural areas can be limited, which sometimes makes it difficult to use these apps effectively." Farmer# 19

With government support and continuous improvements in mobile technology, according to the findings, they believed that mobile apps would play an even greater role in transforming the farming activities they do.

5.3 Infrastructure and Accessibility

Infrastructure challenges such as network coverage, electricity access, and device affordability limit the effectiveness of mobile phones in rural areas. Farmers identified network issues: as one of the biggest challenges, they face including network coverage. In many rural areas, the signal is weak or non-existent according to the farmers. Most of the farmers indicated that they do not have reliable electricity, which means we cannot charge our phones regularly."

"Smartphones and data plans can be expensive, and not all farmers can afford them." Farmer#10

The cost of data being high was also identified Farmers who have smartphones, the indicated that the expense of purchasing data bundles was also prohibitive. Some of the farmers indicated that there were initiatives being provided by the government and other non-governmental organisations (NGO's) did indicate that they will provide solar chargers to help with the electricity issue. But that has not materialized yet.

"We were promised of Community Wi-Fi hotspots and Solar Charging points, but you know your government. They say this now … count for 10 years! It will never happen!" Farmer#12

The Findings also show that farmers believed that one day the mobile phone telephony companies would offer subsidized prices and phones as well as data, though it has not materialized yet.

5.4 Sustainable Farming Practices

Mobile phones contribute significantly to sustainable farming by disseminating best practices and enabling efficient resource management. Farmers gained access to expert advice on soil health, pest control, and crop diversification from the agricultural officers and the ESOKO agronomists using the mobile phone technology. The farmers emphasized the educational value of mobile apps indicating that the technology usage provide information on crop rotation, pest management, and soil conservation techniques. This knowledge helped them maintain soil health and increase our crop yields sustainably. The Mobile phones also provided them with access to farming best practices, enabling us to adopt new techniques, improve our yields, and enhance sustainability in our farming practices.

"The Apps like FarmSense (from Sesi Technologies), LandPKS, and Farm Grow can analyse soil health and recommend the optimal amount of water and fertilizers needed. This not only helps us conserve resources but also ensures that our crops get the right nutrients at the right time." Farmer#17

In addition to sustainable practices, being able to connect directly with buyers and negotiate fair prices also increased farmer's income and allowed them to invest more in sustainable farming practices per the findings.

5.5 Socio-Cultural Adaptability

The effectiveness of mobile phones in promoting sustainability is influenced by socio-cultural factors such as language, literacy, and traditional beliefs. Farmers observed that cultural beliefs played a significant role in how they adopted the new technologies. It was also found interestingly that there were some beliefs and reliance on traditional farming methods passed down through generations. The reasons were that many of the mobile applications are in English and were barriers for farmers who are more comfortable with local languages like Twi or Ewe." Secondly, it was also rallied that farmers with low literacy levels also struggled to navigate apps or understand the information provided. Visual aids, voice messages, and simple interfaces could have helped make these tools more accessible. And usable as they expected

"How did you expect me to read these apps and understand them? Look at me and my age. I did not go to school that much. So, I struggle" Farmer#2

Thus, the above notwithstanding, there is a growing acceptance of mobile technology among younger farmers who are more tech-savvy according to farmer #4. This often helped the older farmers understand and use these applications. Also, when farmers see their peers successfully using mobile apps, they are more likely to adopt them themselves.

5.6 Social Dynamics and Inclusion

Social dynamics, including gender roles and community leadership, influence farmers' access to mobile-based agricultural information. Farmers. "In many rural communities, men were often seen as the primary decision-makers in

farming activities. This limited women's access to mobile technology. But men farmers who are supportive of technological advancements and played the leadership roles because they are the family heads can encourage their wife farmers to adopt mobile applications.

In the traditional farming settings women voices may not be as heard in community meetings. Though they are farmers too. The findings indicated that being part of either MOFA or ESOKO farming cooperative, being part of the farmers WhatsApp group chat got women to be involved in leadership roles within farming cooperatives helping to ensure that their needs and perspectives are considered.

"A lot has changed since I started farming over 15 years ago from the beginning, I was only doing it for the family. Then I have children too. So, I could not go to farms very much, the only way was to use the mobile phone to check my activities. I joined ESOKO and I learnt a lot. Now I teach some of the other farmers how to access WhatsApp messages, videos, and information from ESOKO officers. I now have 40acres of farm lands with 5 staff members. I monitor the activities using the mobile phone". Farmer#24

7. DISCUSSIONS

7.1 Mobile Phones as Catalysts for Knowledge Exchange and Agricultural Learning

Mobile phones have emerged as transformative tools in Ghana's agricultural landscape, acting as catalysts for real-time knowledge exchange and learning among smallholder farmers. Their widespread use enables access to critical agricultural information such as market prices, weather forecasts, and extension services. Farmers increasingly rely on SMS, voice calls, and WhatsApp to communicate with peers, extension officers, and buyers, fostering a dynamic ecosystem of information sharing. As Duncombe (2016) notes, mobile phones help overcome rural service delivery barriers, allowing smallholders to access both market and technical knowledge that would otherwise be inaccessible. Abdulai et al. (2023) reinforce this view, identifying mobile phones as the most commonly used digital tools among Ghanaian farmers, primarily for basic communication and advisory services. These devices function as boundary objects, a concept introduced by Star and Griesemer (1989), which refers to tools that bridge different social worlds

while maintaining a stable form (Star & Griesemer, 1989). Mobile phones exemplify this by connecting farmers, extension agents, and market actors, enabling interpretative flexibility without requiring full consensus on meanings or practices. However, the effectiveness of mobile phones as boundary objects is not without limitations. Digital literacy gaps and limited internet access—particularly among women and marginalized groups—pose significant challenges. These socio-technical inequalities hinder the universal accessibility and utility of mobile phones, challenging the assumption that digital tools inherently democratize information. To address these constraints, the study recommends several interventions: developing localized digital literacy programs in native languages, subsidizing mobile data and devices for rural farmers, and supporting farmer-led WhatsApp groups with trained moderators. These strategies aim to enhance inclusivity and ensure that mobile phones can fully realize their potential as boundary objects in agricultural knowledge exchange.

7.2 Inclusivity and Gendered Access to Digital Tools

The study highlights a critical disparity in mobile phone usage among Ghanaian farmers, particularly affecting women and older individuals. These groups predominantly rely on basic mobile phones, which lack the functionality to support advanced digital services such as agricultural apps, internet-based platforms, and multimedia communication.

The 2024 CSIR study reinforces this observation, revealing that women farmers face significant barriers due to device limitations and affordability constraints. These limitations not only hinder access to vital agricultural information but also perpetuate existing gender inequalities in rural development. Duncombe (2022) emphasizes the importance of gender-sensitive service design in digital agriculture. However, the current digital landscape often overlooks the nuanced needs of marginalized groups. Boundary Object Theory posits that objects like mobile phones can facilitate communication and collaboration across diverse social worlds. Yet, this assumption falters when access is unequal. If women farmers cannot engage with mobile phones due to economic or technical barriers, the device fails to function as a true boundary object. This undermines the

theory's foundational premise of shared usability and mutual interpretability.

To address these challenges, a multi-pronged approach is essential. Designing mobile platforms with voice-based interfaces can accommodate users with low literacy levels and basic devices. Additionally, targeted subsidies or microloans can empower women farmers to upgrade their devices and access digital services. Inclusive cooperative structures that promote training, leadership, and peer support can further enhance digital literacy and confidence. These interventions not only improve access but also foster a more equitable digital ecosystem, ensuring that mobile phones truly serve as boundary objects for all stakeholders in Ghana's agricultural sector.

7.3 Institutional Support and the Role of NGOs in Digital Adoption

The study underscores the pivotal role that NGOs and donor-funded projects play in driving mobile-based agricultural services in Ghana. These initiatives often utilize SMS and Interactive Voice Response (IVR) systems to reach farmers, especially in remote areas with limited digital infrastructure. Abdulai et al. (2023) found that most digital services in Northern Ghana are externally driven, with minimal farmer ownership or long-term sustainability. This reliance on external actors raises concerns about the durability and relevance of these interventions once donor support ends. NGO-led digital tools can function as boundary objects by translating complex institutional knowledge into formats accessible to farmers.

These tools bridge the gap between formal agricultural expertise and local farming practices. However, their top-down nature often limits co-creation and local adaptation—key elements of effective boundary work. While the tools align with Boundary Object Theory in facilitating cross-domain communication, they fall short in enabling meaningful boundary negotiation. The lack of farmer agency in shaping these tools suggests that they are imposed rather than collaboratively developed, weakening their effectiveness as boundary objects.

To enhance the impact and sustainability of digital agricultural services, several policy recommendations emerge. First, involving farmers in the co-design of digital tools ensures

that the platforms reflect local needs, languages, and cultural practices. Second, donor-funded projects should be mandated to include sustainability plans that prioritize local capacity building and long-term ownership. Third, establishing local digital innovation hubs can foster collaboration among farmers, developers, and agricultural experts. These hubs would serve as spaces for experimentation, training, and feedback, encouraging grassroots innovation and digital adoption. By shifting from externally imposed solutions to participatory models, digital tools can become more inclusive, adaptive, and sustainable—truly functioning as boundary objects that empower rather than marginalize.

7.4 Sustainability and the Temporality of Digital Engagement

A critical dimension of Boundary Object Theory is the durability and adaptability of the object across time and contexts. This introduces a temporal aspect to the theory, which is particularly relevant in assessing mobile phone-based agricultural interventions. The study reveals that farmers' engagement with digital tools often diminishes over time due to a lack of follow-up, evolving needs, and insufficient training. Duncombe (2016) and Abdulai et al. (2023) both highlight the short-lived nature of many digital initiatives in Ghana, attributing their decline to poor integration into local systems and the absence of sustained institutional support. While mobile phones initially serve as effective boundary objects—bridging institutional knowledge and local farming practices—their long-term utility is compromised when they are not embedded within enduring support structures.

The fading engagement suggests that these tools, though conceptually durable, lack the practical adaptability required for sustained boundary work. Without ongoing reinforcement, the mobile phone loses its bridging function, revealing a temporal limitation in the theory's application. This challenges the assumption that boundary objects naturally persist and evolve within dynamic social contexts. To address these challenges, several policy recommendations are proposed. First, establishing continuous training programs through the Ministry of Food and Agriculture (MOFA) and local cooperatives can ensure that farmers remain engaged and updated on digital tools. Second, incentivizing telecom providers to expand rural network coverage will

enhance accessibility and reliability. Third, implementing regular monitoring and evaluation mechanisms for digital interventions can help identify gaps, adapt services to changing needs, and ensure long-term relevance. These measures will not only strengthen the sustainability of mobile-based agricultural services but also reinforce the mobile phone's role as a durable and adaptable boundary object in Ghana's agricultural transformation.

7.5 Co-Production and Farmer-Led Innovation

The study identifies a promising shift in digital engagement among Ghanaian farmers, highlighting emerging practices of co-production and farmer-led innovation. Rather than being passive recipients of digital tools, some farmers are actively shaping how mobile phones are used to meet their agricultural needs. A notable example is the formation of WhatsApp groups for peer learning, coordination of input purchases, and sharing of market information. Farmer #24, for instance, not only manages 40 acres of farmland using mobile phones but also trains fellow farmers, demonstrating leadership and innovation in digital agriculture. These grassroots practices align closely with Boundary Object Theory.

When farmers adapt and repurpose mobile phones to facilitate joint learning and problem-solving, the device becomes a true boundary object—bridging diverse knowledge systems and enabling collaborative work. Unlike top-down interventions, these bottom-up digital practices are inherently flexible, context-sensitive, and sustainable. They reflect the farmers' autonomy and creativity, enhancing resilience and long-term engagement with digital tools.

The study offers valuable insights into how co-production can strengthen the role of mobile phones as boundary objects. It suggests that when farmers are empowered to innovate, digital tools become more meaningful and effective. This bottom-up approach contrasts with externally driven models and highlights the importance of farmer agency in digital transformation. To support and scale these innovations, several policy recommendations are proposed. First, funding should be directed toward farmer-led digital communities to enhance their capacity and reach. Second, grassroots innovations should be formally recognized and integrated into national

agricultural strategies. Third, peer-to-peer mentorship programs should be encouraged to foster knowledge exchange and leadership among farmers. These measures will not only promote inclusive digital adoption but also ensure that mobile phones continue to serve as dynamic boundary objects in Ghana's agricultural landscape.

8. CONCLUSION AND FUTURE RESEARCH DIRECTIONS

This study has explored the transformative potential of mobile phone technology in promoting agricultural sustainability in Ghana, particularly among smallholder farmers in the Kwahu district. Grounded in Boundary Object Theory, mobile phones have been shown to function as adaptable tools that bridge diverse stakeholder groups—farmers, policymakers, agronomists, and market actors—facilitating communication, coordination, and knowledge exchange. Their role as boundary objects enables interpretive flexibility, allowing different users to engage with the technology in ways that suit their specific needs while maintaining a shared reference point.

The findings reveal that mobile phones support sustainable farming practices by providing access to real-time weather forecasts, market prices, agronomic advice, and digital financial services. Despite infrastructural challenges such as poor network coverage, limited electricity, and affordability issues, mobile phones have proven indispensable in overcoming geographic and economic barriers. Socio-cultural factors, including gender roles, literacy levels, and traditional beliefs, also influence the adoption and effectiveness of mobile-based agricultural tools. Notably, the study highlights a shift toward farmer-led innovation, where farmers actively shape digital practices through peer learning and community engagement, enhancing the relevance and sustainability of mobile-based interventions.

Looking ahead, future research should explore the long-term impact of mobile phone usage on agricultural productivity, income levels, and food security among smallholder farmers. Comparative studies across different regions in Ghana and other sub-Saharan African countries could provide broader insights into contextual factors affecting digital adoption. Additionally, research into the development and effectiveness of voice-based and

vernacular-language mobile applications could help overcome literacy barriers and enhance inclusivity.

Further investigation into youth-led digital innovation and the role of farmer cooperatives in sustaining mobile-based agricultural practices would be valuable. Longitudinal studies assessing the durability of mobile phones as boundary objects over time—especially in the face of evolving technologies and shifting policy landscapes—would deepen our understanding of their transformative potential. Finally, participatory research involving farmers in the co-design of digital tools and services can ensure that future interventions are contextually relevant, inclusive, and sustainable. By addressing these areas, future research can contribute to building resilient, equitable, and digitally empowered agricultural systems across Ghana and the wider sub-Saharan region.

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