HUNGARIAN UNIVERSITY OF AGRICULTURE AND LIFE SCIENCES

A DIGITAL AGRICULTURAL INFORMATION MODEL FOR SMALLHOLDER FARMERS AND EXTENSION COMMUNICATION: THE CASE OF KETU MUNICIPALITIES, GHANA

Doctoral (PhD) Dissertation

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Gödöllő, Hungary

2023

Hungarian University of Agriculture and Life Sciences

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DECLARATION

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ACKNOWLEDGEMENT

I am much grateful to the Lord Almighty for guiding me through this life-changing academic journey.

My sincere gratitude goes to my beloved grandmother, madam Gladys Mantebea for her timely advice and support throughout my educational journey. Had it not been for your counsel and guidance, I would not know where I would have been by now. I am highly grateful.

My profound gratitude also goes to my supervisor Dr. József Kozári, major professor (retired) at the Institute of Regional Economics and Rural Development, Hungarian University of Agriculture Sciences. Your invaluable insight, advice, and counseling helped me develop this piece of work. Special thanks also go to Dr. Tóth Krisztina my co-advisor for supporting this work when I needed it most.

Also, I would like to express my warmest gratitude to Mr. Amevor Daniel, Mr. Gbetse Walter, Mr. Kudi Emmanuel, Mr. Gideon Atakpa, Mr. Kutsewu Erica, and Ms. Mercy Kpornu for their unflinching support during my data collection and interview; may God richly bless you.

My sincere gratitude also goes to the entire staff and management of the Hungarian University of Agriculture and Life Sciences. Most especially Ms. Tassy Zsuzsanna and Ms. Simáné Dolányi Edit Dr. Aniko. Thank you for the administrative and professional support.

This acknowledgment will only be complete if the mention is made of the Ghanaian government through the Scholarship secretariat and the Hungarian government through the Stipendium Scholarship program. You engineered this achievement with financial support.

I would also like to thank my colleague and friend Dr. Fawozia Adiyia for your sisterly support. My meeting with you in 2017 paved the way for my Ph.D. journey. Dr. Nicholas Imbeah, you can never be forgotten.

Finally, special gratitude goes to colleagues, classmates, housemates, intimate and non-friends, and everyone whose contribution has made this journey successful. God bless you all.

ABBREVIATIONS

FAO: *Food and Agricultural Organisation*

UN: *United Nations*

GSMA: *Global System for Mobile Communications Association*.

GSS: *Ghana Statistical Service*

AEA: *Agricultural Extension Agent*

ICT: *Information Communication Technology*

MOFA: *Ministry of Food and Agriculture*

MTN: *Mobile Telecommunication Network*

TAM: *Technology Acceptance Model*

OECD*:* *Organisation for Economic Cooperation and Development*

DDAIS: *Decentralised Digital Agricultural Information Service*

DAIP: *Digital Agricultural Information Platform*

GDP: *Gross Domestic Products*

AKIS: *Agriculture Knowledge and Information System.*

IoTs: *Internet of Things*

CD: *Compact Disk*

PU: *Perceived Usefulness*

PEoU: *Perceived Ease of Use.*

IVR: *Interactive Voice Response*

SMS: *Short Message Service*

3G: Third-generation wireless

4G: *Fourth-generation wireless*

TAP: *Token Administration Platform*

NFC: *Near Field Communication*

GPS: *Global Position System*

NGO: *Non-Governmental Organisation*

FBO: *Farmer Based Organisation*

T & V: *Training and Visit*

UES: *Universal Extension System*

DAES: *Department of Agriculture Extension Service*

DADU: *District Agriculture Development Units*

SPSS: *Statistical Package for Social Scientists*

1. INTRODUCTION

It has been widely projected that the world's population will reach an all-time high of 9.1 billion by 2050, with about 70% of the population living in urban areas (FAO, 2009). It is therefore anticipated that global food production would have to increase by about 70% (Fan & Rue, 2020; FAO, 2009); for example, major export crops like cereals would have to increase by 1 billion tonnes (FAO, 2009). Smallholder farmers will have a major role to play in meeting this food demand. Globally, smallholder farms serve as the main backbone of the world's food supply systems. More than 60% of food and fiber that are produced on smallholder farms are less than two hectares in size (FAO, 2019). It is estimated that close to 70% of the world's 608 million family farms are operated on smallholder lands (Helfand et al., 2015); although these smallholder holdings account for just 12% of the global farmland, they produce close to 80% of the food consumed in developing countries (Fan & Rue, 2020). For instance, in China, about 210 million smallholder farmers are reported to make up 98% of the country's farming population and produce about 60% of food consumed in Asia (FAO, 2013), while in Sub-Saharan Africa, about 33 million smallholder farms produce close to 70% of the food consumed on the continent (Nyong & Martin, 2019). Smallholder farmers hold the key to the sustenance of food and nutrition security in developing countries, including Ghana.

Agriculture practice on a small scale has a significant and measurable impact on the Ghanaian economy. The sector has been the country's main economic pillar since its independence in 1957 (Enu & Attah-Obeng, 2013). In 2019, agriculture contributed 20% to Ghana's total Gross Domestic Product (GDP). The agriculture industry is also a major source of employment in Ghana, with more than 40% of the population employed directly at different levels of the agriculture sector, especially in rural areas (Nyamekye et al., 2021; Osabohein et al., 2019). The total growth of the Ghanaian economy depends largely on the function of the agricultural sector, as it serves as the primary source of food security for Ghanaians. It contributes about 51% of cereals, 60% of fish, 50% of meat consumed domestically, and 30% of raw materials for industrial goods and services (FAO, 2021; Darfour & Rosentrater, 2016). However, agriculture in Ghana is largely traditional and heavily dependent on smallholder farmers.

In Ghana, smallholder farmers compose the main farming population in the urban and the rural areas; however, the majority of them constitute the rural population and produce close to 90% of the food and agricultural raw materials supply in the country (Hlophe-Ginindza, 2020; Nyanteng & Seini, 2000). They also produce important export crops like cocoa, oil palm, cashew, and shea butter. The Over-reliance of the Ghanaian economy on smallholder farmers to feed its bulging population cannot be overemphasized, yet these farmers face a plateau of challenges that hampers progress in their operations. The risks and responsibilities that smallholder farmers go through on a regular basis do not in any form match the financial, extension, technical, and technological support they get. However, digital technologies (ICTs) have been identified as one of the tools that can help farmers overcome some of the major challenges they face (GSMA, 2020).

Digital technologies have the capacity to help farmers manage and coordinate the essential factors of production in agriculture. For instance, a recent release by the Food and Agricultural Organization on digital technology in agricultural and rural areas (FAO, 2019) highlighted the increasing use of digital agricultural technology tools such as mobile advisories, drones, call centers, digital markets, blockchain technologies, the internet of things, and social media for accessing information. Furthermore, the German International Cooperation, the World Bank, African Union, and the Global System for Mobile Communication (GSM) have also emphasized the growing integration of ICTs and digital technologies in smallholder and rural farmers' daily lives in SSA, including Ghana (African Union, 2021; GSMA, 2020).

The mobile and telecommunication industries in Ghana are well positioned in the Sub-Saharan sub-region to support farmers' information access. The subscription and use of mobile phones and other Information Communication Technology (ICT) devices have increased tremendously in Ghana since the introduction of the first mobile phone in the country in 1992 (Endert, 2018). A report on the Ghanaian mobile and telecommunication industry shows a progressive development in 3G and 4G coverage; while 4G coverage was about 34.9% in 2019, 3G coverage was more than double (80%). Also, the GSM Association's Ghana mobile enable transformation report showed that more than 65%, representing 19 million Ghanaians, were connected to mobile networks in 2019 in Ghana (GSMA, 2017). Also, a recent study by the Oxford Business Group (2020) on the number of mobile phone subscriptions in Ghana reported that mobile phone subscriptions had surpassed the total population in Ghana; they documented about 41 million mobile phone subscriptions in May 2019. These new trends in the communication industry can be an engine for agricultural extension services to link researchers, advisory services, and farmers together to promote effective communication and information dissemination.

1.1 Statement of the problem

Ghana uses multiple extension approaches like Farmer Field School, some aspects of Farmer-to-Farmer, and the Agriculture Knowledge and Information System (AKIS) (MOFA, 2007). However, top-down approaches are used in extension program planning and delivery. The participatory extension approach has been completely ignored. Smallholder farmers are less or not involved in extension program planning. Extension programs are usually developed at the national level and presented to farmers. Smallholder farmers are regarded as agricultural information takers but not as partners who contribute to extension program planning and development (Botchway, 2019). As a result, some of the technologies introduced to farmers are not adopted.

Smallholder farmers in Ghana depend largely on extension services for advisory services on new technologies, government policies, and developments in the agricultural sector. However, the public extension services in Ghana are understaffed (Nyarko & Kozari, 2020; Barnett & Srivastava, 2017). The ratio of extension agents to farmers is about 1:1500, higher than the Food and Agriculture Organization's recommended ratio of 1:400 (Poku et al., 2018; Manfre & Nordehn, 2013). As a result, fewer farmers are covered by the available extension agents, leaving many unattended. Also, for a long time, Ghana has been practicing the home and farm visit extension approach, which involves physical meetings with farmers in groups or individually. Nevertheless, the recent global Coronavirus (COVID-19) pandemic has proven that these forms of extension approach to physical meetings cannot always be assured.

Also, under the pluralism extension approach, both the public and private institutions participate in the extension delivery. The private extension services serve as a support to complement the staff shortage in public extension services. However, the private extension services access comes with terms and conditions that mostly do not favour smallholder farmers. Many private extension providers operate for profits; as such, they provide extension services and farm inputs to farmers on the condition that they will purchase farmers' produce after harvesting; but the prices they offer are sometimes lower than the actual market price (Nyamekye, 2021). Others also require that farmers subscribe to their services, which come with costs that most smallholder farmers cannot afford (Botchway, 2019).

Additionally, the ever-increasing technological innovations in agriculture, such as Genetically Modified crops and animal resources, rampant diseases, and pest outbreaks such as the Fall Army Worms, coupled with the evolution of drone technologies, precision agriculture, Internet of Things (IoTs), and mobile phones are making timely information need vital in agriculture more than ever; farmers, therefore, need current information to make quick and informed decisions.

Dwelling on the developments in Ghana's digital and telecommunication systems, private ICTs and digital solutions have developed mobile applications and digital solutions to provide digital extension and other agricultural-related services to farmers in Ghana. However, smallholder farmers in the Ketu Municipalities wabble with agricultural information access. Their vulnerability became apparent during the recent COVID-19 pandemic, leading to a curfew on mobility and social gathering. During that period, extension agents could not visit farmers, which prevented many of them access to agriculture information. Agricultural outputs in the areas have also declined over time due to increased climate variabilities (Banson et al., 2020).

Although it has been established that lots of farmers have registered for digital agricultural services in Ghana (GSMA, 2020; Esoko, 2019), a past study suggests that less than 5% of farmers in the volta region, where the Ketu Municipalities are located use any form of digital agricultural technologies (Baah-Kumi & Lee, 2016). Research has not been able to identify the types of digital agricultural services available and the associated factors that prevent smallholder farmers from using them in the Ketu Municipalities. Also, a holistic study of smallholder farmers' demographics, digital technology use, perception of digital technology use, and their innovation adoption levels in the Ketu Municipalities has not yet been conducted. Moreover, research on digital agricultural technologies in Ghana generally is scanty. Past research (like (Ntiri et al., 2022; Donkoh, 2019; Etwire et al., 2017) on agricultural digitalization adoption and use in Ghana usually focuses on the Northern regions of Ghana, leaving the Southern regions. Meanwhile, the Ketu municipalities produce a mass of fresh vegetables, rice, and other important agricultural commodities for Accra (the capital) and Lome (the capital of Togo). It is of ultimate importance that the adoption and use of digital agricultural services by smallholder farmers in the Ketu Municipalities are well understood in order to scale up in the region, as they are increasingly promoted for smallholder farmers in many parts of Ghana.

The diffusion of innovation theory by Rogers emphatically states that the adoption or use of agricultural technologies in a social system, like in farming communities, occurs at different levels based on the innovation levels of the farmers in the social system. Similarly, the Technology

Adoption Theory by Davis (Davis, 1989 in Silva & Dias, 2007) indicates that the external environments of farmers greatly influence their perceptions and attitudes toward new technologies. Regardless of how transformational digitalization potential is described in the literature currently in circulation, a holistic understanding of smallholder farmers' digital environment by examining the various factors that impact their digital agricultural technologies decision in the area could help develop a robust digital agricultural service that will help increase farmers access to timely information. Therefore, the aim of the present study is in two folds: first, to identify and evaluate the factors impacting smallholder farmers' digital technologies use, and then to propose a digital agricultural information service to enhance smallholder farmers and extension communication in the Ketu Municipalities. Specifically, the study sought to:

1. Identify and evaluate the digital agricultural technologies commonly used by respondents.
2. Assess smallholder farmers' information needs in the areas.
3. Analyse smallholder farmers' demographic and socioeconomic variables and their relationship with the intention to use digital agricultural services.
4. Identify the innovation adoption categories that smallholder farmers belong to and the factors impacting their digital agricultural technology use intention.

Research questions

1. What is the status of digital agricultural services in the Ketu Municipalities currently?
2. What information do the different smallholder farmers in the Ketu Municipalities need to support their production?
3. Which demographic and socioeconomic characteristics of smallholder farmers impact their intention to use digital agricultural technologies in the area?
4. Which innovation adoption categories do smallholder farmers belong to in the Ketu Municipalities?
5. Which digital extension model will best serve the diverse smallholder farmers in the Ketu municipalities?

Significant of the study

Smallholder farmers' inadequate access to information hinders their ability to improve their productivity and compete in the already competitive market. In order to enable smallholder farmers to have equal access to information to enhance their production decision-making, it is, therefore, necessary to offer a digital agricultural service that is accustomed to their environment and deliver services in the languages they understand and speak fluently. Also, to promote effective digital technology use among smallholder farmers and improve the effectiveness and efficiency of accessing and using agricultural information, it is necessary to identify the main determiners of and barriers to their digital technology use. This will help the extension services to know the main factors constraints or support farmers' digital and new technologies adoption and use so that the appropriate training and support are offered to them.

The use of digital technologies for information access has been widely used in different sectors, including education, e-government, health, banking, and agriculture. However, the development of a decentralised model for its use in a local area has not received much attention. Even in Ghana, most of the ICT extension services are operated at the national level. Therefore, this study will provide a customized digital extension system that can easily be used to access agricultural information. Also, most of the digital extension systems in the market now are mainly designed with commercial and well-educated farmers in mind; as such, the services are widely offered in languages that smallholder farmers and the least-educated farmers cannot use. The result of this study will propose a digital extension model that will be operated in a local language that all farmers understand and communicate easily.

The findings of this study ought to be advantageous to numerous parties. Academics, designers of ICT services, policymakers, organizations of farmers, farmers, and development partners.

This research will be useful for academics, especially those conducting studies on the adoption and usage of ICT, particularly in Ghana. Also, it would be very pertinent for academic research on digital agricultural technology use statistics in Ghana. The methodology would provide designers of digital agricultural technologies with knowledge about what would encourage increased use of these ICT or digital agricultural services in that industry.

It is the duty of government policymakers to develop pertinent regulations for the ICT-based agricultural information sector. Because of this, they require relevant knowledge and empirical facts to develop effective policy frameworks. While creating their rules and offering advice to smallholder farmers, farmers' organizations might find this work helpful. This work would be beneficial to development partners interested in increasing the usage of agricultural inputs for greater production.

1.2 The organisation of the study

The whole thesis is divided into five main chapters, and each chapter is made up of several related topics. The introductory chapter began in Chapter One. It covered the main background of the study, the problem that the study sought to address; the research questions stated, the main objectives and the specific objectives of the study, the significance of the research, the scope of the study, and the general structure of the thesis.

Chapter two contained the various literature relevant to the study that was reviewed. It covered topics and subtopics such as:

- Farm information needs,
- The theories and concept
- Digital platform for extension delivery
- Factors influencing farmers digital technology use and so forth.

Chapter three followed the literature review section; it contained the methods and materials used in the study. It began with detailed background information on the study areas, covering social, economic, climatology, and demographic information. It followed with the research designs employed, the study population, the sample and sampling techniques, the research instruments, determination of reliability, content and face validity (ethical issues), tools used to analyse the data, and how data were presented.

The chapter four covered the result and discussion. The various means by which the results were presented were discussed in this session. The correlation analysis, descriptive statistics, and qualitative results are found in chapter four.

Finally, chapter five contains a discussion of new findings, a summary, conclusions, recommendations, and the bibliography.

2. LITERATURE REVIEW

This chapter sheds light on past studies conducted around the research topic. It contains the theories and conceptual frameworks adapted. The chapter assembles the varied views of researchers regarding smallholder technology adoption. These theories and views help to give the direction of the study.

2.1 Definition of key terms

This area covers the operational definition of the terminologies used in the research.

Smallholder farmers

The word smallholder farmer has no definite definition; organisations and institutions usually use characteristics of farmers who fall within a specific class to define them. These definitions vary from one geographical area to another.

The FAO (2013) defines smallholder farmers as “small-scale farmers, pastoralists, forest keepers, fishers who manage areas varying from less than one hectare to 10 hectares. Smallholders are characterized by family-focused motives such as favouring the stability of the farm household system, using mainly family labour for production, and using part of the produce for family consumption.”

Also, the World Bank defines smallholder farmers as "farmers with a low asset base and operating in less than 2 hectares of cropland" (World Bank, 2017)

Moreover, The Ministry of Food and Agriculture (MOFA) defines smallholder farmers as producers whose farms are less than 2.5 hectares and mostly use simple farm tools and implements, and mainly depend on family labour for crop and animal production (MOFA, 2016).

In this study, smallholder farmers are defined as a producer who grows crops, rear farm animals, and practice fish farming or fishing on a small scale (Avadi et al., 2022). In Ghana and many developing countries, smallholder farmers are mostly classified based on their farm size, the technologies used, the type of animals, and their market scope. Smallholder farmers generally consume significant parts of their produce (Avadi et al., 2022; MoFA, 2006).

Agricultural extension

The FAO (2010) defines agricultural extension as; "systems that facilitate the access of farmers, their organizations, and other market actors to knowledge, information, and technologies; facilitate their interaction with partners in research, education, agribusiness, and other relevant institutions; and assist them in developing their own technical, organizational and management skills and practices."

The International Food Policy Research Institute (IFPRI) explains agricultural advisory or agricultural extension as a service that contributes immensely to farm productivity increase, food security, rural livelihood enhancement, and supports agriculture to function as a pro-poor economic growth engine (IFPRI, 2020).

Agricultural extension and agricultural advisory services are used interchangeably in this study to mean the provision of technical agriculture services to farmers through facilitation and educational procedures such as training and demonstrations aimed at helping farmers gain knowledge and technical skills to improve their productivity, income, and decision-making.

Extension agent or advisor

An extension agent or advisor is a technical officer who advises or facilitates the transfer of agricultural information and technologies to farmers and research institutions; also creates the enabling environment for farmers to learn, interact, and participate in programmes and activities necessary for their farming activities.

Digital technology

Digital technologies are advanced software, hardware, or network solutions that support collecting, storing, analyzing, and sharing agriculture or market information and provide technical support for innovation and decision-making in agriculture (Ingram & Maye, 2020).

Digital technology is referred to modern communication technology devices like personal computers, tablets or iPad, mobile phones, and mobile applications that help farmers, extension agents, and other service providers in the agricultural industry to collect, analyse, and share information to promote learning and decision making. Digital technologies in this context exclude one-way ICT devices such as radio, non-smart television, and CD.

Digital platform

Digital agriculture platforms are technological innovation systems used to unify and provide agricultural services to stakeholders who operate in the agriculture system. The system brings players such as farmers, extension, research, input dealers, and other service providers together to exchange knowledge and information or perform transactions (Lopez et al., 2020). These platforms include social media, the Internet of Things, and so forth.

Digital agriculture

Digital agriculture is the application of advanced technologies in agriculture by integrating them into single or multiple systems to facilitate data generation for farm decision-making and production improvement. It employs the use of sensors, communication networks, the Internet of Things, mobile applications, and so forth (United Nations Global Compact, 2017).

Information and Communication Technology (ICT)

The phrase "information and communications technology" (ICT) refers to a broad range of communication tools and services, such as television, radio, and videoconferencing, as well as hardware and software for computers, networks, satellite systems, mobile phones, and other devices that facilitate communication among users (Huth et al., 2017).

The OECD (2017) defined ICT as a combination of different communication networks, technologies, and service industries that capture, transmit, and display data and information electronically.

We define ICTs as electronic devices that enable farmers, extension, researchers, and other stakeholders in the agriculture sector to share or receive information electronically to make informed decisions. This includes traditional media such as radio, television, compact disk, and more recent electronic devices like mobile phones, personal computers, tablets, or iPad and the like.

2.2 Theories and Models

Theories are a well-substantiated set of explanatory variables that could be used to predict a particular phenomenon (Samaradiwakara & Gunawardena, 2014). A model, on the other hand, is an abstract representation of some portion of the real world created for the purpose of understanding, explaining, predicting, or controlling a phenomenon being investigated (Fried, 2020; Burch, 2003).

Over the years, an attempt to understand consumers' intention and factors underlining their acceptance of new technologies or innovations have led researchers and social scientists to formulate a number of theories. The notable ones among them are the diffusion of innovation theory by Rogers (1995), the Technology Acceptance Model (TAM) by Davis (1989), the Theory of Planned Behaviour by Ajzen (1991), the Theory of Reasoned Action by Fishbein and Ajzen (1975), and the Unified Theory of Acceptance and Use of Technology (UTAUT) by Venkatesh et al., (2003). In this study, the Diffusion of Innovation Theory and the Technology Acceptance Model is applied.

2.2.1 Diffusion of Innovation Theory

The diffusion of innovations is a theory that describes how novel products, practices, or ideas are adopted by a member of a social system. The concept of diffusion of innovation originated from communication in the first half of the 20th century and was later popularized by Everett Rogers, an American Rural Sociologist (Simonds & Rudd, 2016). In the 1920s and 1930s, technological applications in agriculture started expanding rapidly; therefore, researchers started examining how independent farmers were adopting hybrid seeds, modern tools, and new techniques (Kinnunen, 1996; Valente & Rogers, 1995). The aim of the diffusion of innovation theory is to explain or predict how, why, and the level at which people in a specific social system adopt and accept new innovations or behavioural change processes (Scott et al., 2008).

Diffusion is a social process that occurs in a social system as a result of learning a new process or innovation, such as a new evidence-based approach for extending production (Dearing & Cox, 2018). Diffusion, in its basic form, involves a new procedure that is communicated through certain media over time among the people in a social system. The main dependent variable in the diffusion study is adoption time. Diffusion studies can be conducted among small groups like Farmer Based Organizations or larger groups like towns and cities (Swanson, 2008).

Adoption of innovations has been one of the most researched topics in rural sociology and diffusion studies. One of the commonest theories often used under adoption study is the Diffusion of Innovation Theory, developed by Everett Rogers, a rural sociologist (Rogers, 1962 p.83; Dearing & Cox, 2018). Rogers synthesized research from over 508 diffusion studies across the fields that initially influenced the theory. Using his synthesis, Rogers produced a theory of the adoption of innovation among individuals and organization (Easley & Kleinberg, 2010). According to Rogers, adoption is a decision of "full use of an innovation as the best course of action available," and rejection is the decision "not to adopt an innovation" (Rogers, 2003, p.177). He defined diffusion as the process in which an innovation is communicated through certain channels over time among members of a social system. Roger's theory aimed to elaborate on how with time, a new idea, practice, or technology gains momentum and spreads through a specific population or social system (Rogers, 2003). The theory concludes that individuals, as part of a social system, adopt new technologies, behaviour, or practice. The adoption of innovation means that individuals use or do something differently from the normal ones known to them. The surest way to adoption is that individuals should first perceive the new technology or behaviour as new or innovative. It is at this point that diffusion is possible. Diffusion goes beyond the two-step flow communication model, focusing more on the conditions that increase or decrease the probability that a new technology or practice will be adopted by members of an identified society.

Many diffusion studies involve technological innovations; therefore Rogers (2003) often used the word "technology" and "innovation" interchangeably. He defined technology as "a design for instrumental action that reduces the uncertainty in the cause-effect relationships involved in achieving a desired outcome" (Rogers, 2003, p.13). Two parts of technology were outlined: the hardware and the software. The hardware is "the tool that embodies the technology in the form of a material or physical object," while the software is "the information component of the tool" (Rogers, 2003, p.259). Rogers emphasized that the adoption of an innovation in a given social system varies with time. Adoption does not occur at the same time; instead, it happens in a time sequence where some people adopt earlier than others (Easley & Kleinberg, 2010).

2.2.2 Elements of diffusion

Innovation

According to Rogers, "An innovation is an idea, practice, or project that is perceived as new by an individual or other unit of adoption" (Rogers, 2003, p. 12). Innovation can be a technological advance that creates new or improved products, or they can be symbolic representations that change the meaning of products. Innovation may have been invented a long time ago, but if individuals perceive it as new, then it may still be an innovation for them. Agricultural extension agents are usually tasked to promote or introduce new innovations to farmers using different techniques and methods; the success of these innovations among farmers is measured by the rate of their adoption or spread within a geographical area.

Innovation is adopted differently by individuals and subsequently spread in a social group. Some innovations are quickly adopted, whiles others are adopted slowly, some are never adopted or abandoned shortly after adoption. For instance, in 1957, Ford released its Edsel car model which failed woefully to meet the expected market adoption and diffusion; although the car was the most carefully designed and the finest in the American automobile industry at that time (Drucker, 1998). Earlier research identified three main reasons why the new product failed in adoption. The model of the car did not appeal to the targeted adopters (Musolf, 2008). The shape of the car and the name

Edsel, which happens to be Ford's son's name, was seen by potential adopters as old-fashioned (Chukwuma-Nwuba, 2013). Additionally, the product suffered from inadequate market information. The Edsel was supposed to be marketed on the basis of the information received from poll, unfortunately some old-fashioned snake-oil selling method, intuitive rather than scientific, was used. Also, the car was released at a time when there was an economic recession in the United States (Schwarzkopf, 2015). Young argued that the Edsel failed adoption because of the company's intuition and the disregard of market realities at that time (Chukwuma-Nwuba, 2013).

Uncertainty is one of the core obstacles to the adoption of new technology or idea. A technology's consequences may create uncertainty. "Consequences are the changes that occur in an individual or a social system as a result of the adoption or rejection of an innovation" (Rogers, 2003, p. 436; Sahin, 2006). In order to reduce the uncertainty of adopting innovation, potential adopters should be given details about the innovation to learn about its pros and cons and the associated consequences (Heidenreich & Talke, 2020).

Communication Channel

In order for potential adopters to gather information about a new product, communication from the originators of the product play vital role in getting the potential adopters informed about the product. Rogers defined communication as "the process in which participants create and share information with one another in order to reach a mutual understanding" (Rogers, 2003, p.5). Communication starts from a source (originator) and passes through a medium to the receiver. Rogers states that "a source is an individual or an institution that originates a message. A channel is the means by which a message gets from the source to the receiver" (p. 204). Diffusion is a kind of communication that includes elements of communication such as innovation, two individuals or other units of adoption, and a communication channel. Rogers identified two main communication channels: mass media and interpersonal. The mass media consist of radio, newspapers, and television, while the interpersonal consist of two-way communication between two or more individuals. Diffusion in communication is considered a very social process that involves interpersonal communication relation (Rogers, 2003, p.19)

In the interpersonal channels, communication may have a characteristic of homophily, that is, the degree to which two or more individuals who interact are similar in certain attributes such as beliefs, education, socioeconomic status, and the like; the diffusion of innovations requires a certain degree of heterophily, which is the degree to which two or more individuals who interact are different in certain attributes.

Social system

The social system is the physical, social, or cultural environment in which individuals belong and engage in a joint problem-solving to accomplish a common goal. The social system represents a boundary within which the diffusion of innovation is examined. The degree of diffusion of innovation within the social system depends upon its special values or norms. In their study, Erumban and de Jong (2006) analysed that "the socio-cultural environment, perceived values, available institutions, and political ambiance might influence perception of the individual within a society in a certain way, and these factors may consequently impact the adoption decisions"

(Erumban & de Jong, 2006). Furthermore, a social system that is modern-oriented readily accepts innovations more than a traditionally oriented social system (Rogers & Bhowmik, 1970). Much research has found culture and norms in a social system to influence consumer behaviour and considerable variation in the adoption rate of the same innovation in different social systems (Vejlgaard, 2018; Dwyer et al., 2005). Also, a study by Yaveroglu and Donthu on the influence of culture on innovation and imitation in a cross-cultural diffusion process comparison found that in a society where individualism is high, low on uncertain avoidance and low on power distance are more likely to have a faster innovation adoption rate than a society of the opposite (Averoglu & Donthu, 2008).

Time

Time as an element in the diffusion of new ideas is very critical because time is involved in the innovation-decision process, innovativeness, and an innovation's rate of adoption. The innovation-decision process is the mental process through which an individual passes from first knowledge of an innovation to forming an attitude towards the innovation, then to a decision to (adopt) make full use of an innovation as the best course of action available or a decision not to adopt an innovation (rejection); then to implementation of the new idea; and finally to confirmation of the decision process in order to decrease uncertainty about an innovation's expected consequences (Rogers et al., 2019).

According to Rogers (2003), the time aspect in the diffusion of innovation is mostly ignored in behavioural research. Rogers explained that the addition of the time dimension in diffusion study demonstrates its key strengths. The rate of innovation adoption, the process of innovation diffusion, and categorization of adopters all involve a time dimension (Sahin, 2006).
Innovations are rarely adopted instantaneously; therefore, time duration is very important for innovation adoption. Research conducted by Ryan and Gross on hybrid corn adoption in Iowa found that farmers adoption of the introduced hybrid corn occurred for more than ten years, and most of the farmers only dedicated small portions of their lands to the new corn breed in the first year after adoption (Tolentino & Rod, 2012).

2.2.3 Adopter categories

The innovation adoption curve developed by Rogers classifies the entry of users into various categories based on their willingness to accept new technology or ideas. The curve follows a bell-shaped curve, and it is useful in segregating consumers into five different adopter categories as described below:

2.2.3.1 Innovators

The innovators are the first in the adopter category of Rogers (2003). They are the first to adopt a new idea, technology, or innovation. They are made up of a small percentage of the adopter population, almost 2.5 percent. Innovators are mostly young and have the highest social class. They are risk-takers by nature and get excited by the possibilities of new ideas. They are always eager to try new things, to the point where their venturesome almost becomes an obsession. Innovators' interest in new ideas leads them out of a local circle of peers and into social relationships more cosmopolitan than normal. They usually have substantial financial resources and the ability to understand and apply complex technical knowledge. Innovators accept the occasional setback when new ideas prove unsuccessful (Ayisi et al., 2022; Rogers, 2003).

2.2.3.2 Early Adopters

Early adopters are the second category of individuals who adopt innovation faster after innovators. They consist of about 13.5 percent of the total adopter population. They are the most influential people within any social system and often have thought leadership (opinion leadership) for other potential adopters. Early adopters' approval of a new product, idea, or technology usually leads to market saturation. They are young, well-educated, have more financial lucidity and higher social status; they have a reasonable approach to risk and are more socially forward than other adopters; also, they are more discrete in adoption choices than innovators and do not want to be the last people to know about a product (Ayisi et al., 2022).

2.2.3.3 Early Majority

The early majority is a third group that appears in the adopter category. Statistically, they represent 34 percent of the adopter population. People in this category tend to be less affluent and less tech-savvy than early adopters. They are thoughtful and care about accepting new technologies; they are often referred to as value shoppers. The early majority will adopt a new idea or product if they are certain that it will be valuable to them; they are risk-averse and always want to ensure that their scarce resources are spent wisely on valuable products. They mostly seek the opinion of the thought leaders (early adopters) when making adoption decisions on new products. They also rely on the recommendation of known people who have used the new products. Furthermore, they read reviews, articles, and brochures about the new product or technology to determine its usefulness. The early majority usually represents the first major wave of traffic for producers of the new product because 34 percent of potential adopters are in this category (Ayisi et al., 2022).

2.2.3.4 Late Majority

The late majority also represents 34% of the adoption population. Individuals in this category are older, less affluent, less educated, have less money, and a bit orthodox; they are skeptical about innovation and have below-average social status; They will only adopt an innovation after almost everyone has adopted it; they are only influenced by peer pressure. They are the group that will do thorough research about a new product and would want to see pictures or videos of people using the products before they will adopt them. Individuals in the late majority category often put their resources towards tried and tested solutions only but fail to take risks (Ayisi et al., 2022).

2.2.3.5 Laggards

Laggards are the last group in the Rogers' adopter category. They are the third highest population (16 percent) in the adoption category. They are adamant to changes, and they value traditional methods of doing things. They are reluctant to change. By the time laggards adopt the new technology, it might have already become obsolete. They are old, have the lowest social status, are poor, show little to no opinion leadership, and they only stay in touch with family and close friends.

Laggards' acceptance of a new product or technology is a sign of the product declining. They are not moved by peer pressure (Ayisi et al., 2022).

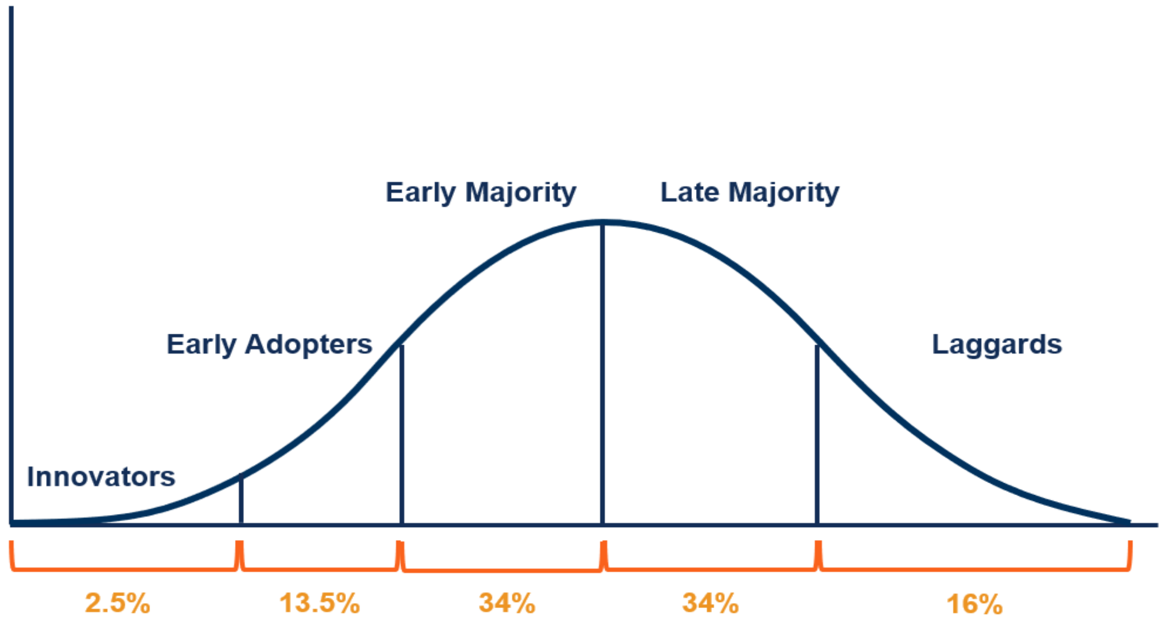

Figure 1. Adopter categorization based on innovativeness (Sources: Kaminski, 2011)

The diagram shows that only a few people in the adopter category adopt innovation early. This group made up 2.5 percent of the total population. The individuals who actually control the market success of a new idea or product are the early majority and the late majority. Individuals in this group together form 68 percent of the total population. Members in this group have varied attitudes towards accepting new products, but their final acceptance of innovation leads to its market booming. Laggards, on the other hand, are the third highest adopter category; they form 16 percent of the adopter population. They are adamant about accepting innovations, but once they adopt, they become loyal and will not easily change for a different product (Ayisi et al., 2022).

The adopter curve makes us understand that innovation adoption does not occur at the same time on the same level in a social system; therefore, the one who tries to quickly push a new product or innovation to consumers without doing a diligent assessment is likely to fail in its acceptance by the masses. Therefore, knowing the adopter categories of the potential consumers of innovation will enhance its marketing strategies.

Criticism of DOI

The diffusion of innovation theory, like many other models and theories has been criticised by researchers. Atkins (2005) are noted among many of the critics of DOI. They stated that DOI, from its incision, has a pro-innovation bias. According to some of them, DOI assumes a change to be a good thing and demonstrates this view in the value-laden classification of late adopters as laggards. They further indicated that DOI emphasises individual blame at the expense of a more nuanced understanding of the impact of social structures on the innovation adoption decision (Kelly, 2012).

New technologies or ideas are implemented to solve problems or enhance situations in society. The adoption of these technologies requires a length of time; they must first be known by the potential adopters; therefore, awareness becomes important in the technology adoption process. The rate of awareness and knowledge of innovation is more rapid than its rate of adoption. Thus, the fact that an individual gets to know technology does not mean he or she is adopting it. It must go through a lot of social, mental, and emotional scrutiny before a discussion has arrived. This process will include many institutions.

2.2.4 Application of the Diffusion of Innovation Theory in this study

Many studies have applied the diffusion of innovation theory to study innovation adoption at different levels and in different fields. For instance, Zhang et al. (2015) applied DOI in the health sector to study the factors influencing patients' acceptance and usage of consumer e-health innovations in Australia. Also, Simin and Janković (2014) tried to see the possibility of applying the DOI theory in organic farming. However, no study has so far applied it to the study of smallholder farmers' digital technology use in Ghana. Furthermore, the classification of smallholder farmers into the various adopter categories in the Ketu municipalities has not been considered by any study yet. This study will be the first to use the DOI constructs to classify smallholder farmers in the Ketu Municipalities in Ghana.

Moreover, smallholder farmers are considered to belong to different social systems in the farming communities they operate, and within these social systems, there are many factors influencing their everyday decision concerning new technologies adoption and use. Based on the factors existing in the farmers social systems, they find themselves in different adopter categories. Some adopt or use new technologies early than others. We cannot assume that all farmers belong to the same adopter group. Therefore, it is important that the various groups that they belong to are correctly identified. This gives direction on educational or communication strategies to adopt to promote new technologies to farmers with the aim of increasing their usage. This will help the extension services in the municipalities know the dominant adopter groups that smallholder farmers belong to. This will help them in their extension communication program planning to develop the appropriate educational method and resources to promote new technology adoption.

2.2.5 The Technology Acceptance Model (TAM)

Technology acceptance is about how individuals embrace and use new systems or technologies for the purposes they are designed to accomplish a goal or task (Godoe & Johansen, 2012). Potential users' acceptance of technology has been identified as the demonstrable wiliness within a user group to adopt technology or systems to perform activities intended to support (Aldhaban et al., 2016). Acceptance, in that case, can be seen as a function of user involvement in a system or technology use. Acceptance can also be used as an important determinant to evaluate the success or failure of new technology adoption in a social system. Additionally, acceptance has been conceptualised as an outcome variable in psychological process that users go through in making decisions about technology (Samaradiwakara & Gunawardena, 2014). Understanding technology acceptance is important to enable a superior design process that will improve the user experience of new technologies. Researchers have studied a range of topics on technology acceptance, from individual user characteristics to internal beliefs and their impact on usage behaviour. Theories and models have been formulated to model users' technology acceptance and explain or predict user acceptance of technology to account for rapid changes in both technologies and their environment (Samaradiwakara & Gunawardena, 2014; Oye et al., 2012).

The current study is anchored on the Technology Acceptance Model (TAM). The TAM is an information systems theory coined from the Theory of Reasoned Action, which theorises that social behaviour is motivated by an individual attitude that is designed to predict information system use (Buabeng-Andoh, 2018). Fred Davis developed TAM in 1986 in his quest to model and predict the readiness of consumers to adopt and use new technology (Davis,1989). Since then, several studies across different disciplines have adopted and modified the model.

TAM primarily studies factors at the individual level and provides a theoretically grounded conceptualisation of individuals' intention to accept and adopt new technology (Alambaigi & Ahangari, 2016). TAM is specifically tailored to model users' acceptance of information systems or technologies (Lai, 2017). It spells out causal relationships among external variables, beliefs, attitudinal constructs, and usage behaviour (Holden & Rada, 2011). TAM postulates that when new technologies are presented to potential users, several factors, notably perceived ease of use (PEoU) and perceived usefulness (PU) are the basic influential factors that inform when and how to use the new technologies (Kalayou et al., 2020; Holden & Rada, 2011). The model could be adopted to assess new technologies, by evaluating the behavioural intention to use; and existing used technologies, by assessing usage behaviour (actual use). TAM studies have demonstrated that the model, if properly applied, can explain about 50% of the variance in technology acceptance levels (Venkatesh & Davis, 2000). The key features of the model that distinguish it from other models are its emphasis on the perception of the potential users of the new technology. For instance, the originator of the innovation or the technology may see the invention as useful and ease to use; however, the potential adopters may not see the new technology the same way as the creator or originator. The technology will only be adopted when the potential adopters share the same beliefs as the originator.

TAM has become well-established as a robust, powerful, and parsimonious model for predicting potential users' acceptance of new technology (Venkatesh & Davis, 2000, p.19).
The model establishes that the assessment of perceived ease of use and perceived usefulness can predict individuals' behavioural intention to accept a new system or technology. It also emphases that behavioural intention, in turn predicts actual system use. TAM has established its relevance and applicability among different users. However, the model is not well applicable in group behaviour contexts (Sargolzaei, 2017).

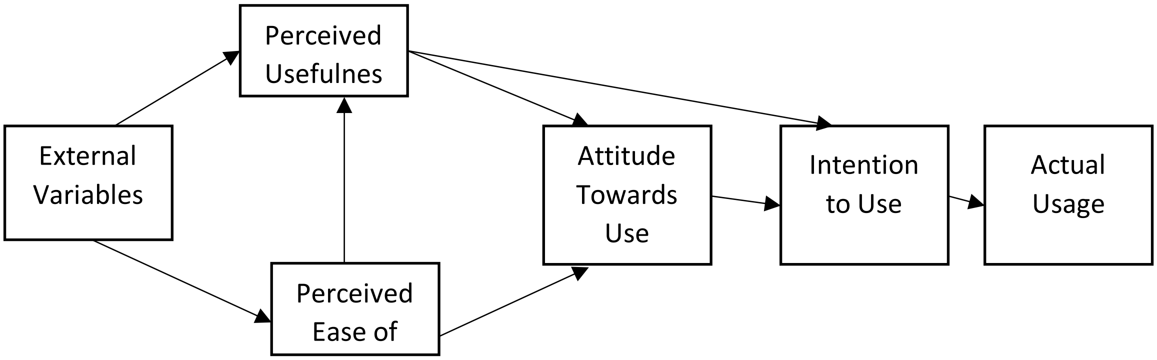

Figure 2. The original Technology Acceptance Model (Sources: Davis, 1989)

Primarily, TAM is centered on two constructs: the perceived utility and the perceived facility, which are individual beliefs affected by external variables. Both constructs, in turn, affect "attitude towards using" and behavioural intentional use," which end up affecting actual usage (Jimenez et al., 2021; Davis, 1989 in Silva & Dias, 2007). The TAM is used to represent the mutual relationship between external variables which affects the acceptance of technology by user and factors which affect actual behaviour. This model hypothesises a relationship between external variables and perceived usefulness and ease of use (Alambaigi & Ahangari, 2016). Individuals tend to use new technology with the aim of enhancing their work performance perceived use. Nevertheless, the use of the new technology may be affected if the individuals feel the effort is not worthwhile. i.e., it is too complicated to use, although useful.

The attitude intention relation in play in TAM implies that individuals form an intention to act towards the directions they have positive feelings. Additionally, the relationship between perceived usefulness and use intention is based on the premise that in a social system (farming community), individuals form intentions in relation to behaviours that they consider increasing their job performance. TAM is a behavioural model which may refer to questions related to the user and his or her perceptions concerning the technology in question. Therefore, the constructs should be developed in a way to capture personal opinions and treat assumptions with respect to third persons (Holden & Rada, 2011).

2.2.6 Application of tam to the study

Since the development of TAM, it has received several theoretical and empirical applications and validation in different fields in academia. However, its application in studying smallholder farmers' digital extension services use in Ghana has received little attention. Past studies such as (Park et al., 2022; Zarafshani et al., 2020; Alambaigi & Ahangari, 2016) have used the TAM constructs to study teleconferencing systems, mobile banking, mobile phone acceptances, and e-learning in vocational education, financial institutions, and cooperate industry. These studies did not cover smallholder farmers technology use.

Perceived ease of use was defined by Davis (1989 in Silva & Dias, 2007) as a subjective perception that believes using a particular technology will be free of mental and physical efforts. Davies's definition implies that before someone uses a technology, they have already formed a mental opinion on it and hope it meets that expectation. Studies that attempted to examine the influence of PEoU on adoption innovation in the agricultural sector mainly focused on certain aspects of agriculture, such as soil, organic farming, agrochemicals, and other farm inputs adoption (as in Bosompem, 2019; Kalayou et al., 2020; Holden & Rada, 2011). The study of smallholder farmers perceived ease of use of digital agricultural extension services in have not yet been carried out in Ghana, especially the Ketu Municipalities.

Also, perceived usefulness (PU) is the subjective perception of an individual that using a particular innovation or technology will improve their work performance (Davis, 1989, p.320). farmers regard PU as one of the important variables in new technologies adoption, owing to the fact that smallholder farmers resources are scares; therefore, they would like to invest in technologies that will give them higher returns on their investment. In this regard, external variables such as age, education, income, household size, land size, access to digital devices, and other social amenities play important roles in determining the usefulness of technologies to smallholder farmers. Many studies have explored how different external variables influenced PU, PEoU, and its subsequent impact on behaviour intention. Nevertheless, the direct effect of these variables, such as demographic, socioeconomic, access to services, and devices, have not been considered, especially in the context of smallholder famers in Ghana. The current study, therefore, argues that the final decision of farmers to adopt or use digital agricultural extension technology will greatly be impacted by the above-mentioned external factors, together with their perceived ease of use and perceived usefulness. The study, therefore, adopts the theoretical framework of TAM by examining the main factors that influence smallholder farmers intention to use DAIS in the Ketu Municipalities in Ghana. We believe that finding these factors will help to identify and propose a model that the smallholder farmers in the study areas can use.

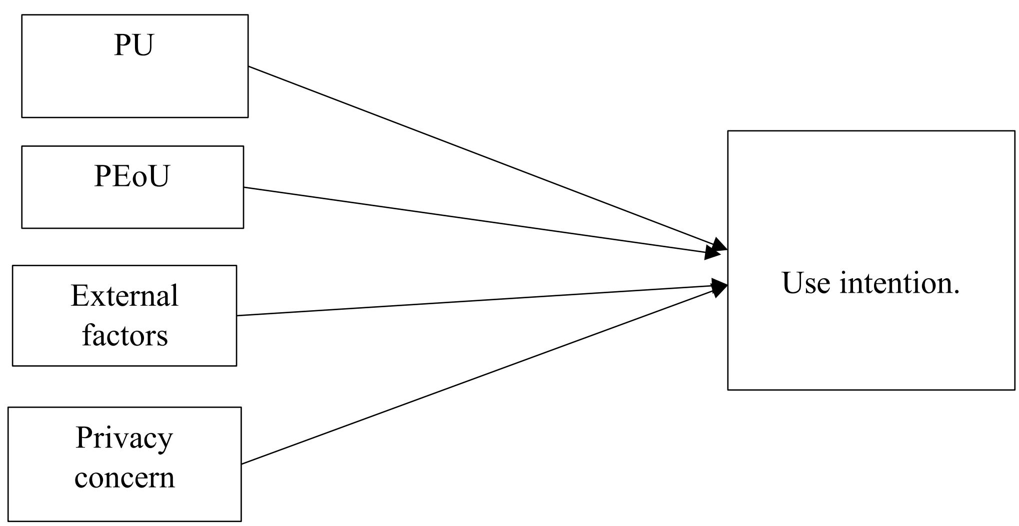

Figure 3. Conceptual framework
(Modified based on the TAM original framework by Davis, 1989**).**

2.3 Importance of digital technologies

The advent of modern technologies has influenced many lives and economic activities around the world. Modern technologies have altered the way business and household activities were carried out in our societies decades ago. It has ushered in an era of marvels where workers can complement technology (labour-augmenting technology) to increase work efficiency and labour productivity. The agriculture sector, as a branch of the global economy, has experienced a conspicuous digital revolution over some years now. The sector has seen a great deal of agtech that has contributed immensely to innovations in production systems, work efficiency, and increased productivity. Wolfert et al. (2017) observed that technological advancement in agriculture had paved the way for digital platforms, such as e-commerce platforms, agro-advisory apps, big data, satellite systems, computational power, and remote sensing to facilitate agriculture information sharing among producers. The technophilic in agriculture continues to introduce more tools and devices that enhance agricultural information sharing and access. Modern Information and Communication Tools (ICT) such as mobile phones, computers, software applications, and social media, among other things, provide the enabling environment for agricultural producers to interact with other players within the industry. Daum (2020) observed that in recent years, ICTs had become one of the main driving tools used by farmers to manage the essential factors of production (land, labour, capital, and soil) in agriculture (Nyarko & Kozári, 2021).

Also, ICT applications have the potential to identify and find a solution to some of the numerous problems faced in the field of agriculture, which includes prolonged droughts, pest and disease outbreaks, seasonality, and spatial dispersion of farming; high transaction costs and information asymmetry (Anh et al., 2019). ICT application along the agricultural value chain (from farm to fork) could offer opportunities for actors within the chain to obtain accurate, timely, and relevant information, which will not only contribute to profitability but also enhance food security, sustainable and remunerative agriculture (Purnomo & Lee, 2010). ICT also has the potential to resolve the challenges faced by governments, farmers, and other land users in the valuation, registration, and taxation of land (Nyarko & Kozári, 2021).

ICTs have the ability to intensify the linkage between extension, research, and farmers. ICT can be a medium through which information on new research findings can be communicated to extension workers by the research institutions for onward communication to farmers. Also, farmers can use the same ICT platform to communicate feedback on the new technologies from their field experiences to the extension workers for a relay to the research institutions for appropriate action. Furthermore, ICT has the means of creating a platform (WhatsApp or Facebook group) that will have farmers, extension workers, and researchers on board to share valuable information for a rapid response, which will help break the weak linkage between these three parties. Annor-Frempong et al. (2006) argued that ICTs are among the modern tools that facilitate rapid information delivery and knowledge sharing among farmers, extension agents, and other stakeholders such as research institutions (Nyarko & Kozári, 2021; Purnomo & Lee, 2010).

Promoting innovation among farmers needs technical skills and experience from the extension agents. Farmers' adoption of an ICT programme may require the extension officers' ability to combine their practical experience with ICT knowledge acquired to demonstrate how effectively the new technology works. Annor-Frempong et al. (2006) noted that ICTs could provide access to up-to-date information on agricultural literature and facilitate information exchange among major actors in the agricultural value chain. It also creates the needed platform to train extension officers on new approaches in extension delivery. Higher knowledge in ICT could ease the workload of extension officers and possibly enhance quality delivery. Tata and McNamara (2018) observed that extension officers who used ICT in Catholic Relief Services SMART Skills and Farm book (CSSF) project worked with more farmers than those who did not use ICT. They further stated that the use of CSSF enhanced the competency of the extension officers, making them more comfortable using the internet and helping more farmers access the internet than control group extension officers. Galanouli et al. (2004) found that training in ICT leads to improved computer skills and work efficiency. ICT training for teaching instructors in the United Kingdom was found to help improve their confidence in using ICT devices for instruction (Tata & McNamara, 2018). There are different ways by which ICT training can be organized for extension officers and farmers. In essence, they can be done through formal college teaching methods or informal procedures such as training workshops. Wu and Wang (2005) proposed that ICT knowledge can also be achieved through on-the-job training to increase extension officers' ability to use technology in their work with farmers. Annor-Frempong et al. (2006) observed that very few (23.7%) of the extension officers in Ghana had had professional training on ICTs; the majority (40.2%) were noted to have received self-informal ICTs training through the possession of ICTs devices at home (Nyarko & Kozári, 2021). Digital technologies help to improve rural and smallholder farmers livelihood by providing the appropriate platforms to access timely information, increase choice, reduce transaction costs, broaden their knowledge of production activities, and link them to input producers and produce buyers (Awuor et al., 2016).

2.3.1 Improved productivity

Productivity in the agricultural sector has seen tremendous growth since the introduction of mechanized technologies at the beginning of 1940. Mechanized agricultural technologies such as the use of irrigation schemes, farm implements like tractors, slashers, disc ploughs, planters, hallower, among others, and the introduction of agro-inputs like fertilizers and pesticides changed the production processes in agriculture. Through technological application, plant genes were modified, giving birth to traits like disease resistance, early maturity, and drought tolerance, resulting in the Green Revolution in the early 1950s (Patel, 2013; Tian, 2021). Mechanised agriculture technologies, which have now metamorphosed into Information Technologies and digital technologies (Emmanuel et al., 2020), play a key role in providing information on current trends in agriculture to farmers. They facilitate in providing information such as changing weather patterns, new systems of farming, the emergence of new crops and animal breeds, existing processing plants, market information, agricultural clientele services, and available agricultural credits, regardless of their agroecological location (Nwabueze & Ozioko, 2011). Also, digital technologies have bridged the knowledge gap by making it possible for farmers in developing countries to see what their colleague farmers in Developed countries or other sides of the globe are doing. They learn and share their experience with them, contributing to improved labour skills and increased productivity (Ali, 2013).

Digital technologies such as artificial intelligence, analytics, and connected sensor in the past years contributed immensely to yield improvement. They still have the potential to monitor farm activities to ensure the efficient use of irrigation, agrochemicals, tools, and labour for sustainable production across crops and animal husbandry (Goedde et al., 2020). The correct application of digital technologies in agriculture will cause the sector to increase in yield output which can add in excess of about 500 billion US dollars to the world's GDP (Musa et al., 2022). Emerging technologies contribute to effective decision-making, allowing better risk and variability management to enhance farm output and farmers income. As a digital tool, the Internet of Things (IoT) has bridged the information access gap by providing platforms for smallholder and commercial farmers to access crops and livestock data using simple and less expensive devices (Maraveas et al., 2021; Goedde et al., 2020).

Smart technologies such as blood sensors applied in animal production help detect early illness, pests and diseases, nutritional deficiency, and abnormal growth. This enables early treatment to maintain a healthy herd and meat quality. Additionally, environmental sensors collect ventilation data in animal pens and process and adjust the temperature when necessary to maintain a good environment for animal growth. Better environmental conditions increase productivity and milk quality in animals. Technologies also provide more opportunities for farmers to survey crops and animals on a larger land area within the shortest possible time with the help of drones. Drones, through their sensors, could identify specific nutrients deficiency and the appropriate fertilizer or pesticide provided. This reduces waste and ensures maximum crop growth (Maraveas et al., 2021; Goedde et al., 2020; Nakshmi et al., 2020).

2.3.2 Good postharvest practices and Value addition of farm produce

Postharvest losses are major problems in many developing countries. Quite large quantities of agricultural produce go waste few days after harvesting due to improper handling during and after harvesting. Others also go waste due to poor processing and storage (Anbumozh et al., 2021). However, modern digital cooling chambers offer opportunity for smallholder farmers in Nigeria, Kenya, and Tanzania to reduce postharvest loss by preserving fresh tomatoes in their homes (Islam, 2020). ICT creates the opportunity for agricultural producers, marketers, and distributors to monitor and control quality procedures of food and agricultural products during processing and value addition (Nakshmi et al., 2020). Digital farming help cut down postharvest losses through the digitalisation of foods and agricultural produce supply value chain (Nasirahmadi & Hensel, 2022). Technological innovations involving digital sequence information play critical role in enhancing efficiency in plant aggregation, crops and food quality assurance, transportation, and marketing (Anbumozh et al., 2021).

2.3.3 Improved decision-making by the farmer

Farm records serve as the main source of information for management decision-making on-farm activities. Record keeping provides histories of farm input purchased, orders and payments made, and information on creditors and debtors. With the increasing application of digital technologies in agriculture, farm record access has become easy and available. Digital technologies enhance record-keeping in farming operations, which reinforces farmers' decision-making. For instance, the use of applications and Farm Management Systems (FMS) enhances record-keeping and information sharing. Mobile apps enable farmers to share farm information with coworkers or management with just a click of a button. This help to make a timely decision, achieve the task on time, and also improve the planning and coordination of farm activities. Records kept on the internet are available and accessible anytime as far as there is available internet access. This means historical information can be referred to anytime to take technical decisions and receive updates from subordinates. Livestock data, market information, and crop production data can easily be generated through the use of ICT devices than the manual process.

ICT, a branch of digital technology, enables policymakers to access timely information, study and gain better understanding of what happens in the agricultural environment and formulate the necessary policies and programmes to support farmers and rural area development. ICT can also be a medium to address socioeconomic challenges in most rural areas. For instance, issues concerning gender inequalities can be addressed through regular briefings on gender inclusiveness programmes (Nakshmi et al., 2020).

Digital technologies contribute to real-time and actionable information dissemination to those in charge of rural community development to take precautional measures against the possible occurrence of disaster in farming communities, and in the event of a disaster, they increase the efficiency of the responding activities. The abundance and fast spreading of digital technologies have caused an exponential surge in data availability and accessibility. More and more data are collected from farmers, farms, rural areas, and others. These data contribute to an effective policy decisions, accurate forecasting, and prediction in agriculture.

2.3.4 Improved efficiency and service delivery at the farm

Digital technology advancement continues to enhance farm productivity and labour usage. Through automated farm machines, farming activities like irrigation, pesticide spraying, fertilizer application, and feeding of farm animals can be scheduled and carried out at different time intervals without human labour; thus, bringing efficiency to farming operations. Also, digital technology applications such as remote sensing and Global Positioning system help to locate farms, crops, animals, and markets easily. The proper allocation of farms and knowledge of farm size enhances the effective use of seeds, irrigation, and pesticides, among others. Furthermore, GPS creates the opportunity for agricultural engineers to appropriately demarcate different areas into different agroecological zones (Krishna et al., 2017; Ali, 2013). Also, farmers have adopted ear-tag technology created by Smartbow (part of Zoetis) to monitor cattle's location, health, and heat (Islam, 2020). Additionally, livestock professionals use technology from Allflex for intensive electronic tracing of disease outbreaks (Birner et al., 2021).

Digital technologies are not only benefiting smallholder farmers, but also larger farming enterprises as well. Through the use of cloud computing and the internet of things, commercial farmers are able to manage their farms from remote locations. Sensors, drone technologies, and CCTV cameras are able to capture and record activities on the field and send reports to the enterprise manager. Based on the data received, management and technical decisions are made to improve or regulate farming activities. The internet of things contributes to several gains in agricultural production. It uses in-situ sensors to trace the sources of agricultural products and their effects on the environment and the supply chain in general. It also offers real-time monitoring of soil, animal health, crop conditions, and pest activities on the field.

2.3.5 Weather forecasting and climate-smart farming

The role of weather and climate in agriculture production cannot be underestimated. Through the use of digital technology devices, agricultural producers are able to access regular weather information, which enables them to plan their agronomic activities ahead of time. Farmers are able to determine the quantity of water required for irrigation and when to irrigate a particular field (Ireri, 2020). ICT-enabled weather information technologies such as the Accweather, Rainsat, and Ghana weather applications enable smallholder farmers to access weather information services through smartphones in almost every part of Ghana (Sarku et al., 2021). Tools like weather satellites use digital technologies to monitor agro-climatic information. It is able to determine wind direction, barometric pressure, wind speed, air pressure, relative humidity, precipitation, and soil moisture content (Marolla, 2018). All this information helps to make important decisions concerning when to clear their fields, transplant seedlings, and apply pesticides and fertilizers, thus planning their production to minimize risks (Demestichas & Daskalakis, 2020). It also enables agricultural professionals such as extension advisors, researchers, and policymakers to get the necessary information in other to offer technical support services to farmers (Sarku et al., 2020). ICTs are integral to national infrastructure; they contribute immensely to public and private agricultural enterprises. They enable agricultural enterprises in distant locations to connect with other business enterprises to transact business. They serve as a medium to link producers, suppliers, and consumers together (Nwabueze & Ozioko, 2011; Chisita, 2010).

Sarku and others (2021), in their analysis of digital platforms in climate information service delivery, found that digital technologies have created the opportunity for multiple weather information service in Ghana, which varies in coverage, timing, and information content. They further found that ICTs are creating platforms for state institutions and private and international organizations to collaborate and provide timely weather information services to farmers employing combinations of services like mobile telephony, Short Message Service (SMS), call centres, and Interactive Voice Response (IVR).

2.4 Barriers to digital agricultural adoption

The importance and use of ICTs in agriculture have recently been widespread among farmers. ICT programme planning, implementation, adoption, and usage in agriculture depend on many facets such as infrastructure, government policy, sociocultural environment, economic, and human resources (Purnomo & Lee, 2010); these key factors, among others, could impact positively or negatively on the adoption and use of digital technologies among farmers.

Past research on digital technologies application in agriculture has identified many factors influencing smallholder farmers' ICTs adoption. For instance, a study by Musa et al. (2013) found that inadequate skills in digital technology and lack of electricity facilities were the key factors that affected farmers' and extension agents' agricultural information dissemination and access. Barriers limiting smallholder farmers' digital technology adoption and use usually relate to farmer education level, gender, age, and sometimes income (Meso et al., 2005). Also, Ogutu et al. (2014) observed a noticeable difference between DrumNet patrons and non-patrons; however, no significant difference was observed in gender.

The unavailability of digital technology infrastructure in rural areas poses a great challenge to farmers' agricultural information access digitally (Munyua, 2007). Also, a study of digital information access among smallholder farmers in Gezira State in Sudan identified low education attainment, low income, socio-culture, and unavailability of customised local contents of digital information as the main challenges impacting farmers digital technologies adoption in the area (Purnomo & Lee, 2010). Also, using a multinomial logistic regression analysis, Nmadu et al. (2013) empirically studied the application of ICT in acquiring market information among smallholder farmers in Nigeria, the study identified illiteracy, language, and poverty as the main constraints to smallholder farmers' digital technology use. Similarly, a study of farmers in East Africa's digital technologies adoption found a lack of infrastructure, low literacy, and unavailable information services to be the key barriers to farmers information access in Kenya (Odini, 2014; Purnomo & Lee, 2010). Furthermore, Samii (2008) argued that the unavailability of digital technology infrastructure and lack of access to appropriate agricultural information content by smallholder farmers prevent them from establishing contacts with key players such as processors, traders, and consumers in the agricultural value chain. The differences in geographical areas sometimes influence the kind of constraints farmers face regarding digital technology access. For instance, while studies in developing countries mostly identified factors such as poverty, education, and unavailability of digital technology facilities as the most prevalent barriers to farmers digital technologies adoption, studies in developed countries found time constraints, satisfaction with farmers' current practice and cost as the main barriers to adopting new technologies (Paudel et al., 2011). Meanwhile, Munyua (2007) explained that the major problems with digital technology adoption in developing countries are infrastructure, network connection, government sector policy, human resources, and training. Ali and Magalhaes (2008) however classified the barriers to adopting digital technologies into organisational and technical factors. Perceived difficulty of using, infrastructure, and technical support were the most cited technical barriers, while cost, language barriers, and lack of localised content were prevalent organisational barriers. Studies such as (Nyarko & Kozári, 2021; Purnomo & Lee, 2010) have identified demographic characteristics such as age, education, gender, marital status, ethnicity, experience, and informal training as the most dominant factors influencing smallholder farmers digital technology adoption. Moreover, Braimok (2017) adopted a qualitative research method to examine the opportunities and challenges of ICTs for women farmers in Kenya; and found that high cost, time, and usefulness of ICTs to immediate needs were the key barriers to women dairy farmers ICT adoption. Using factor analysis to evaluate the responses of 120 farmers surveyed in Ebonyi State, Williams and Agbo (2013) identified infrastructure, technical, institutional, financial constraints, and language barriers as the main hindrance to farmers digital technologies adoption. The authors concluded that overcoming these barriers will increase digital technology adoption among farmers in the area. Furthermore, a recent analysis of how farmers use mobile phones to access market information in Kenya found that, among other factors, mobile phone design, limited amount of phone credits, illiteracy, electricity availability, and the perception that mobile phones are meant for only voice call rather than SMS communication were the dominant factors barred farmers from using mobile phones to access market and agricultural information effectively (Wyche & Steinfield, 2016). Similarly, in a linear statistical survey, Tadesse and Bahigwa (2015) observed that although most farmers in their study participated in information searching, only few of them used digital technologies. They attributed it to the lack of relevant content.

Past studies identify varieties of barriers to farmers digital technology adoption and usage. Many of these barriers are beyond the control of the farmers. Considering the smaller nature of the smallholder farmers holdings, coupled with their lower income realised from production, it is very difficult for many of them, especially those in developing countries, to purchase or subscribe to digital technology services. This consequently limits their access and application of many of the new digital tools in their production and economic sustainability areas. This implies that smallholder farmers need to be considered during policy implementation to overcome the digital divide and ensure equal application of digital technologies in agriculture. Government and agriculture sector policies must support smallholder farmers digital technology intervention programmes.

2.5 Traditional Media and Modern media

The communication and information-sharing landscape in our society has transformed for about a decade now. Societies have moved from the era of being information recipients to sharing and interacting with information. Until recently, traditional media served as the main channels for disseminating agricultural innovations and best practices to farmers across the globe. However, the transitional advancement in digital technologies and the increasing number of modern ICT devices have changed how information is transferred, accessed, and disseminated within the agricultural sector (Nyarko & Kozari). New media is increasingly becoming the most preferred media for sharing and receiving information among firms, farmers, and agricultural enterprises (Auwal, 2015).

New Media

New media, also called digital media are the forms of media native to computers and broadly use computer technologies for the operation and redistribution of information (Lee, 2019). New media is digital and internet media. They include information delivered through digital devices such as augmented reality, virtual reality, DVDs, Video games, and CD-ROMS (Elcomblus, 2020).

Computers

Computer as an ICT device not only performs arithmetic operations but also serves as a powerful source of data processing, analysing, and storage (Mwakaje, 2010). A computer can accept and process large amounts of data within a split of second. As powerful as they are, they are affordable and readily available to almost everyone.

Computers are modern electronic devices found in almost every field in the world, even where one may not expect them. They have become important devices in human life due to their accuracy, fast, and efficiency in accomplishing tasks. Many computers have an all-in-one design that provides a built-in keyboard and pointing device; they also come with an in-built rechargeable battery component that enables their batteries to be recharged and operate for many hours without needing external power sources or when there are power interruptions (Sarku et al., 2020). Computers, especially laptops, are easy to carry and require small space. This makes them so convenient to use for everyone. Computers obtain signals from their storage and input devices before transforming them into visible output.

Information created on a computer is easily backed up, accessible, and shared whenever necessary, so even if a farmer loses information, he or she can easily retrieve it. Farmers who are computer literate can work remotely using a computer when they are far away from their farm. They can send and receive updates on activities taking place on the farm. They can also use it to shop online for farm inputs and other equipment.

Computers also provide a medium for farmers to connect to the Internet and other online databases to find information relevant to their field of operation. Important information can be copied, downloaded, or saved and printed to have a hard copy version. A computer can process thousands of data in sounds, enhancing reliability and accuracy while maintaining a minimum cost ratio. Farmers and researchers gain similar advantages by using computers. Consequently, research and technical information get to farmers with greater speed and accuracy than used to (Auwal, 2015). Computers are useful for word processing, data storage, the Internet, and digital communications. They are valued pieces of technological devices that have worked their way into many offices, firms, homes, and farms worldwide.

Smartphones and tablets

Smartphones offer users multiple mode flexibility. They contain cameras, FM radio, wifi, GSM, MP3 players, and Bluetooth features, which enable them to perform multiple functions, such as VoIP calls through Session Initiation Protocol and normal phone calls through analog signals (World Bank. 2017). Smartphones are lower-end phones with embedded applications that enable users to access multiple media formats and provide basic voice and SMS functionalities, covering other functionalities of ICT devices that are stand-alone appliances (Anuga et al., 2019).

Smartphones and tablets can keep farmers connected to the Internet through the 3G and 4G network feature embedded in them; so that they can access a wide range of agricultural information on internet websites and other media platforms. They also have micro-USB and Bluetooth capacity. They also support high-definition video calls, which makes it possible for farmers and technical officers to hold a virtual meeting and discuss issues affecting their work, through the video call, agricultural extension agents can explain a concept to farmers while they watch the action live. Virtual video calls bring knowledge to farmers doorsteps with just a little or no cost at all. Furthermore, smartphones and tablets allow farmers and businesses to access electronic mail. In this case, smartphones function as normal computers. Farmers can communicate with fellow farmers or technical officers through email on their smartphones; all that is required is mobile internet data or wifi connection. The information sent through email remains a record that can be retrieved anytime. Emails create instant and easily accessible records. Farmers having quick access to email records will not only enhance their work performance but also give them more time to focus on other important things. Smartphones utilise an operating system that enables the installation of a third-party application. These apps, such as Facebook, LinkedIn, Whatsapp, and others, enable farmers to reach out to both local and international markets.

Internet of Things

Since the discovery of the Internet in the 1990s, communication and information sharing have never been the same. The Internet has proven to be one of the most valuable resources in the information and communication industry.

Email

Electronic mail offers practical opportunities for agricultural advisors, agricultural input dealers, and enterprises to communicate directly with farmers by sending messages directly into their inboxes. Farmers who have the means of accessing the Internet can easily read the messages or see the advert for new farm inputs, implements, or innovations.

Social media

The number of individuals subscribing to social media is increasing at an alarming rate every single day, making them one of the best tools for communicating with different classes of professional groups. Social media offer means for technical officers, researchers, and firms to communicate directly with their clients and followers. A farmer can post a question or share a challenge faced in his or her area of operation, and a quick response can be received from any of the experts available on the page to salvage the situation. Also, organic content, which includes infographics, videos, audio, and writing posts on social media, can reach millions of audiences within a few hours.

Traditional Media

Traditional Media comprise orthodox information and communication technologies that have been part of our culture for over a century (Lee, 2019). They include radio, television, magazines, newspapers, pamphlets, and billboards. These media existed before the advent of the internet and other online technologies. Firms, advisory services, and agro-enterprises have used these media to reach farmers, clients, and others to inform and motivate them to adopt or purchase new products and services (Indeed, 2021; Lee,2019). Traditional media are mass media collectively due to their ability to simultaneously disseminate information to large audiences (Elcomblus, 2020).

Radio

Over the years, radio has served as one of the most useful and widely used ICT resources for transferring information to rural farmers. It is one of the oldest conventional digital ways of information sharing and remains relevant in delivering agricultural information to a wide range of rural farmers (Sarku et al., 2020).

Radios come in different forms, big, medium, and small. Some use batteries, while others use both battery and electrical power. The information delivered on the radio reaches so many farmers within a short period of time. Very important information can be communicated to a group of farmers more quickly on radios than through a newspaper.

Radio is one of the best media for creating awareness of innovation in agriculture among many farmers in a farming community (Anuga et al., 2019).

In rural areas where access to electricity is a problem, farmers use batteries as their main energy source to power their radios; these batteries are usually expensive, and many smallholder farmers cannot afford them. Additionally, programmes aired on radio are time-bound programme broadcasted at a specified time period, and if farmers are not available at that time, they would not have the opportunity of hearing the programme again. Also, farmers do not have the chance to reverse the radio to play back what was not heard clearly. Radio is not ideal for disseminating long or very technical information, as many farmers may not be able to grasp the message well. In many farming communities' farmers listen to radios while performing another activity; in this case, their attention is divided some of the important information may not be understood. Also, radio serves as a one-way communication medium. After the broadcast, farmers do not have the opportunity to give their opinion or ask questions or seek clarifications. In this way, the radio serves as an information-giving medium, not an interactive one.

Television

Tv combines vision and sounds together for viewers to get a better understanding of the topic under discussion. It also serves as an instant medium to send information directly to a large number of farmers. Television is, however, not available to every farmer. Demonstrating agricultural programmes on television increased access among viewers (Odinga, 2018). Very few farmers in rural areas can afford or have access to television. Although television can transmit information to a larger number of farmers, the number is sometimes limited to about twenty to thirty audience due to the smaller nature of the screen. Television easily holds the audience attention as the activities can be viewed directly. It also offers opportunities for the agricultural extension agents to explain further to the understanding of farmers because not everything can be well explained in plain words without the farmer seeing it done. For instance, the colour and shape of insect pests cannot be explained to farmers without them viewing them in plain words. Television is limited to its sources of obtaining signals, such as cable connection, HDMI connectors, and others.

Print media.

Print media, as a communication tool in agricultural extension help, deliver agricultural innovations to many farmers. Hardcover books, paperbacks, periodicals, newspapers, magazines, pamphlets or brochures, and graphics or visual publications (such as photo stories and comics) are all different types of print media that are used to communicate to the public (Pour, 2011). Frequent printing and distribution of print media material to farmers help keep them updated on the current trends and innovations in farming. Agriculture experts use photographs and audio-visuals for summarizing, explaining, and reinforcing verbal communication during meetings with farmers (Odinga, 2018).

Print media consist of published resources like books, billboards, pamphlets, Newspapers, and leaflets, while electronic media include television, mobile phone, computer, and the rest (Apata, 2010).

Print media play a key role in communicating agricultural information to literate farmers. The increasing rate of literacy among farmers in recent years gives good opportunities to use print media for mass communication. They widen the scope of agricultural information dissemination, and they are less expensive, farmers can afford and read them at their own convenience, and print media messages are permanently printed, which can serve as a reference document or record (Adejo, 2015; Hassan et al., 2010). Print media serve the purpose of adding to the quality of the extension messages by reaching out to a large number of farmers. They are produced for widespread distribution to create awareness of new agricultural innovations (Odinga, 2018). They also enhance extension message delivery, especially when pictures are incorporated into texts. Extension agents use them as reference materials during farmers meetings to explain ideas or concepts clearly. Using photographs, models, and flip charts helps agents demonstrate what the result is likely if a farmer adopts the technology.

Despite the benefits of print media, they are limited to only farmers who can read; some of the information they provide may be outdated, not all farmers may be able to understand the content due to language difficulties, and writing style may also impair their reading or appeal to farmers, and some can be too expensive to farmers (Adejo, 2015).

2.6 Difference between traditional media and new media

Accessibility

In traditional media, information is usually limited to a particular region or locality. People outside such locality or community cannot access the information. The information delivered is not transferrable. It is only the people available at that time can benefit from the information. However, in new media they are ubiquitous. Information shared on new media are available to a wider range of people at local, regional, and international level. New media also promote virality (Lee, 2019). Messages sent online can easily be shared among colleagues, and they, in turn, share with others; this makes the information reach many audiences within the shortest possible time.

Communication

Traditional media offer one-way communication platforms. Farmers only receive information but cannot ask questions or ask for clarification. In case a farmer did not understand what was broadcasted, there would not be an opportunity for him to hear it again. Repeated broadcasting is not always the same as the earlier one. The information may be altered. New media however offer a platform for two-way communication: farmers can post their questions, extension agents can offer a quick response to their query, and if the farmer needs clarification, he or she can ask and get a response and vice versa. Similarly, a question can be posted on social media, and it will remain there for many days, and anytime an expert sees it, he or she can post a response that can be viewed by all farmers having similar issues (Elcomblus, 2020).

Mobility

Traditional media are less mobile, and usage is somewhat limited. For instance, a farmer cannot carry a television with him or her when going to a farm or market; even a radio that looks a bit mobile is limited in certain situations. Farmers can carry the radio to the farm but cannot send it to the market. Many of them also need extra space to carry them. Mobility and usage are very high among farmers in new media ICT tool like mobile phone is always with-it users; farmers carry mobile phones with them going to the farm, meeting, and markets. They spend much more time interacting with colleagues on it than on any other devices, which is handy too.

Cost

Traditional media require less or no data at all. Access to radio and television programmes are usually free once the farmer has access to power. However, it is very expensive to market a product on such media channels. However, new media are highly data-driven. Much information that are accessible on new media, such as social media, requires internet data; without the data, the information is not available. Although some offer offline information, the majority of information is online-based (Elcomblus, 2020). Internet data is expensive; therefore, farmers who do not have money are less likely to access them. Although accessibility to new media looks quite expensive from the farmers point of view, they also offer a less expensive way farmers for farmers to market their products and services. Posting a product on many social media is free, for example, Facebook, WhatsApp, Twitter, Instagram, and the likes.

Adaptability

The content of traditional media cannot be customized. Information aired on radio, or television is available to everyone who tunes in at that time. Even audiences that the information is not meant for can have access. Basically, traditional media is unable to screen its audiences (Pour, 2011). In the case of new media, the content can be customised to meet specific demographics. Social media platforms such as Facebook, Messenger, and WhatsApp could be used to create platforms to share tailored information with specific groups of farmers. For instance, information concerning livestock production can be shared with only livestock farmers in such groups.

2.7 Mobile phones and agriculture information access

Mobile phone usage in the agricultural sector has increased greatly in recent times; it has become one of the ICT devices with high levels of ownership among farmers (Anuga et al., 2019). Farmers and other agricultural workers used it to reach out to fellow farmers or workers for assistance (Alhassan et al., 2013). It can be used for calling, texting messages and receiving messages, receiving payments, and market information. They are simple and straightforward to use. Mobile telephony has dominated the world communication industry in recent years.

Mobile subscription has increased tremendously globally, especially in Sub-saharan Africa, in the past ten years (Anadozie et al., 2019). A study by Lee (2019) found that 3 out of 5 people in the world own a mobile phone. SMS carries limited information, and literacy is needed for one to be able to read it. Mobile technology is considered the potential innovation transformative platform for farmers. Mobile phones are vital in agriculture development because they give social, economic, and security benefits to farmers (Anadozie et al., 2019). Given their unique characteristics, mobile phones use radio spectrum in transmitting signals, therefore, they do not require physical infrastructures like roads and phone cables. Their power station base can be powered using generators in areas where there is no electricity (Jagyasi & Pande, 2011). Operating mobile phones, especially for calls and listening to audio recordings, requires just a little education, therefore almost everyone can use them. Mobile phones are not only useful for voice communication, but they also make it possible for data transfer, which is applicable in agricultural sectors.

A study by Masuki et al. (2010) in Uganda found farmers' peak use of mobile phones during the planting and harvesting seasons. They noticed that beginning of the farming season, farmers use the phones to inquire about seed sowing time, availability of seedlings, and other farm inputs from technocrats and input dealers. Also in the mid-season, farmers enquire about pesticides and fertilisers availability using mobile phones, while in the late season, towards harvesting, mobile phones are used to communicate with traders about the prevailing prices of agricultural produces; this enables them to negotiate properly and sell their produce at a competitive price.

Farmers stated that the availability of mobile phones made it easier to connect to old customers and notify them of the availability of new farm produce, which enables them to know the quantity each buyer wants, so they are able to mobilise them together for transportation (Masuki et al., 2010).

Farmers use mobile phones (27%) to share farm, market, and financial-related information; this gives them some sort of security regarding farm knowledge exchange and information access (Khan et al., 2019). The use of mobile phones for accessing market information has increased among farmers due to the fact that in many rural areas, farmers are far from the purchasing outlets; therefore, mobile phones enable farmers to reach potential buyers quickly (Khan et al., 2019).

A study to find out the benefits of farmers using mobile phones in their farming activities and the related difficulties they face in Nigeria by Ogunniyi and Ojebuy (2016) postulated that among the features on the mobile phone, farmers used the radio feature the most, while voice call was the highly utilised service. They further documented that the use of mobile phones increased farmer productivity, market access, profit margin, and reduced production cost. Similarly, Niemi et al. (2015), in their attempt to find the role mobile telephony play in marketing agricultural products in Ghana and Uganda, stated that the use of mobile phones in agriculture communication could assemble farmers, sellers, and buyers under one umbrella, thereby enabling each of them benefiting equally. Also, employing the linear statistical method to analyse the application of ICT in rural marketing by farmers in Ethiopia, Mwakaje (2010) observed that there were fewer farmers who resorted to mobile phones to obtain marketing information, and these fewer farmers bargained for a higher price, sold more farm produce, and gained more profits than the farmers who did not use mobile phones. Furthermore, Salia et al. (2011) researched the effect of mobile phone use on fishing market efficiency and livelihood, they found among other things that mobile telephony connected fishermen to fish mongers, suppliers, and other fish folks more efficiently, which offered them security and cost savings while away on the sea.

2.8 Importance of mobile phones in agriculture

The adoption of agricultural-related services offered through mobile phones and other ICT platforms by smallholder farmers improves their innovations, access to farm credits, and agricultural knowledge, as well as building their confidence in the use of new digital technologies (Hoang & Drysdale, 2021). Fu and Akter (2016) noted that the needy farmers who participated in a demand-driven innovative mobile phone-based information system in their study gained more benefits than the farmers who were not needy. They, therefore, refuted the claim that modern technologies benefit rich farmers more than poor farmers. Their study concluded that mobile phone application in agriculture is capable of generating important benefits for the poor. The study further opined that the integration of audio and video technologies in mobile phones helps smallholder farmers with low levels of education or less land to benefit equally from extension advisory services (Coggins et al., 2022; Fu & Akter, 2016).

Wolfert et al. (2017) stated that the increased technology applications in farming had paved the way for the development of digital platforms, such as e-commerce and agricultural advisory applications, to support information delivery among farmers. Digital technology tools such as mobiles, personal computers, software applications, and social media offer the opportunity for farmers and other agricultural value chain actors to connect and transact business (Nyarko & Kozári, 2020). They also have the potential to identify and find solutions to some of the many challenges faced in agriculture, such as pest and disease outbreaks, increased drought, and high transaction costs (Gerber & Alishe, 2017).

Mobile phone technologies in agriculture, such as electronic agriculture (e-agriculture), are progressively changing communication and information access among farmers, input dealers, and agricultural technical officers. Mawazo (2015) observed that digital agricultural information delivered through mobile phone offer more convenient ways of delivering useful and up-date market information and weather forecast to farmers more readily that the traditional extension method of information sharing. Digital agricultural service through mobile phones provides the opportunity to extension agents to cover many smallholder farmers and processors at the same time without extra cost on transportation. Moreover, Etwire et al. (2017) attested that mobile phone-based extension services enable extension advisors to deliver need-based information and extension services to farmers at a very moderate cost. Furthermore, E-agriculture platforms have the capacity to provide current and accurate market information, such as prices of commodities and agricultural inputs; climatic and weather information that is needed to make critical production information (Nyarko & Kozári, 2020).

Similarly, Jhunjhunwala et al. (2013) found that agricultural support services offered through mobile phone call centre services offered farmers personalised solutions, especially for farmers who faced technical problems and sought help using the mobile-based services. Additionally, mobile phones enabled farmers to connect to a call centre web technology, where they log complaints about challenges they face in their operation; available technical officers offer rapid response service to them (Pongnumkul et al., 2015). Mobile phone applications also enable smallholder farmers to send pictures, videos, voice recordings, and text messages to seek technical solutions. For instance, extension agents and plant pathologists use a mobile system that supports plant disease identification to identify and analyse plant diseases from pictures captured by farmers on a diseased crop (Jagyasi & Pande, 2011).

Meena et al. (2018) studied different types of mobile applications in agriculture and associated sectors in India and found that mobile phones, especially smartphones, assist in different areas of agriculture, encouraging farmer innovation adoption and application of digital technology in education. Similarly, in India, mobile phone applications are a powerful tool for converging farm information, farmer data, and agricultural market information in the agricultural value chain (Bajpai & Beriya, 2022).

Smartphones can also be used to assemble current and past price data for farmers in their nearby markets, and possibilities can be offered for some triggers on specific price events. An advanced option may also provide price forecasts for crops. Along with prices, all nearby markets/avenues (including eNAM availability, and online channels servicing the area) for crop sale as well as the availability of agriculture inputs/seeds, etc., can also be shown to the farmer.

2.9 Existing digital agricultural services facilitating agricultural information access in developing countries.

Agricultural advisory apps are developed to provide a medium for extension agents and farmers to communicate and share information that is required to improve service delivery and productivity in the agricultural sector. They allow farmers to connect to other farmers within their circles or outside their jurisdiction.

The mobile telecommunication industry in developing countries keeps experiencing rapid expansion for over a decade now. The ever-increasing introduction, reduction in price, and usage of mobile phones, smartphones, and other digital devices are making virtual and electronic communication more achievable in many low-income economies worldwide. It is also paving the way for extensive digital innovations in the agriculture sector. State institutions, private organisation, and individuals are leveraging these new technologies to develop and implement digital solutions that link farmers, consumers, researchers, and extension together to promote good practices and growth along the agricultural value chain. Many of these digital services can be found in India, Pakistan, Nigeria, Tanzania, Kenya, and others.

2.9.1 Popular digital agricultural services in Kenya

iCow

In Kenya, a digital agricultural information system called iCow has been developed to serve as a competent agricultural centre for livestock farmers. It is a comprehensive mobile phone-enabled agricultural digital information centre, which aims to provide smallholder livestock farmers with up-to-date livestock information and digital solutions geared toward improving productivity (Holland et al., 2012). The iCow offer service to farmers through SMS and voice message in many local languages. It is compatible with basic phones and smartphones (Amankwah-Amoah, 2019).

The iCow services are provided by Green Dream Technology in partnership with the Safaricom Foundation and International Livestock Research Institute (ILRI). It runs on a fee-for-service model; subscribers are charged a small premium for all services obtained through the system. This is achieved through a cost-effective, scalable mobile phone extension service. The platform provides varied information services such as weekly messages on livestock production, livestock calendars, a farmer SMS library, and a specialist directory. Farmers are sent information on the best dairy practices. Allows farmers to register their cows, and to receive individualised text messages on their mobile phones, including advice for veterinary care and feeding schedules, sends prompts to farmers to collect and store milk within the days of a cow's cycle, a database of experts, and updated market rates on cattle prices (Emeana et al., 2020). iCow is based on the concept that daily updates on animal husbandry practices and routine management measures such as farm hygiene, vaccinations, and deworming. Reduce disease incidence, improve animal health, and thus reduce the intake of antibiotics (Mapiye et al., 2021). The App has a platform called "iCow Soko," a marketplace for farmers. The Soko contains a contact of sellers and buyers; all that a farmer has to do is to search with keywords of the products available for sale or needed to buy, and details of potential buys and sellers appear for connection. The iCow App has over one million subscribers in Kenya (CTA, 2017).

The iCow has helped improve daily cow health and reduced cattle mortality, increasing dairy milk output by more than 20% (Lexi, 2014). A study by Marwa et al. (2020) observed that by applying iCow extension advice services by livestock farmers, their dairy milk production per cow, milk income, and household income have increased by 13%, 29%, respectively, and 22%, respectively.

M-Shamba

M-shamba is a mobile-based B2B digital platform that supplies information to farmers through mobile and web platforms. It employs various mobile phone features, including cross-platform applications applicable to smartphones and feature phones, and SMS to offer technical information such as agronomic practices, harvesting, weather forecast, climate, agri-finance, and marketing (Emeana et al., 2020; Thuo, H. 2016). Information to farmers is customised based on their locations, the type of production that they are into, and their preferences. The App also permits farmers to share information on chosen topics with different farmer groups on the system via SMS. A farmer can use the platform to post a question on a trending issue in agriculture and receive a crowd-sourced response in minutes from colleague farmers across the globe (Abila & Oloo, 2017).

An interface called virtual city has helped many smallholder tea farmers keep track of green tea leaf performance, which resulted in timely intervention and improved productivity (Munene et al., 2018). M-shamba is a digital platform that supports smallholder farmers' digital learning on agronomy, good agricultural practices, food safety, and agribusiness through Interactive Voice Response (IVR) service, SMS, and USSD (Makini et al., 2020). The digital platform uses real-time data to march market demand with the producers' supply, creating a ready market system (Munene et al., 2018). Registered farmers pay monthly premiums to enable them to continue receiving information from the App. M-shamba bridges the gap of information asymmetry between extension and farmers by acting as a virtual extension agent, disseminating information from research to farmers. When a farmer is registered into the system, the App collects information about their location, weather condition, and the type of agricultural product they produce; this enables the App to provide SMS updates to the farmer in the field he or she practices (Emeana et al., 2020). M-shamba offers a platform that supports Kenyan farmers in producing high-quality agriculture products and, at the same time, links farmers to small and medium-sized vendors in urban and rural areas (Munene et al., 2018). Farmers have a guaranteed market through the App and receive instant payment through mobile money (Munene et al., 2018). Market demands are marched with farmers' supply, reducing post-harvest losses and food waste at the production level. M-shamba works with more than 12 000 producers in rice, tomatoes, potatoes, onions, and indigenous chicken value chain. Over 1000 metric tonnes of farm produce are traded weekly. Registered farmers pay monthly premiums to enable them continuously receive information from the App.

mAgri

mAgri app is a digital agriculture information platform that operates on mobile phones and smartphones to disseminate current agricultural innovations, weather updates, and market information to smallholder and commercial farmers in Botswana in USSD and SMS form. The mAgri compliments the limitedness of extension officers by serving as a virtual agricultural extension platform that provides the opportunity for farmers to establish contacts, chat, share information with technical officers, research, and connect with buyers and input dealers (Phalaagae, 2017). Additionally, it has features such as agri tips, Wiki search, and email that farmers can use to access or send information. The multiple functions of the App by combining USSD, SMS, and online services make it possible to be used by both underserved farmers and commercial farmers by giving them effortless access to timely agricultural innovations (Caine et al., 2015). The services offered by the mAgri cover crop production, animal production, financial, and market information. The mAgri is a self-service App that allows farmers to set up their own mobile stores which contain their products and service, and this makes it possible for other farmers or buyers to reach out to them easily. It also enables users to search for and compare prices of several products and services on their mobile phones. The App does not only connect farmers to updates locally, but it also connects farmers with other farmers around the globe to share ideas and information useful in their fields of operation (mAgri, 2016).

Modisar

Modisar is a mobile and a web base application that was developed in Botswana to revolutionise livestock farming in Southern Africa. The digital solution operates on android phones and desktop computers. The application was developed to stimulate the interest of the youth in livestock production and expand the sector's productivity through digital technology (Phalaagae, 2017). Modisar operates as a livestock management platform providing farmers with technical information such as animal health management, good ranch management practices and connecting producers to market and financial institutions (Phalaagae, 2017). The App help livestock farmers take control of their production by tracking farm records, cattle herds, farm cost, and sales (Costopoulou et al., 2016). Modisar is posed to offer the best livestock management techniques and standards to farmers to reduce the risks and failures associated with livestock production (Okoroji et al., 2021)

2.9.2 Popular digital agricultural services in Nigeria

Digital agricultural technology services are taking centre stages in the Nigerian agricultural sector. Among these services, the notable ones among them are the e-Wallet and Hello tractor.

e-Wallet

e-Wallet is a digital agriculture system that operates on a mobile phone; it allows farmers to use vouchers for the purchase and distribution of agricultural inputs in Nigeria. The public extension services in Nigeria use this platform to provide farmers with information on fertilizers, improved seeds, pesticides, and other important agricultural services (Uduji & Okolo-Obasi, 2018). To access the input, farmers must register on the electronic system; the registered farmers then receive an SMS alert on their phones containing the e-wallet voucher. The farmer can redeem his or her fertilisers or seeds at the agro-input dealer after the system has confirmed his or her biodata. The accomplishment of the registration conditions guarantees the issuance of an e-wallet voucher with a Token Administration Platform (TAP) contactless card, which is connected to the farmer's biodata through the tablet Near Field Communication (NFC) interface. The contactless allows farmers to access their fertiliser or seeds in areas there are no networks by using a smartphone as a smart card (Emeana et al., 2020; Obayelu, 2016). All the farmers need is to tap their card against a Nexus 7 tablet at the redemption point. The tablet contains the biodata of all the registered farmers. The input dealer at the redemption checkpoint confirms the farmer's identity and validates the type of inputs allocated to the farmer and then supplied. This helps the extension services and the ministry of agriculture to track the number of inputs issued in a particular state and how many need to be supplied (Obayelu, 2016). The farmer also uses the e-wallet platform to pay for the difference in the price of the fertilizer provided by the government. It was reported that through the e-wallet platform, farmers were able to buy more than 1.2 millions of fertilizers within 120 days (Obayelu, 2016),

Hello tractor.

Hello tractor is an agricultural mechanization service that leverages on digital technology to connect smallholder farmers to agricultural mechanization services, mostly compact tractors. The App employs mobile technology to offer access to cost-effective tractors that farmers can rent through their mobile phones. Hello tractor work by connecting tractor owners to farmers through a digital app (Daum et al., 2021). The App uses the concept of "uber". It has a GPS-based monitoring device that tracks all tractors it handles on its platform through a tracking device, therefore providing real-time information about the location of the tractors to their owners (Sorunke, 2019). The monitoring system records the GPS location data and active working hours, analyse fuel consumption against output and operator activity which can be viewed through smartphones or a computer. It also has a digital booking interface that helps connect farmers to the nearest tractors (Sorunke, 2019). Also, Hello tractor app contains a weather forecasting system that allows clients to monitor the weather to make informed decisions.

The App also provides platforms where smallholder farmers connect with financial institutions and agro-dealers (Hello Tractor, 2019.) Farmers can choose the tractor they want to rent through the device. The data also help owners to identify the maintenance need of their tractor, and control theft or fraud (Foote, 2018). Hello tractor help smallholder farmers save money because they can easily locate tractor services around them through the use of the mobile App. Tractor owners also make more profits due to the hello tractor app's ability to connect them to farmers in their vicinity on a regular basis (Daum et al., 2021; Jones, 2018). Smallholder farmers who do not own smartphones or computers book the tractor services through a booking agent; the booking agent then processes the farmers' information through his or her smartphone or computer. The farmer receives the service based on the information provided by the farmer (Jones, 2018). Hello tractor offers secure platforms for farmers, and private and public sector players to securely exchange services. The App also enables tractor owners to track their tractor usage, assess farm impact, and receive alerts on their cell phones when service or repair is needed. Hello tractor, through its digital app services, has raised around 1.2 million in start-up funds (Daum et al., 2021). Hello, has served more than 22,000 farmers, resulting in more than a 100% increase in farmers' yields (World Bank, 2019). Through the digital App, hello tractor controls about 75 percent of the private tractor operation in Nigeria. Quite recently, hello tractor has partnered with John Deere to deploy about 10,000 tractors through a lease-operate-own model, which leases tractors to farmers at an affordable price until they finally finish the payment (Hello Tractor, 2018).

2.9.3 Popular digital agricultural services in DR Congo

DR Congo is among the developing countries that are making progress in the application of digital technologies in the agricultural sector. The commonly used digital agricultural service in the country is Mobile Agribiz.

Mobile Agribiz

The mobile Agribiz (Mobile Agribusiness) is a digital technology platform with a mobile application and a web-based interface. The application is carefully designed, putting smallholder farmers at the center; it, therefore, does not require much technical knowledge to access it by users (Agribiz web, 2014). Mobile Agri biz is designed to assist smallholder farmers select the best crops that suit a particular geographical area based on climatic and weather data available to them (Van greunen, 2020). This helps farmers to decide when and what to plant at a particular point in time. The application provides the environment for farmers to connect to the available markets and link with buyers and other producers. It operates by recording farmers' biodata on a plotted map contained in the App. Farmers regularly update the system with their products, such as the type of crops available, location, quantity, and the price sold. Potential buyers connect to farmers through SMS, based on the update from the mobile Agribiz (Agribiz web, 2014; George et al., 2014). Mobile Agribiz is revolutionising agricultural information access in the Democratic Republic of Congo by creating the possibility for smallholder farmers to participate in commercial supply chains, assisting smallholder producers in growing what the market needs to cut down loss and waste (Agribiz web, 2014). The technology is unique in the DR Congo agricultural information system due to its ability to combine three features: provision of agro-skills to smallholder farmers, provision of timely agricultural information, and linking of producers to the market.

2.9.4 Popular digital agricultural services in Uganda and Tanzania

The adoption and application of digital agricultural services in agriculture in developing countries have not left Tanzania and Uganda behind. The two countries have a common digital agricultural service called GroFarmer.

GeoFarmer

GeoFarmer is a modern digital technology application in agriculture that serves as a complementary digital extension service in developing countries such as Uganda and Tanzania. The App enables multiple-way communication channels between smallholder farmers, extension agents, researchers, and among farmer groups (Hiestermann, 2017). It serves as an information knowledge centre where farmers, extensionists, and researchers collect and share useful information geared toward good agricultural practices (Eitzinger et al., 2020). The digital platform provides real-time information in both online and offline modes, making it ideal for smallholder farmers in remote areas with limited internet connectivity. The App can be used on desktop computers and smartphones. GeoFarmer is a cost-effective digital platform that monitors farm production systems and provides interactive feedback between users in a specific geographical region. The App was developed adopting the Progressive Web Application (PWA) technology, which makes it compatible with many ICT devices, such as personal computers and smartphones (Eitzinger et al., 2020; Hiestermann, 2017). GeoFarmer enables farmers to share step-by-step best agricultural practices with their colleague farmers to also practice.

2.9.5 Popular digital agricultural services in India

Digital agricultural technology services are taking centre stage in the Indian agricultural sector. Among these services, the notable one the IFFCO Kisan agriculture APP.

IFFCO Kisan agriculture APP

It is a mobile data-driven App serving as a one-stop shop information platform providing agriculture content to Indian farmers. The App is a subsidiary of Indian Farmers, Fertilizer Cooperative Limited, which aims to provide customized information to farmers according to their information needs (Naseera & Jeelan, 2017).). The App can be downloaded for free through the google play store, and it is compatible with mobile devices accessible to 2G and 3G services (Darabian, 2016). The App offers different information to farmers through its modules, such as agricultural advisory, weather, animal husbandry, market prices, and agronomic practices in the form of SMS and a customer helpline in selected local languages (Darabian, 2016). IFFCO Kisan agriculture APP has connected more than 170,000 smallholder farmers to the systems, assisting them with tailored agricultural market information.

2.9.6 Popular digital agricultural application and services in Ghana

The Ghanaian agricultural sector has seen quite a few digital agricultural services emerging, however only few ones are widely spread across the country. The popular ones are E-agriculture of the Ministry of food and Agriculture, Esoko, and farmerline.

The Electronic platforms of the ministry of MOFA

The Ministry of Food and Agriculture launched its first electronic agriculture programme in 2013 (Munthali et al., 2018; MOFA, 2013). The programme covers all the major agricultural sectors in Ghana, focusing on animal production, crops, fisheries, gender, and services (FAO, 2017). The e-agriculture system aimed to provide farmers, technical officers, and other value chain actors the platform to access comprehensive and current information on animal production, farm management techniques, market information, crop production, and extension services without any hustle (Sarku et al., 2020; FAO, 2017; MOFA, 2013). The e-agriculture system has three main components: the e-extension (mobile app), the e-farm information, and the e-learning and resource center.

The e-extension application integrates mobile telephony and internet services to enable AEAs to capture farmer information, record occurrences, and take note of important agricultural activities to facilitate prompts and effective responses to farmer needs (Munthali et al., 2018; Akpotosu et al., 2017; MOFA, 2013).

The homepage of the electronic extension (e-extension) platform of the ministry of food and agriculture had three key features. The collection of the Global Navigation Satellite System (GNSS) location data, the crop-specific production data of farmers found beneath a tab called farmer. Data obtained through the 'farmer' tab was assumed to be vital for planning and managing an intervention. It also facilitates the creation of unique, randomly generated identification numbers for farmers to help regulate and manage the government's subsidies offered to farmers. The idea was to enable input dealers on the national input subsidy programme to run online identification checks to verify farmers who are eligible and those who are ineligible for the national input subsidy programme. So as to prevent fraud and double access of input by farmers and dealers. Under the farmer tap, existing farmers details can be modified using the "edit farmer" it helps to keep farmers information up to date. The list of farmers can also be viewed under the farmer tap. All farmers registered in the system can be seen under this tap. The farmer tab also has another tab called 'field visit report'; this enables extension agents to record their new findings and details about farmers' farming activities. These details are stored on the digital platform for decision-making.

Detail of the Farmer tab

In order to enable farmer registration:
1) add farmer: farmer name, upload farmer's picture; farmer's sex, family size, mobile number, crop(s) produced, GNSS location, and district name.

2) list farmers: to retrieve farmers' records.

3) field visit report: digitize farmer monitoring.

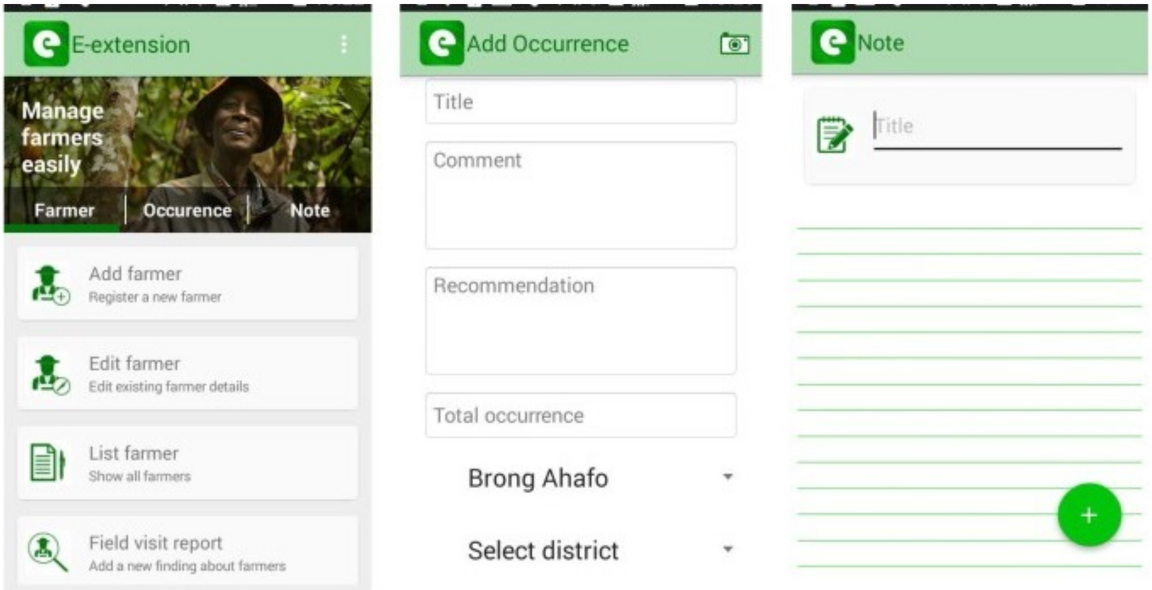

Figure 4. E-extension farmer tab; E-extension occurrence capture; E-extension note capture (left to right) (Source: MOFA, 2013).

Occurrence tab

To report pest or disease occurrence, 1) label occurrence and location (GNSS and district name), upload pictures, document preliminary diagnosis and recommended prescription, and report the acreage affected; and 2) occurrence finding: to retrieve records of occurrences.
The 'occurrence' provides opportunities for AEAs to report diseases and pests issues they observed on a farmers' fields. There is no limit to the number of occurrences that can be reported. The reporting officer gives details of the observed incidence and the possible recommendations to avert them. The region, district, and area are captured in the report to make it easier for the responding authority to identify the exact location. It also helps the technical officers at the Agricultural Extension Directorate to source timely information on the extent and location of such an event. The occurrence reporting in the E-extension platform was considered very important for detecting early warning systems to facilitate rapid and coordinated responses to developing issues in farmers' fields. The occurrence information is stored in a database with a dashboard. This helps the technical officers and researchers trace and monitor the farmers' and extension agents' occurrences and activities.

Note tab

The note tab is a general platform for AEAs to document general issues confronting them or they come across on the field. It can range from agriculture to non-agriculture issues. Provided it worth paying attention to. AEAs can report, for example, bad farm practices observed on the field, which need to be addressed by the District Agriculture office or the technical officers at the Directorate of Agricultural Extension Services. The incidence reported in the note tab is not considered an emergency as compared to the 'occurrence tab. 'This tab serves as an additional information centre. For instance, if a field officer finds an innovation introduced by farmers, this innovation can be captured for technical officers to research into it for either replication in other areas or development to be part of the general practices. The note tab therefore aimed to provide additional information to be considered for decision-making. The app also has a unit that links to the E-agriculture website (http://www.e-agriculture.gov.gh), where the extension agents are supposed to have access to other agricultural service providers' repositories.

The E-Agriculture web portal (E-Learning and Resource Centre)

The e-agriculture website homepage has three main classes of tabs.
The upper tab has the various sectors under the Ministry of Food and Agriculture, the partners, and a forum tab. In the upper tab, all the sectors, such as crop services, veterinary, extension, animal production, engineering, PPRDS, and women in agricultural development, are listed under the MOFA tab. The forestry, cocoa, and fisheries which are sub-sector under the ministry, are also located on the same tab. The same tab also has the development partners, value chain support, and agricultural statistical data. The last tab on the upper tab is the forum, which is meant for registered members on the platform to post topics or questions for discussion. Interestingly, the topics and discussions under the tab are in Italian. The official language used on the website is English; therefore, it is a bit of a surprise to see all discussions held on the forum be in Italian.

The second category of tabs is the service providers in the middle of the homepage. This area lists the research institutes, Agric finance, input suppliers, processors, marketers, FBOs, Transport, and policies of the ministry of agriculture.
The final area is the farmer corner tab. On top of it is the submit profile, where organisations can register by filling in their company's profile and the services they offer. The farmer corner should contain articles and other publications that seek to help farmers update their knowledge or learn something new about their farming operations.

Figure 5. MOFA's E-agriculture interface. (Source: MOFA, 2013).

The e-farm information system

The e-farm information system has an audio library and a call centre, where farmers can call specific toll freelines and speak to technical officers on various topics. The system was to function as a national call centre for farmers where they can call to make inquiries and discuss key issues confronting them in their various operational areas. The system was supposed to operate in the major local languages spoken in Ghana; however, getting operators in the local languages was difficult. The commonest languages farmers would likely get operators to speak were Twi and English. This means that farmers from other regions who cannot speak any of these languages may have to wait for days or another time to try if they can speak to a technical officer in their local language.

The idea behind the e-agriculture system was to bridge the communication gap between the extension services and farmers in Ghana. This was to be achieved by creating a multi-stakeholder, people-oriented, cross-sector platform that will bring together stakeholders representing relevant constituencies of e-agriculture that will result in agriculture modernisation; and increase agricultural production and productivity. The platform layout matches its core objectives. However, there are many aspects of the system that need to be looked into to ensure the system serves the purpose it was meant for.

Firstly, the e-extension platform was designed to serve as an information-gathering tool. The application only allows technical officers to collect data from the field, which is later stored in a cloud. Aside the data collection function, the app does not serve any other meaningful purpose. Also, the platform can only be used by agricultural technical officers. It was not designed for farmers use. Only AEAs have it on their phones to register farmers and document occurrences on the field. A technology that is meant to bridge communication gap between the agricultural extension services and farmers needs to have a platform where both farmers and technical officers can share and communicate. Limiting the app to only AEAs to report incidences without farmers involvement would not eliminate the communication gap; it would mean that AEAs' presence would be required anytime there is an incident. Already, the extension services are faced with under-staff challenges. Therefore, a new technology in the sector should not burden staff with additional duties but rather provide solutions.

Secondly, the e-extension app used English as the only operational language. This meant that even if farmers were to use the system, only the educated ones could access the content. No other local language was incorporated into the system. Technologies that use multiple languages have proven to have higher accessibility rates than those that use a single language, especially in areas where many languages are spoken.

Thirdly, the application was only available in online mode. This implies that areas with internet access cannot use the system. Many farms in Ghana are in remote areas where internet access is very difficult due to unreliable mobile network services. Therefore, AEAs who visit farmers in this location may find it difficult to report occurrences on time. Information that needs to be sent for prompt action may delay. Mobile applications with offline content will be very useful in these areas. It will boost AEAs' confidence in using the technology for reporting issues of great concern. It will further help eliminate the digital divide between those who have access to a good stable internet connection and those who lack stable internet connections.

Furthermore, the e-agriculture (web version), which is supposed to serve as an information and knowledge competent centre lacks current information. As of the time of this review (May 2022), the current information update on the webpage was October 17, 2019. This suggests that the system has been out of use for a very long time; therefore, the information found there is less credible. Additionally, many of the tabs that are supposed to link users to input dealers are not functional, and the fewer ones that function, too, do not display detailed information that will benefit users. For instance, the seed suppliers tab has not information to display, while the Wienco agriculture and YARA Ghana tabs display information, there are no contacts or links for users to follow. Also, the Agro marketing, Transport, and FBOs tabs are all empty. Moreover, a very important tab (Agric statistical Data) that is supposed to provide information for research and decision-making has outdated data. The latest "Facts and Figures" available at the time of this review was from 2015, which translates into seven years old data. Also, one thing that will surprise users of the system is the forum. The forum is an area where topics are supposed to be posted by registered users to further discussion and opinion sharing, however, one will be enthralled to see that the topics and discussions there are in Italian, which is not the official language supposed to be used on the platform. Digital platforms aimed to promote technology adoption, and good agricultural practices must be able to provide credible and reliable information. The system needs to be updated consistently to provide up-to-date information that are useful to its users. The system must be able to prevent malicious attacks that would make users feel secure in using the system. The current State of MOFA's e-agriculture does not guarantee users security and privacy protection.

Furthermore, the e-agriculture system lacks self-taught resources to promote self-learning among technical officers and farmers. Self-taught resources such as "how-to-to" videos, demonstration videos, info-graphs, and bulleted guidelines stimulate individual learning and promote better understanding among farmers. Digital technology platforms that incorporate these self-learning resources serve the purpose of a knowledge centre where both AEAs and farmers can join the system, learning new methods or procedures on their own. The adoption and usage of such systems are higher than those that lack them (Asare-Kyei, 2013).

Esoko

Esoko (formerly called TradeNet) is a for-profit private technology service delivery company that focuses on delivering agribusiness information to farmers in Ghana and other African countries (Gebru et al., 2019; Subervie, 2011). The company was established in 2005 in Ghana and now has a presence in 20 other Sub-Saharan African countries (AGRA, 2015). Esoko seeks to increase profitability in the agricultural sector by creating links between agribusinesses, NGOs, Projects, governments, and smallholder farmers (FAO, 2017). The company originally started as electronic market information platform (virtual market), offering real-time agribusiness information such as input prices, commodities availability, market prices, contacts of merchants and traders (Esoko, 2022; Mapiye et al., 2021). Nevertheless, after few years, the company 54realised that farmers need more than just market information; it therefore extended its operations to advisory services, weather forecasting, data collection and so forth (AGRA, 2015; FAO, 2017). The services offered by Esoko currently are digital surveys: using mobile phones, tablets, and web-connected computers to collect customized data on market prices, and users' biodata (farmers, marketers, distributors) which are available on its database (Asare-Kyei, 2013). The registered members on the platform are classified by location, type of commodity, occupation, or service. The platform is open to all registered members to upload bids, sell, or purchase agricultural commodities or services. Offers can also be uploaded using the online web, where prompt messages are sent to sellers and buyers whenever there is a match between the seller and the buyer (Mapiye et al., 2021). Also, based on farmers' preferences, they receive bulk SMS (twice a week) as a reminder of activities to be performed on their farms (FAO, 2017; Asare-Kyei, 2013). Furthermore, the platform has a helpline where registered farmers can place calls to inquire about their operations (Fugar, 2019; Van Schalkwyk et al., 2017).

In Ghana, Esoko has partnered with the Social Enterprise Development Foundation (SEND) West Africa, an NGO that helps smallholder farmers with mobile phone access and supports them with SMS alerts services (Subervie, 2011); Vodafone Ghana to establish the Vodafone farmers' club, which aims to provide crop specific information, weather, nutrition tips, and market price updates to smallholder farmers (Esoko, 2019).

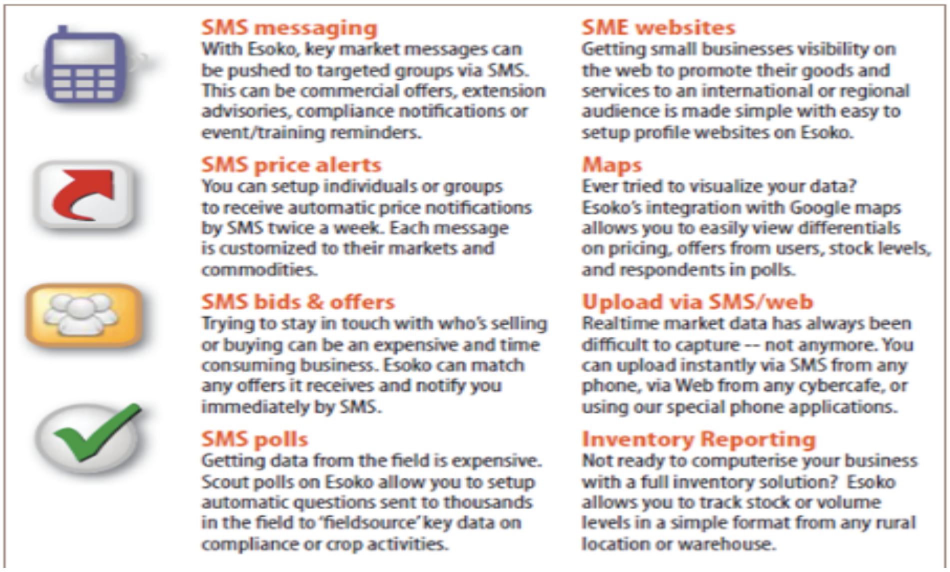

Figure 6. Services offered by Esoko Ghana (Source: Esoko, 2019)

The website homepage of Esoko contains six main items: the Solutions, About Us, Resources, Contact, Sign-up, and social media (Facebook, Twitter, Linkedin, and Youtube).
The Solutions has sub-titles (Surveys, content, messaging, and deployment). The surveys contain details of the data collection activities undertaken by the company, the past surveys, the number of countries they have covered, and the clients or partners they have worked with. The content, conversely, contains the type of information services the company offers farmers. The services listed under the content are market prices, weather forecasts, extension services, and custom messages. These services are offered through SMS, IVR, and Call centre. The messaging area also provides details of the nature of the message services the company offers to its clients. The services are bulk SMS, Scheduled messages, and Reports. Finally, the 'solutions' contains a deployment interface, which shows the personnel management services clients can be acquired from the company. They recruit, train, and manage field personnel for data collection services.

The second Interface on the home page is the 'about us', it contains information such as the company's mission, vision, activities, achievements over the past years, and career opportunities.
The third Interface is called the 'resources'; this is where the company's blog can be found. It contains all the publications the company and its partner organisations have made. The food prices are also located in the resource interface; monthly records of major food commodity prices from the major cities are posted there. It is supposed to be updated periodically; however, the latest food price data available on the page as of the time of this review was October 2020. About 18 months old. The 'resource' also contains the media: the company's videos and documentaries repository.

The contact interface on the home page contains a registration form that individuals are required to fill out and state the topic or service of interest when making inquiries. The company's physical address, telephone number, email address, and helpline number can be accessed from this Interface.

The sign-up Interface redirects to the 'insyt', an integrated platform for data collection, communication, and project management. It is designated for companies or entities seeking the company's services for data collection and other digital services. There are three types of services that can be chosen from under the Interface: Standard, costing $25 a month, enterprise, costing $299 a month, and customized service, which has no value assigned but is required to contact the company. The first two services have trial versions that last for only seven days with limited feature access.

Finally, the social media interface. It links directly to the company’s social media platforms except for the YouTube link, which does not link to any platform.

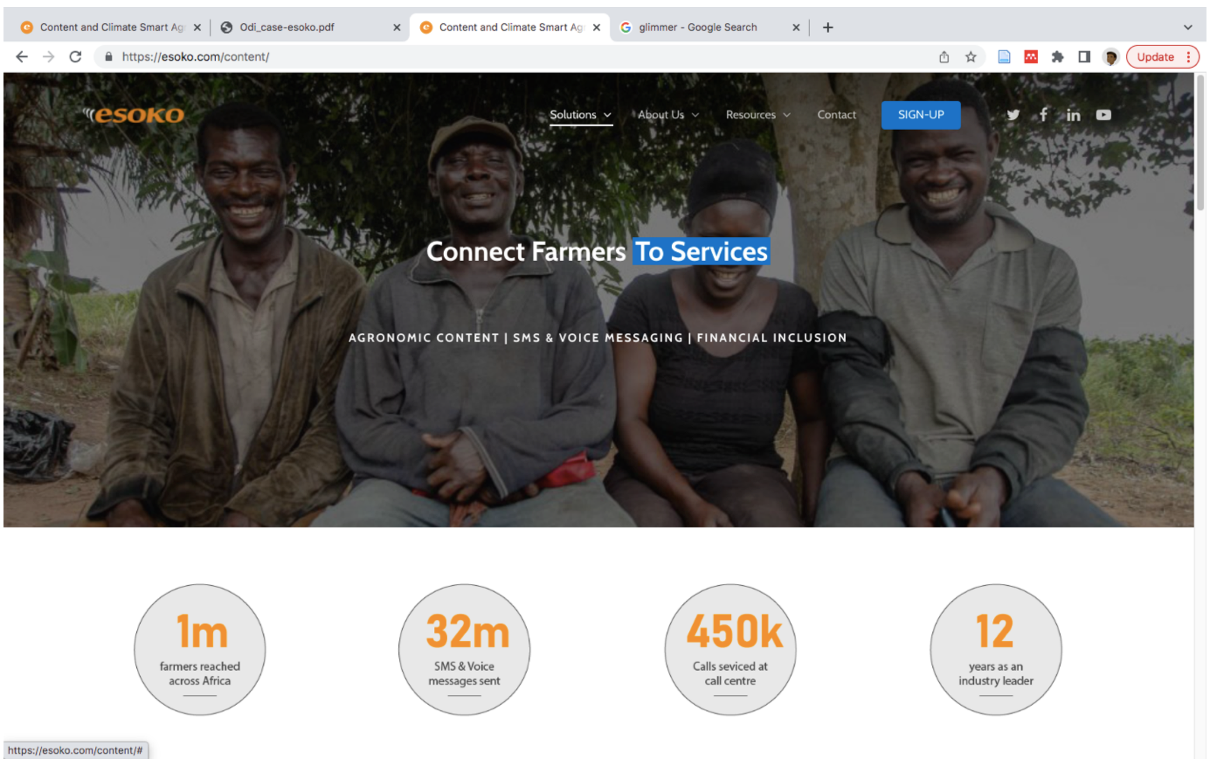

Figure 7. The main homepage of Esoko Ghana (source: Esoko, 2019)

Esoko has proven that using digital technologies could increase smallholder farmers access to agricultural information and increase agricultural innovation adoption significantly. Esoko's ICT-mediated services have been able to reach about one million smallholder farmers in its operational countries (Esoko, 2019). In spite of the tremendous services Esoko's ICT-mediated services offer to farmers and business enterprises, access to the services by smallholder farmers is constrained by affordability. Primarily, Esoko is for profit organisation, therefore it works with farmers based on sponsorship from donor-funded projects or contracted by locally based out-growers (Gebru et al., 2019). This makes it difficult for all smallholder farmers to access the services offered. Majority of the farmers Esoko works with belong to an out-grower. The out-growers are small local agribusinesses that go into contract with smallholder farmers (20-40 farmers), where the out-growers provide inputs, and advisory services that the farmers need for their production and the farmers also agree to offer a certain volume of their produce to the out-growers to buy after harvest at an agreed market price. Esoko then offers the agreed services to the farmers on behalf of the out-growers and gets paid by the out-growers. Most of these contracts are time bound; the moment the contract ends, the farmers have to bear the cost of the services themselves. Many farmers may exit the service due to a lack of subscription fees.

The digital services offered by Esoko are not integrated. They primarily focus on crop production and virtual market services, leaving animal production out. Many smallholder farmers in Sub-Saharan Africa practice the mixed farming type of agricultural production. They may prefer paying for a service that can offer crops and animal production services in addition to market information updates. Therefore, an integrated agricultural information delivery service is more important for many smallholder farmers to join the service.

Also, since the company is profit-oriented, it does not play the role of agricultural knowledge competent centre, where farmers can visit their website and find how-to-do videos or self-learning materials that they can watch or read to perform certain farming activities. they rather report on the company's achievements, operations, and headline news. The monthly food price data are not also updated periodically on their website.

Farmerline

Farmerline is an agricultural technology social enterprise focused on providing a system that helps smallholder farmers access quality agricultural inputs, advisory services, and market information through a network of local agribusinesses. Farmerline's mission is to transform smallholder farmers into successful entrepreneurs by creating lasting profit from their productivity (Meunier et al., 2018; FAO, 2017a; Lampe et al., 2017). The company does this by linking farmers to current information, available markets, and resources via ICT tools, field agents, and critical analysis of field data from farmers and their communities (FAO, 2017a). The services offered by farmerline include mobile messaging, weather updates, pests and diseases projections, market information updates, agri-credit services, and agricultural inputs and food commodities delivery services (Lampe et al., 2017). The delivery network comprises warehouses, heavy-duty tracks, and motorbikes that transport goods and services from urban to rural areas.

The homepage of farmerline Ghana website contains six major headings (Quality inputs, buy commodities, intelligence, our story, Careers, News, and media), representing the major services they offer. The quality inputs are the input service area. Under this platform, individuals can request farm inputs by filling out a form on the page. The company later contact the client who requested the inputs for arrangement and delivery. Buy commodities services look like quality input services. Commodities such as cereals and yams are available for sale in large quantities. Once an order is placed on the website, the company makes the necessary arrangements for payments and delivery. The intelligence is where the technical services are offered. Farmer education and training can be found here. Issues relating to cocoa projects and agro inputs services are also found under the intelligence. A farmer or a client can fill out a form on this page to request to speak to a technical agent. Our story, on the other hand, summarises the company's journey, mission, team, and achievements while the careers advertise job opens. The news and media contain publications about the company, achievements, and contracts won.

The home page does not contain updates on input prices, weather forecast information, demonstration videos, infographic, and links to other service partners. Farmers who visit their website may not find any publications to help them deliver service.

Figure 8. Homepage of Farmerline Ghana (Source: Farmerline, 2020*)*

Furthermore, farmerline has a mobile application called Mergdata, the app works on a simple phone. Through the merged data app, SMS and voice messages on weather forecasts, market prices, agronomic practices, good agricultural practices, and finances are sent directly to farmers' phones in their preferred local languages (Sakyi, & Abdul-Fatawu, 2017). Farmers can also use their phones to connect to other markets to purchase farm inputs and services.

The mergdata was originally developed to deliver updates to smallholder farmers through SMS, but consistent evaluation led to the inclusion of an audio option, where messages are delivered in the form of voice recordings in different languages to farmers (Sakyi, & Abdul-Fatawu, 2017). The mergdata has a component that enables users to create surveys or gather information such as survey responses, images, audio, and global positioning data. It can be accessed both offline and online. Also, it has a web interface that allows for data analysis and report generation.

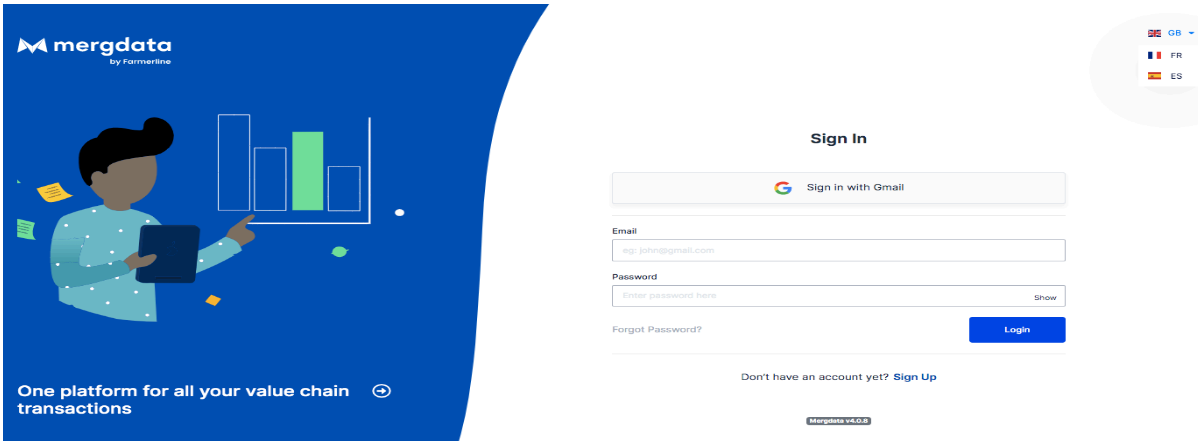

Figure 9. Homepage of Farmerline's Mergdata. (Source: Farmerline, 2020)

The farmerline's mergdata is independent of its main website. It can be accessed on both google play store and the internet. Access to the mergdata platform is through registration. Three languages (English, French, and Spanish) are available to users. After successful registration, the Interface opens with the company name, the account manager's name, and the role. Two main modules can be found on a company's homepage: data management and farmer management. The data management contains the data collection, which has tools such as mergdata fact sheets, farmer profile, and farmer group. These tools detail the company's contacts, the profile of every farmer the company manages, and the farmer groups. The farmer management module also contains farmer identification and field mapping. The module summarises farmers' biodata and their field activities. Companies registered with farmerline pay subscription fees to access the communication and data collection tools (Sakyi, & Abdul-Fatawu, 2017).

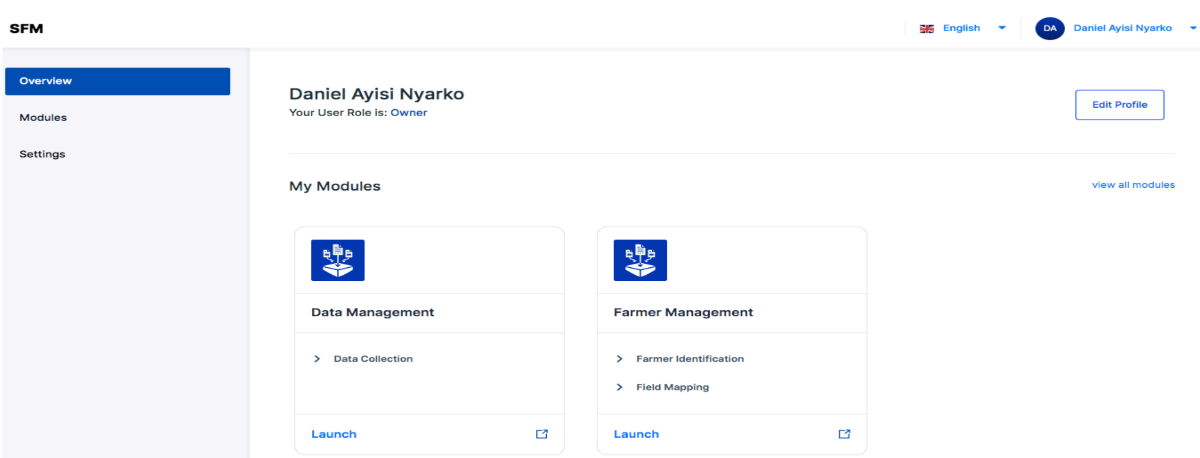

Figure 10. Homepage of a registered company on Farmerline's Mergdata
(Source: Farmerline, 2020)

Farmerline's mode of operation is like Esoko. Both companies are for-profit agrit-tech, combining business with social services. Farmerline provides subscription-based services to farmers and licenses its software to agricultural enterprises and other organisations that deal with farmers to generate income profit. Farmerline usually works with agricultural enterprises that contract them to offer specific services to smallholder farmers, the company pays for the service fee on behalf of the farmers. these contracts with the agricultural enterprises are for specific periods, so when the contracts end, farmers are asked to pay for the services themselves or terminate the service. This implies that farmers who may not have the funds to pay the subscription fee may not enjoy farmerline's services. With this financial impediment, farmerline has not eliminated the digital divide between the "have" and the "have-not" farmers. Therefore, to eliminate this barrier, there is the need to have a digital agricultural platform accessible to all categories of farmers.

Furthermore, farmerline's digital platforms lack integrated services for farmers. The activities of the company focus more on commodities sales, crop production, and some aspect of fish farming. Animal production services are totally eliminated. This suggests that the company's operations are geared towards areas where profitability is higher or can be realised within a short period of time. Smallholder farmers information needs are complex and vary with time, especially those in developing countries where farmers combine crop production with animal production. An innovation that serves multiple purposes will be preferred to those that serve a single purpose.

Also, farmerline does not function as an agricultural competent centre company. It rather serves as an agricultural marketplace where goods and services are offered. Agricultural competent centres provide platforms where farmers, and agricultural industry players learn and develop their skills. Competent centres provide services such as How-to-do videos, infographics, self-taught publication materials, and bulletins that focus on broadening farmers' knowledge while increasing good agricultural practices for sustainability. Agricultural competent centre is important for both agricultural technical officers and farmers' skill development.

The digital platforms operating in Ghana sought to improve agricultural information dissemination by using digital technology to improve agribusiness, food security, farmer livelihood, and rural development. Two main bodies were found in the review to be responsible for the operation of digital agricultural information platforms in Ghana: the government through the Ministry of Food and Agriculture and the private sector (Esoko and Farmerline). The private sector service providers are for-profit, while the government services are non-profit. The private sector digital agricultural service operators were more active and responsive to clients; they over readily available input, market, and advisory services to their clients. Their services are based on subscriptions. For instance, Esoko and Farmerline work without-grower farmer groups who contract them to provide advisory services to their members on an agreed period. The moment the contract ends, the services are terminated. Only farmers who can afford their services can continue signing new contracts with them. Farmers who were not part of the out-grower groups may not receive technical advisory services from the company. Their system of operation does not eliminate the digital divide between the farmers who can afford it and the farmers who cannot afford it. Also, both Esoko and Farmerline operations were largely limited to crops. Animal production, which is also an important field in the Ghanaian agricultural sector, is not covered. The mode of operations and the requirements involved in accessing the Esoko and Farmerline services do not make them digital agricultural systems for ordinary smallholder farmers. Therefore, a more affordable, open, and integrated digital agricultural system will be ideal for smallholder farmers in Ghana.

The digital services offered by the Ministry of Food and Agriculture are more farmer-centered, affordable, and integrated than Esoko and Farmerline. The e-agriculture platforms cover crop production, animal production, fisheries, extension advisory services, marketing, and other agricultural value chain activities. However, the system is malfunctioning. The information on the online system is out of date. The e-agriculture systems and all their components are not serving farmers as intended.

In order to encourage smallholder farmers to adopt technologies and use new digital technologies, it is important that the system serves farmers' needs, gives up-to-date information, and be more localised, affordable, and accessible to all farmer groups irrespective of their economic background or productivity level. Also, considering Ghana's culture and language diversity, the agricultural extension system needs a decentralised digital agricultural platform that will serve as a knowledge centre for farmers, extension agents, researchers, processors, and the value chain actors. The current model seeks to serve this need.

2.10 Farmer information needs

Information in the field of agriculture is very critical, just like in any other business or organisation. Timely and authentic information will help farmers make good decisions, reduce costs, and increase productivity. Essential agricultural information within the farmers' jurisdiction plays critical roles in decision-making towards good agricultural practices, processing, trading, and marketing. Agricultural information can be defined as technical or general information packaged to add to or improve existing production methods, practices, farm management, marketing, and processing in agriculture (Fidelugwuowo, 2020; Zezza, 2002). Agricultural information is important to agricultural advisory services, research, and development. Hoffmann et al. (2007) stated that agricultural information, knowledge, and skills are key valuable resources for farming and that the study of the processes in which farmers obtain and share agricultural information could be vital to agricultural research, advisory service, policy decision, and leading to more efficient farming. The lack of appropriate and timely agricultural information has been documented (Oladele, 2011) as a key factor limiting agricultural growth in developing countries.
Agricultural information can be classified into two broad categories: technical and business information (Oladele, 2006). The technical information covers production activities such as land preparation, nursery, animal husbandry, irrigation, pest and disease control, fertilization, harvesting, processing, climatic data, and other cultural practices, whereas the business information relates to economic activities. These includes credits, supply, distribution of agricultural products, and marketing (Sani et al., 2014). Agricultural information is generated through research efforts and can be grouped into scientific (research and technical information), legal (plant regulations, land tenure systems, agricultural product certification), and commercial information such as marketing, labeling, input distribution, credit information and so forth (Ugwu & Kanu, 2011). Also, Ozowa (2008) maintained that agricultural information in Nigeria is complex and can therefore be classified into agricultural credit, marketing, and technology. Agricultural information forms critical components of farmer education, extension advisory, research and development activities, and different farmer groups require different information at different times (Vidanapathirana, 2012). Apart from farmers, many individuals and organisations,

such as researchers, teachers, students, policymakers, programme managers, actively use agricultural information (Zaman, 2002). Agricultural information originates from diverse sources but serves the same purpose. i.e., equipping users with the skills and knowledge to improve agricultural productivity. Figure 11 gives the sources where agricultural information originates and the potential users of this information.

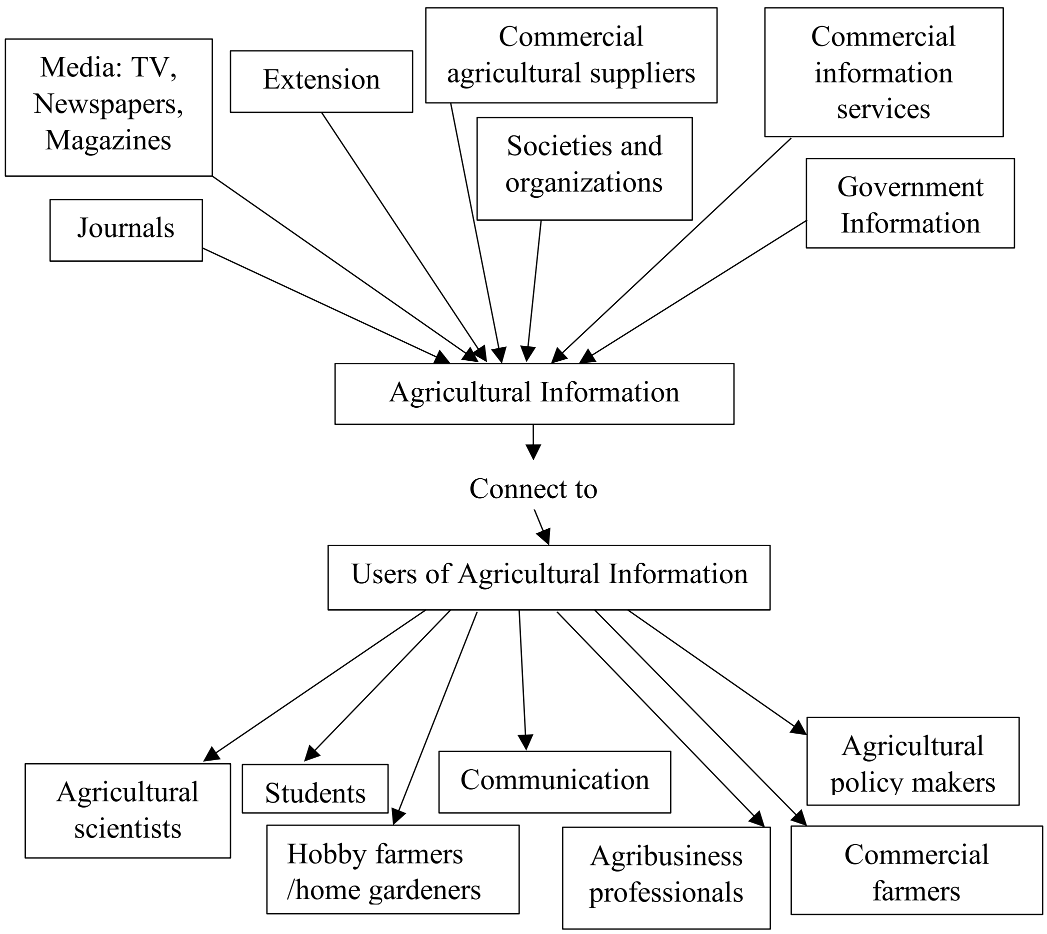

Figure 11. The flow of agricultural information *(*Source: Vidanapathirana, 2012*)*

A study of sources of agricultural information to famers in the Imo State of Nigeria showed that more than 88 percent of the farmers obtained their information from the agricultural extension service, while 72 percent indicated they obtained fellow farmers (society), 63 percent indicated radio and 43 percent indicate television and the likes (Opara, 2008).

Smallholders' information needs

The aim of most smallholder farmers is to make efficient use of their scarce resources to maximise productivity, increase profitability and improve their livelihood. To achieve this, smallholder farmers need different information at different points in time, and identifying the appropriate information and using them at the right time helps farmers to reduce production costs, time wasting, and make full use of labour and resources (Sylvester, 2015). Smallholder farmers can seek agricultural information from varied sources such as extension advisors, policymakers, researchers, farmer organisations, and colleague farmers (Ballantyne, 2009). Farmers information needs differ from one farmer group to another based on different factors such as socioeconomic situations, availability and access to resources, size of holdings, agroclimatic conditions, laws and regulations governing land tenure systems (Glendenning et al., 2010). These and other important factors, including government structure and policy directions, socio-culture norms, individuals' beliefs, and practices, as well as gender roles, determine how farmers seek and obtain agricultural information (Haworth et al., 2018; Obayelu & Ogunlade, 2006). Among the smallholder farmers circle, the information needed, and access vary between the educated farmers and the uneducated farmers; while the former can access complex information and make an informed decision, the latter requires more support to do so (Paltasingh & Goyari, 2018). An in-depth understating of farmers information needs is ultimately important to finding the appropriate solutions to some of the major problems smallholder farmers face in their production field.

Miranda and Tarapanoff (2008) defined information need as the State or process started when one (a farmer) perceives that there is a gap in information or knowledge available to solve a problem and the actual solution of the problem. i.e., information needs are about farmers feeling that there is a gap between their current knowledge and the knowledge or skills required to perform certain farm operations. Similarly, Kaniki (1995) defined information needs as the State of lack of desirable requisite or commodity, i.e., information necessary to deal with a situation as the individual sees fit (in Sani et al., 2014). Nikolas (2005) opined that information needs occur when a farmer identifies a gap in his or her State of knowledge or practice and seeks to find solutions to that anomaly as anomalous of knowledge. According to Chen and Lu (2020), farmer information needs are not only restricted to agricultural information, but also policy information, education, gender, and work information. Zhang (2012) classified farmers information needs into five groups, which were policy, knowledge, technology, marketing, and technical information. Similarly, farmers information needs were classified into five main headings by (Ozowa, 2008): agricultural technology, marketing, inputs, credits, and extension education (Vidanapathirana, 2012). The information needs of farmers are greatly related to the farming period decision-making. The decision-making for the farming period consists of the land size, labour, inputs availability, when to plough, the period to sow seeds when to transplant seedlings, irrigation system, pest and diseases control, harvesting period, marketing and processing (Sarku et al., 2021). Other information such as agricultural tools prices, environmental conservation, soil management practices, land rights and leases, animal husbandry, and feed management information were prominent information needed by farmers (Sarku, 2021; Lwoga et al., 2010). Elly & Silayo,2013) studied the information needs of rural farmers in Tanzania and found that more than 70 percent of the farmers surveyed information needs were on agronomy, livestock production, marketing, agricultural credits, and value addition. The study further observed a significant difference between crop farmers, animal farmers, and processors information needs. It was therefore recommended that an extension programme or project implementation should consider this valid difference between the different farmer groups. Also, in a study by Bhawaria and Chayal (2017), organic composting, improved storage facilities, market availability, and subsidies were identified as the most needed agricultural information among smallholder farmers in India. Moreover, Salau et al. (2013) research observed numerous and diverse information needs among farmers in Nasarawa State in Nigeria. The key information needs identified were animal husbandry, crop management, pests and diseases control, agro-input sources, and marketing.

A study of farmers' household information needs in rural Guangdong revealed that many of the rural farmers were more concerned about agricultural research information and technology information on crop pest management, crop varieties cultivation, and farm management practices (Huang & Zhang, 2011). Assessing the agricultural information needs between developed and less developed countries, Yan et al. (2012) identified that the most needed information among rural farmers in developed countries was human communication information, knowledge and skills training, and health care information. It was also established that the rate of information needs in rural areas in developed countries was lower than that of rural areas in developing countries. Naveed and Anwar (2013) also interviewed 84 Pakistani smallholder farmers to identify their information needs. Using a structured questionnaire, the authors identified soil management, seeds, crop agronomy, harvesting, and animal production as the main area in which farmers need information.

Similarly, in an empirical literature review, Zhang and Yun (2009) reviewed that farmers in rural areas in China need information on new agricultural technologies, income, rural development policies, education, and training. Also, Zambian smallholder farmers need analysis revealed that many sought information on land management, irrigation, forestry machinery, farm drainage, and farm management (Naveed & Anwar, 2013). Furthermore, assessing the difference between older and younger farmers concerning their information needs, it was established that age differences influence farmers' information needs. Older farmers were identified to be inclined to administrative information, market information, and livelihood issues, while younger farmers were more concerned about technology and labour information (Zhao, 2007). Moreover, Nikam et al. (2022) specifically assessed the information needs and sources of information for cotton farmers in two regions in India. the study showed that the information needs of the farmers in the two regions varied significantly. The cotton farmers who produced under irrigation had a positive impact from the information they received from the technical officers. On the other hand, the farmers who produced under rainfed did not have any positive results from the same information received from the technical officers. The study concluded that general information might not yield the same result with different farmer groups; hence, agricultural information is needed to suit different farm groups.

Singh et al. (2013) surveyed 102 dairy farmers in Punjab State to ascertain their information needs and seeking behaviour. The results from the study showed that more than 70% of dairy farmers needed information on government subsidies, feed, and fodder, while about 65 percent sought information on animal breeding and animal health.

Animal nutrition and feeding information, reproduction, health care management, and general management information were prominent information sought by animal breeders (Subash et al., 2015). Byamugisha et al. (2010) observed that urban farmers in Kampala's information needs were diverse, and the information they obtained was used for different purposes due to the heterogeneity of their farming enterprises. Also, a study of 150 poultry farmers in rural communities in Ghana revealed that the major information needs of poultry farmers were, egg storage procedures, feed and nutrition, vaccination, pests and diseases management, shelter, pesticide application, debeaking, and marketing; while lack of skills to access information and inadequate poultry resources were identified as the major constraints to poultry farmers information access (Folitse et al., 2018). Moreover, an assessment of fish farmers information needs in Tanzania revealed that farmers need information on water quality treatment, fingerlings management, spawning operations, fish preservation, and processing (Benard, 2018).

Available literature shows that gender influence information needs of different farmer groups significantly. In Ethiopia, Men needed information such as agricultural marketing, soil fertility, and farm management, while women sought information on value-addition techniques, crop planting, and irrigation (Lwoga et al., 2010). Available literature found that women in agriculture in Nigeria need information on agricultural climatology, soil improvement, farm credit, and farm management, besides having access to improved seeds, market prices, and other agricultural inputs (Okwu & Umoru, 2009; Sabo, 2007). Furthermore, a study of rural farmers in Maharashtra information needs was chiefly on seed availability, crop production, pesticide availability, irrigation water management, and weather updates (Bachhav, 2012).

The review identifies that agricultural information is complex, heterogeneous, and time-bound. Farmers need this information to plan their production activities, purchase input, and farm operations. Empirical literature study has demonstrated that agricultural information output is varied and extensive; therefore, it needs to be created, transferred, and used by farmers based on their need for information. From the foregoing, it may be said that farmers, wherever they are, require diverse information, whether scientific, commercial, or legal, as long as that information hinges on their success. Consequently, any farmer who sells his produce will need commercial information in the same way that he or she will need information about the weather, soil, buyers, and loan facilities.

2.11 The influence of language on farmer technology adoption and usage

The importance of language in communication and assimilation of scientific content among farmers cannot be downplayed. Messages sent to farmers in languages they easily understand reduce barriers to communication, promote mutuality, and speed up technology adoption (Asenso-Okyere & Mekonnen, 2012). In societies where there are many ethnic groups with different languages and cultures, the use of foreign languages as official language sometimes affects usage, access, and trust in new technologies (Ninsiima, 2015). Many of the emerging digital technologies usually come with English as the primary language for their setup, and very few of them incorporate other languages in them to give users options to select from. However, the presence of local languages is mostly eliminated from these options. The increasing use of only foreign languages in the development of technologies meant for farmers and extension communication poses a major challenge to farmers' adoption and utilisation of these new technologies since the large majority of smallholder farmers, especially in developing countries, are not literate and lacked the basic training and skills (Chisama, 2016). Additionally, the adoption of only foreign languages in the designing of digital technologies, such as mobile apps and the like sometimes do not factor in the cultural environment of the farmers, this further affects their adoption or usage. Technologies that are wrapped in the languages understood by the farmers increase familiarity (Wamala, 2010).

In Nigeria, a study of the effect of multilingual farm broadcasts on access to agricultural information by Oladel (2006) established that for farmers to understand and benefit from the information shared on radio or television, the language of the programme should be in the local language that the farmer understands. The study also recommended that programmes and technologies meant for farmers should explore multilingual sources to ensure farmers benefit fully from them. Also, Peters et al. (2012) reiterated that when information retrieval is combined with language translation in modern technology devices, it helps monolingual users access important information in other languages in their native language. The author further exemplified that such methods have been implemented and given proven results in agribusiness, rural economy, and marketing in countries like Vietnam, Indonesia, China, and Japan (Oladele, 2006). for agriculture information to be useful and widely accessible, the agricultural information should be recorded and indexed in local languages; this would serve as a great opportunity for addressing the information asymmetry between the extension, research, and farmers (Das et al., 2016; Oladele, 2006).

Furthermore, in the quest to explain the importance of language in sociocultural development, Prah (2001) explained that in Africa, the cultural base of the general society, which is established on African languages, offers the genuine means for the development of a society which includes the masses and raises them socio-culturally and economically from where they are based on what they possess. Many farmers regarded the same language with the extension agent as critical, as they could understand the agent's technical information better than through an interpreter.

Jain et al. (2018) designed a conversational agent called FarmChat to meet the information needs of smallholder farmers in India. An evaluation study of the system with 34 farmers guided by the system's usability, acceptability of the system information, and understanding of users' unique preferences, needs, and challenges faced with the system. The study results from the 626 inputs provided by the farmers showed that the farmers liked FarmChat's preciseness and responses in local languages. They also expressed great interest and trust in its information, found it easy to use, and stated that the chatbot has the ability to meet their daily farming information needs. Moreover, Cameron (2016) conducted a feedback study on Plantwise implemented programmes using a mixed-method approach. The study revealed that the Plant doctor and Knowledge Bank application users were comfortable using plantwise materials in their local languages and therefore requested that more materials be produced in their local languages to reinforce understanding. The study further observed that plantwise materials had been developed into about 18 languages. Additionally, the online Knowledge Bank incorporates google translate to factsheets into about 70 languages to make agricultural information easily accessible across many geographical areas.

A study into how ICT can serve as a bridge to social equity and sustainable development in India by Mehta and Kalra (2006) reviewed that inadequate ICT content in local languages creates challenges for the dissemination of ICT initiatives implemented by the various local governments and private enterprises. The study echoed that the support for local languages and their incorporation into applications appropriate to farmers and rural people will greatly influence how farmers and rural dwellers see these applications as an urban intrusion or a tool designed to meet their needs. The content available in most ICT initiatives must be localised, considering the various languages available in the regions. An observation was made of an initiative made by Hewlett Packard and other agencies working on integrating local Indian languages into new technologies that will enable masses of the rural population to use new technologies. This initiative aims to reduce the digital divide between the literate and the less literate. A prototype of a system that enables farmers and other users to call in and query a server using a voice command for information from its database has been developed. Based on the query, the appropriate news is then played back to the users. Also, a system that operates on technologies such as automatic speech recognition, VoiceXML (Voice Extensible Markup Language) to specify the dialogues, a text-to-speech engine for playback of typed-in content and multimedia has been configured to support spoken Hindi and Telugu, the two widely spoken languages in India. The development of software like word processing, spreadsheet, and others that support local languages will go a long way to enable wider use of ICT initiatives in India. Also, if such technologies appropriately adapted to the local dialects of the regions could reduce much of the handicap posed by illiteracy in rural areas. ICT initiatives cannot achieve the scalability desired for financial sustainability without having content made in their native languages (Mehta & Kalra, 2006). The poor rural farmers know a great deal; they can identify their needs and know their circumstances, problems, and aspirations more than anyone else. Therefore, technologies meant for them should have local contextualised information and languages more than foreign languages. The technology contents that are not limited to alien languages but rather extend to local ones ensure that the farmers are able to understand the content of information delivered to them (Ccchini & Scott, 2003).

In many developing countries, radio reaches many people, but agricultural information transferred through such an ICT medium does not necessarily reach many people. Most often than not, there are many local languages and dialects that digital information can be translated into, but due to the cost of translation, it is often ignored, which accessibility of this important information by the masses (Islam & Grönlund, 2011). Translating ICT message content into local languages and using easily understandable words were useful for better understanding and motivating farmers to implement recommendations. Although some translated contents were slightly difficult for some farmers to comprehend, many considered the messages appropriate and well-understood. Farmer stated that translating messages into local languages was a welcome idea (Makau et al., 2018). However, in a survey of 93 farmers' households using self-administered questionnaires by Awili et al. (2016), in the quest to analyse the factors influencing effective communication of agricultural information among farmers in Kisumu County in Kenya, the study found language barrier as the key hindrance to effective communication between farmers, extension agents, group leadership and agricultural input dealers. Language barriers also constrained the understanding of farmers education programme on the radio (Awili et al., 2016). Similarly, illiteracy, linguistic diversity, linguistic deficit, and technology deficit were also documented to include the nature and type of language barriers (Egbokhare, 2004).

Also, in Nigeria, English illiteracy was observed to be a key barrier to access to modern digital technology devices that serves as a link between producers, input, and the produce marketers (Sani et al., 2014; Oladele, 2006). With the poor literacy level of farmers, and the low level of education among agricultural extension agents, the adoption of multilingual to provide agricultural information in Nigerian languages will increase the exploration of information services. Translating technical information into several local languages is critical in agriculture because it is often important for the end user who does not master the source language due to low literacy levels (Vidanapathirana, 2012).

Anoop et al. (2015) analysed ICT-based market information services in Karal using a structured interview and the logistic regression model. The results from the study showed that the language barrier was among the top problems farmers faced in their use of new digital technologies since most of the internet services were in English. Also, Baddegamage (2014) observed in a study that analysed ICT in the Sri Lankan cinamon industry that English being the main language of new technologies became a barrier to many farmers ICT adoption. The less educated farmers in Northern Nigeria were also observed to face difficulty using existing mobile phone applications in the area due to their lack of content in the local language, which is Hausa. It was therefore put forward that those special mobile applications customised to the indigenous language of the farmers be produced to increase agriculture information dissemination and technology adoption (Anadozie, 2022).

Furthermore, Dey et al. (2001) found in their study of Bangladesh farmers use of mobile phones for communication that language posed a great impediment to rural farmers use of mobile phones. They explained that many of the mobile phones found on the market support only the English language, and most farmers in rural Bangladesh were less educated and lacked proficiency in English; as a result, they were not able to understand the technical terminologies such as user busy, out of network area, low battery, and others. Their study concluded that these language difficulties cause anxiety among farmers, which could result in low patronage of these new technologies.

2.12 The role of Agricultural extension in innovation transfer

Agricultural advisory or extension services have gained popularity widely due to the systems' ability to transfer agricultural knowledge, information, technical advice, and new innovations to farmers and rural inhabitants using various methods. The modern extension has its background from the Green Revolution era, where new technologies, practices, and knowledge were used to increase grain production to feed the world after the Second World War (Cook et al., 2021; Pingali, 2012), although the history of extension can be traced to earlier efforts meant to control rural population (Bartlett, 2010). Agricultural extension programmes have been key instruments used to address poverty, unemployment, and food security issues in rural areas around the world (Danso-Abbeam et al., 2018). This is because extension programmes are farmer-centred, combining local knowledge and practices with new technologies to support rural adult education, provide farmers with problem-solving skills, and stimulate smallholder farmers and rural dwellers interest in agricultural knowledge and information system (Kirt et al., 2022; Altieri et al., 2012).

The FAO (2010) defines agricultural extension as; "systems that should facilitate the access of farmers, their organizations, and other market actors to knowledge, information, and technologies; facilitate their interaction with partners in research, education, agribusiness, and other relevant institutions; and assist them in developing their own technical, organizational and management skills and practices." By the FAO's definition, extension functions as a support service that facilitates the connection between knowledge, business, research, and personnel. It, therefore, serves as a platform for making agriculture, business, and other agriculture-related services more operational and efficient to meet people's needs (Danso-Abbeam et al., 2018; Bonye et al., 2012). The international Food Policy Research Institute (IFPRI) explained that agricultural advisory, also called agricultural extension, contributes immensely to farm productivity increase, food security, and rural livelihood enhancement, supporting agriculture as a pro-poor economic growth engine (IFPRI, 2020). The agricultural extension uses different approaches and techniques to introduce new products and services to farmers to diversify their production and income-generating activities. This helps them to be more resilient to unexpected shocks that may beseech them in their farming business (Nyarko & Kozári, 2021). Davis and Franzel (2018) opined that the agricultural advisory service could serve as an instrument to assist smallholder farmers in breaking the cycle of low productivity, climate change vulnerability, food insecurity, and poverty. Also, the extension could serve as a good medium to provide farmers with undiluted information and knowledge on new agricultural practices, market solutions, and access to finance (FAO, 2019; Francis, 2014). This information is very important to smallholder farmers, who are the main engine behind the agriculture and food supply value chain in most developing countries. Extension services use multiple tools that encompass educational methodologies, communication techniques, group dynamics, and practical approaches to share knowledge, promote technologies, and communicate new information to rural and smallholder farmers (Sousa et al., 2016).

Promoting agricultural innovations adoption among smallholder farmers requires a clearer understanding of how the innovations work and the long-term benefits associated with the innovation. Therefore, extension agents' technical skills, knowledge, and experience in using digital technology are imperative to support smallholder farmers information needs. ICTs have been appraised to be a medium that could offer up-to-date information on farm productivity, facilitate rapid information exchange among actors in the agricultural value chain (Annor-Frempong et al., 2006); the rightful knowledge of extension services in their application will ease their workload as well as promoting quality service delivery. In a study of digital technology applications in agricultural extension delivery, Tata and McNamara (2018) found that extension officers who had knowledge of ICTs and adopted them in the Catholic Relief Services SMART

Skill and Farm book (CSSF) project increased their work with farmers more than the agents who did not adopt ICTs. The study concluded that the adoption of CSSF enhanced extension agents' competency, which made them more comfortable using the internet than other extension agents. Extension services around the world continue to reform their mode of operations, policies, and practices to meet the increasing information needs of farmers that advancement in agriculture presents. The agricultural extension sector in Ghana is no option for this tread.

2.13 Agricultural Extension System in Ghana

Agricultural extension services evolved strongly in Ghana in the early 1970s to respond to the World Food Crisis when there was an urgency to increase agricultural productivity in the country (Antwi-Agyei & Stringer, 2021). Today, agricultural extension services adopt the pluralistic extension approach, which involves multiple actors such as the government (MOFA), NGOs, private companies, and cooperatives working together.

2.13.1 Public sector extension system

The largest body that offers agricultural extension services in Ghana is the State, through the Ministry of Food and Agriculture (MOFA) and the Directorate of Agricultural Extension Services (DAES). MOFA has offices in all the regions and districts in Ghana with technical officers from the public extension directorate who support farmers with extension advisory services. The public extension system in Ghana, like in many other countries, has gone through so many reforms after Ghana's independence. Initially, the agricultural extension approach practiced under the public extension system in Ghana was the Training and Visit (T&V) model. The T&V extension model faced numerous challenges, including a lack of innovations and rigidity in its implementation and practice (Klerkx & Gildemacher, 2012). It was later reorganised to form the Unified Extension System (UES).

The Unified Extension System (UES) assembled all the segmented extension services in other departments under one big umbrella called the Directorate of Agricultural Extension Services (Rivera & Alex, 2004). Under this new extension approach, agricultural extension agents performed multiple tasks instead of specialised activities. This type of extension approach used the top-down approach of information dissemination, i.e., the decision-making, programmes, and policies were made by the body responsible for the extension services without the inputs of the farmers who were the direct beneficiaries of the extension programmes (Munthali, 2021). The Unified Extension System (UES) received lots of criticism and backlash from stakeholders and industry experts due to its inability to coordinate farmers and stakeholders in problem-solving (Havard et al., 2011), its poor linkage of agricultural value chain actors, and lack of localised contents for farmers (Karpouzoglou et al., 2016; Lambrecht et al., 2015; Klerkx & Gildemacher, 2012). The extension activities under the UES were designed based on the objectives and standards set by the DAES. This centralised system of operation brought up questions about the ability of the extension system to respond farmers and rural people needs effectively. As a solution to the Unified Extension System (UES) impasses, the Ministry of Food and Agriculture decentralised the operation of the extension services in 1997 (MOFA, 2002). District Agriculture Development Units (DADU) were established in all the districts of Ghana. Under the decentralised extension system, the concept of demand-driven extension services was implemented with the aim of increasing total productivity, farm income, and improve farmers livelihoods (Rivera & Alex, 2004). The decentralised extension system provided the best opportunity to actively involve stakeholders to promote pluralism which is now the core of agriculture and rural development in Ghana. Today, Ghana's public sector extension practice has shifted from the top-down, one-size-fits-all approaches (T&V) to more inclusive participatory approaches such as commodity-based participatory, the farmer field school, and, more recently, the innovative ICT-based approaches (DAES, 2011). The new approaches encompass strong science, research, and extension linkages with a wide range of service providers such as the government (MOFA), Non-Governmental Organisations (NGOs), and the private sector working together to support farmers in diverse ways.

2.13.2 Private sector extension provider

Anumber of private companies offer agricultural extension services to farmers. unlike the public extension system, private extension companies usually focus on specific commodities like cocoa, oil palm, rubber, cotton, and horticultural crops. Other private companies offer general extension services to farmers but on subscription or contract bases. The private extension companies in Ghana are mostly into input supply or commodity-buying companies (Rivera & Alex, 2004). They offer extension services to farmers that purchase their services on credit; the company and the farmers go into an agreement, the farmer agrees to receive the inputs and the extension services for the whole production season, and in return, the farmer sells the farm produce to the input dealing or commodity buying company (DAES, 2011). The scope of the private extension services does not extend to farmers outside the contracting group; therefore, the extension of their services to other farmers will depend on the type of crops produced, the profitability level, and the market demand for the crop or commodity (Munthali, 2021).

Also, there are Non-profit Organisations (NGOs) that offer extension services to support what the Ministry of Agriculture offers. They play prominent roles in the extension and advisory services in Ghana; NGOs into extension can be classified into donor-funded projects (the Netherlands Development Organization (SNV), AGRA), international NGOs (World Vision, Action Aid, and Catholic Relief Services) with independent funding streams, and domestic NGOs (Community Aid for Rural Development (CARD), Social Enterprise Development Foundation (SEND)-Ghana (Moore et al., 2015). They focus mainly on improving farmers livelihoods (MOFA, 2002). However, the NGOs usually do not have their own extension agents; they fall on the ministry of agriculture for extension agents. They often provide resources like Motorbikes, fuels, and others to cushion the mobility of the extension agents. The NGOs form of extension support service often increases the workload on the public extension agents. They sometimes compete with MOFA for the limited number of extension agents available. The NGOs extension system can be effective when they concentrate more on farmer-to-farmer extension services, which are less costly and less demanding. Aside the NGOs in extension services, cooperatives, and farmer association extension services also exist.

Farmer cooperatives support their member with product-specific information, guiding them on procedures and protocols to observe to achieve standardisation for products. They also provide a member with market information, input prices, and link them to producers and buyers. Cooperatives operate in the frame of mutuality.

2.14 Agricultural extension agent's role in technology transfer

The main role of extension is to influence farmers' decision-making and skills to adopt and apply agricultural innovations. Basically, how agricultural information is delivered to farmers by extension agents has changed with time as new sets of information and communication technologies evolve. Also, changes in extension communication have been driven mainly by social and economic activities, such as structural changes in agriculture as a result of economic development, the emergence of new digital technologies, and decentralisation of agricultural activities (Norton & Alwang, 2020)

Agricultural extension officers, also called rural advisors, serve as the principal technical advisors assisting farmers with technical information to support their production and other farming activities. In Ghana, extension officers are usually assigned to farmers in a specified geographical location called "operational areas" they live among the farmers in the operational area or a nearby town and are mandated by the Ministry of Food and Agriculture or private entities to disseminate proven and recommended agricultural innovations to the farmers in the area. They also play the role of livelihood enhancement promoters through home and farmer visits (Nyarko & Kozári, 2021; MOFA, 2016). Extension officers in Ghana, therefore, serve as the first point of contact on issues relating to agricultural production, agribusiness, rural development, and some extent, food and nutrition security. Additionally, they empower women, marginalised groups, farmer associations, and other identifiable groups in rural areas with the requisite knowledge, attitude, information, and practices to enhance their welfare (Azumah et al., 2018). The knowledge, attitude, and competence of an extension agent are very important in this regard. Because they spearhead food and agriculture information in rural areas, any inaccurate information, practices, or procedures given by the extension agent will go a long way to affecting farmers productivity, livelihood, and future technology adoption. They should therefore be in the position to have good knowledge of the subject matter, technical issues, and knowledge on new digital technologies to assist farmers in using them to their advantage (Purnomo & Lee, 2010). Past study has demonstrated that agricultural extension can play a critical role in farmers technology adoption through extension educational programmes (Richards et al., 2018); therefore, extension agents must be versatile in knowledge, embrace challenges that new technologies introduce, and be prepared to use them to support farmers to adopt and adapt innovation and ideas (Karubanga et al., 2016).

The usage of digital technologies among agricultural extension agents is influenced by multitudes of factors, ranging from institutional and infrastructural factors. A study of extension advisors in Iran identified officers' level of education and English proficiency as the leading factors that affected their ICT application in extension activities (Haghighi, 2008). Also, Annor-Frimong et al. (2006) observed that low economic status, ICTs phobia, high cost of ICT devices and services, and ICT policy and infrastructure were the leading factors constraining ICTs use and application in extension advisory services in Ghana. Similarly, an analysis of factors impacting Caribbean farmers new technologies adoption identified extension officers' ICT knowledge as one of the key factors that affected farmers use and application of innovations (Strong et al., 2014). Also, past study findings suggest that individuals' perceptions are key determinants of digital technology use (Park et al., 2022). Thiga and Ndungu (2015) observed a lack of awareness as the main reason for extension agents not using ICTs for extension delivery in Kenya. The extension agent's knowledge of ICT use influences how they gather information, the speed of disseminating information, and how they respond to farmers needs in a timely manner.

However, Nyarko and Kozári (2021) studied the use of (ICT) among agricultural extension agents and its implications on extension delivery in Ghana and found that the most pressing factors that influenced extension agents' ICT use were poor network connections, lack of ICT training opportunities for extension agents, and inadequate ICT infrastructure. The primary factors found in theoretical and empirical literature impacting extension agents' digital technology use include but are not limed to education, income, agents' taste, risk aversion, and access to information and training (Norton & Alwang, 2020).

2.15 Role of digital extension service

Digital extension or e-extension encompasses the use of smartphones, digital applications, text messages, audio messages, and videos to complement the traditionally known extension models with the aim of reaching masses of farmers within the shortest possible time. Digital extension can bring to scale the traditional extension models and can fill up the absence of technical assistance and extension agents, and at the same time, carry technical information to the marginalised communities. Digital extension services can be adapted to communicate with both farmers and extension agents, deliver practical knowledge on agricultural production, and share important information on the use of other electronic devices, thus reducing the effects of the digital divide. They can also function as emergency support units to farmers through a will-packaged call centre, mobile apps, or other digital platforms providing important technical assistance to farmers on issues relating to their fields of production. Moreover, research has found that agricultural extension education through ICTs to help farmers raise yield in Kenya, Burkina Faso, and Asia (Pan et al., 2018). It also helped increase the value per hectare in Southern Africa (Owens et al., 2003). Additionally, Van Campenhout (2017) noted that an extension service offered through mobile phones positively influenced household crop choices.
Governmental organisations, NGOs, private establishments, and start-ups are actively developing or introducing digital extension services to either cushion the traditional extension services or take over the entire role of extension delivery in areas where the traditional face-to-face extension services is not accessible.

3. MATERIALS AND METHODS

This section of the study covers detailed description of the study areas, the research methods used, the study population, sampling techniques, data collection and analysis procedures.

3.1 Study areas

The study was conducted in the Ketu North and Ketu South Municipalities of the Volta region in Ghana. The Volta region is located in the south-east part of Ghana; it shares boundaries with the Republic of Togo to the east, to the west with Greater Accra, Eastern, and Brong Ahafo regions, to the North with the Northern region, and to the South with the Gulf of Guinea (Ghana Statistical Service, 2014).

The region has a tropical climate characterised by temperatures between 21-32 degrees Celsius. It has two rainfall seasons: March to July (main season) and August to October (minor season). The region is also unique in agroecological zones, which consist of the Sahel-Savannah and mountainous wooded savannah in the North, the semi-deciduous forests zone in the central, and the coastal grassland, mangrove swamps towards the South. The average rainfall in the region ranges between 1168 mm and 2103 mm (Nyatuame et al., 2014). These unique climatic features place the region higher above other regions in terms of diversity in agricultural production.

Specifically, the Ketu North and South municipalities were selected for this study due to their strategic locations and diversity in agricultural activities. The municipalities are located along the Accra-Aflao main highway. The Ketu municipalities are unique because they share a boundary directly with Lomé, the capital of the Republic of Togo, to the east, to the South with the Gulf of Guinea, and to the west with the Keta Municipal. The two municipalities together occupy a land size of 851 square kilometres with a population of about 367,963. more than 80% of the population speaks the ewe language, the dominant language in the region (City population, 2022). The average annual rainfall in the two municipalities is the same, which is 850mm towards the coast and increases to about 1270mm upland (MOFA, 2011). The municipalities have the dry equatorial climate type, which consists of Savannah woodland of short grassland, small clumps of bushes, and trees towards inland, while the coastal area has coastal scrub, grassland, and mangrove forests in the marshlands (Ghana Statistical Service, 2014). The areas towards the South of the municipalities have about 30 kilometres of the lagoon, stretching from Blekusu to the Keta lagoon; this provides means for aquaculture farming. Additionally, there are about ten fishponds covering a total area of about 5.05 hectares in the area.

Figure 12. Smallholder agricultural activities in the municipalities. (Field data, 2021)

Agriculture forms the primary occupation in the area; it employs about 70% of the working population in the municipalities. Almost every household in the area engages in agricultural activity. Farming in the area is predominantly small-scale. Farm sizes range from 0.5 hectares to 2.5 hectares (MOFA, 2011). The commonly grown crop in the area includes maize, cassava, sweet potatoes, cowpea, rice, Mango, coconut, and vegetables such as okro, onion, carrot, pepper, and others. Also, due to the municipality's closeness to the Atlantic Ocean, fishing activities form a major part of agricultural activities. It is estimated that about seven thousand eight hundred and eight-two (7,882) fishermen are found in the municipality (MOFA, 2011). The major farm animals raised in the area include but are not limited to cattle, sheep, goats, pigs, grasscutters, and poultry. Additionally, the processing of agricultural products such as gari, tapioca, biscuits, fish, starch, and poultry feeds is commonly practiced in many parts of the municipalities.

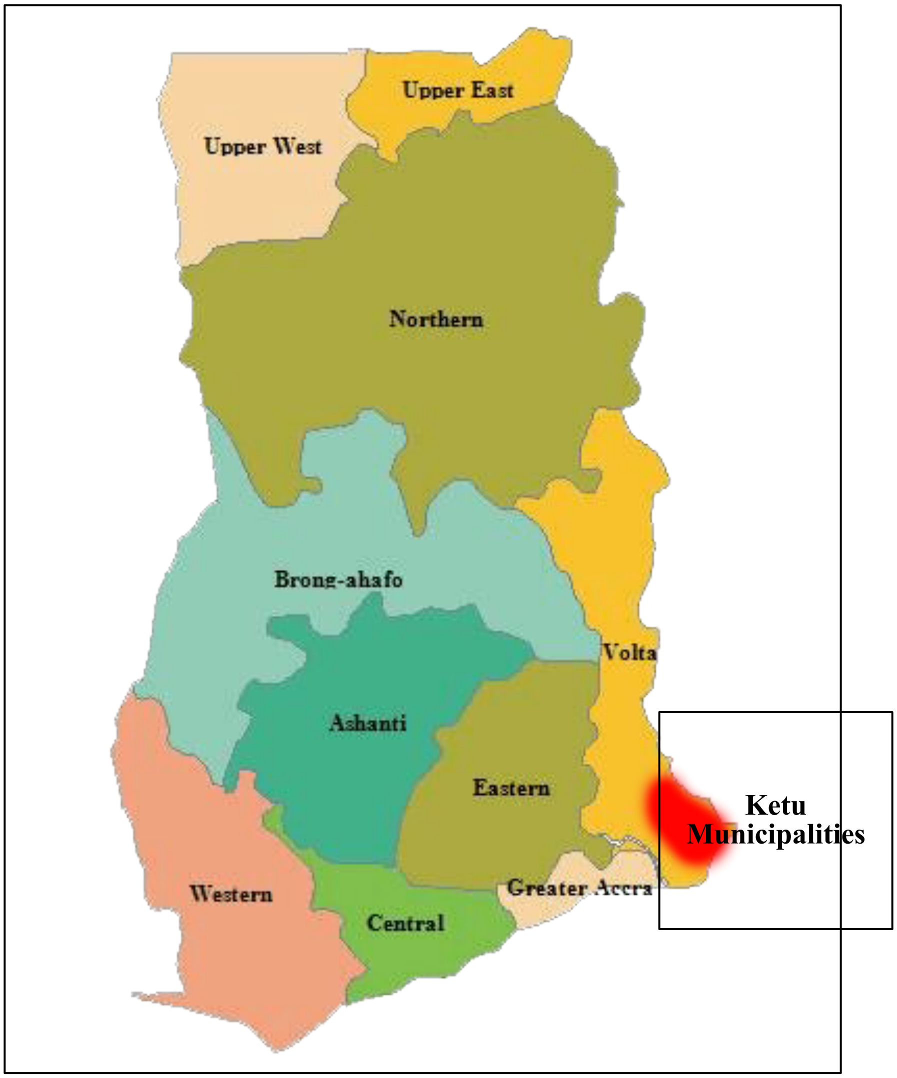

Figure 13. The map of Ghana shows the study area *(*Ghana Statistical Service, 2010)

3.2 Data collection

The study employed a mixed-methods research approach. Mixed methods research design focus on collecting both quantitative and qualitative data in a single study. They help provide deeper and better data for describing and understanding phenomena (Venkatesh et al., 2013). Mixed methods are mostly used in studies designed to gain a holistic understanding of a situation from different points of view. It, therefore, combines responses from interviews or observations with numerical data from surveys (Creswell & Creswell, 2017). Past studies (like Inkster et al., 2018; Makate et al., 2016) have used a mixed methods approach to assess farmers technology adoption in diverse ways. This study used mixed methods approaches to gather smallholder farmers opinions through interviews and establish relationships between dependent and independent variables from the survey.

3.2.1 Population and sampling techniques

The population of a study was described by Kalton (1983) as an element of units under study. The elements could be persons, households, farm enterprises, institutions, or any other unit. In this study, the population consists of small-scale farmers who are crop producers, animal farmers, agro-processors, and fish farmers. Smallholder farmers were selected for this study because they constituted most farmers in the study areas. This study adopted the exploratory sequential research approach: qualitative data collection was first conducted, followed by quantitative data collection. The data collection was done in three phases.

3.2.2 Data collection phase one

In order to gain insight into the digital environment and farmers information needs in the study areas, qualitative data were collected through focus group discussions and one-on-one interviews. Prior to the qualitative data collection, the main researcher established contact with the extension agents at the municipal department of agriculture in the study areas to discuss the research objectives and to help the researcher identify the main categories of farmers in the study areas. The categories of smallholder farmers in the study areas were identified based on the research objectives and interaction with extension agents. The researcher, together with the extension agents, agreed to organize four focus group meetings. The extension agents were informed to arrange separate meetings with the identified smallholder farmer categories. The extension agents were given enough time to find the appropriate time suitable for most participants to schedule the meeting. The first focus group meeting was scheduled after two weeks of meeting the extension agents. The participants of the first focus group meeting were crop producers; they were twenty-one in number; the second meeting consisted of fifteen livestock farmers; the third meeting was for fish farmers and fisher folks, they were eighteen participants, and the final meeting consisted of nine agro-processors.

Participation in the focus group discussion was open to all members of each farmer category. Prior to the meeting, the participants were informed of the objectives of the study, the topics to be discussed, and the data that would be collected. The participants were also informed that their participation in the research was voluntary, and in case any of them felt they could not continue again, they could leave at any time without any loss or cost to them. Before the focus group discussions, the lead researcher recruited three staff from the department of agriculture as research assistants to help collect data and interpret the local language when necessary. The recruited staff were given three days of training on data collection and recording. The training session was also used to explain the questions in the questionnaire to them. During the focus group discussion, participants were also asked to complete a questionnaire that captured their demographic and general data on their farming activities.

Figure 14. Focus group meeting with smallholder farmers (Field data, 2022)

Two days after the focus group discussion, nine participants who had used digital agricultural platforms before were randomly selected for a one-on-one interview to enquire more about their experiences with the use of digital agricultural platforms. This was done to get in-depth information. The data from the focus group discussion were recorded by all four members of the research team. The notes were later compared and coded, and themes were generated for discussing the results.

3.2.3 Data collection phase two

Phase two involved the collection of quantitative data.

3.3 Sample and sampling techniques

The research team could not get the total population of smallholder farmers in the municipalities from the department of agriculture, so the study used multistage sampling techniques to select the sample for the quantitative data.

First, the municipalities were divided into two (Ketu North and Ketu South) based on the original demarcation by the Local government System. Secondly, the towns in each municipality were grouped into three zones based on the operational areas zoning used by the agricultural extension department. Altogether, six zones were created in the study areas.

The sample size for the study was calculated using the Qualtrics sample size determination of unknown population size (Qualtrics, 2020). According to the Qualtrics formula, when the marginal error is +\- 5%, the confidence level can be 90%, 95%, and 99% confidence intervals. The standard deviation should be 0.5, while the Z-score (standard score) should be 1.96 to give the correct sample size.

Formula

$$\text{Sample size } (\boldsymbol{n}) = \frac{(\text{Z-score})^2 \times \text{StdDev} \times (1-\text{StdDev})}{(\text{Margin of error})^2}$$

$$\text{Sample size } (\boldsymbol{n}) = \frac{(1.96)^2 \times 0.5 \times (0.5)}{(0.05)^2}$$

The formula gave a sample size of 385; however, to reduce the error that may have occurred during the multistage sample procedures and unreturned questionnaire, the sample size was adjusted by a 7.5% increment. This increased the sample size to 414. Based on the sample size, each zone was allocated a sample size of 69. Simple random and purposive sampling techniques were used to select the respondents in each zone. Purposive sampling techniques were used to select all the participants who took part in the focus group discussion. A simple random sampling technique was used to select the remaining respondents by assigning numbers to the households. All the households with odd numbers were selected to participate in the study. Table 1 gives details of the zoning of the study area and the total sample size.

Table 1: Study areas and sample selected.

Area	**Zones**	**Selected sample**	
North	One	69	207
	Two	69	
	Three	69	
South	One	69	207
	Two	69	
	Three	69	
Total			414

(Author's own construction, 2022)

3.4 Instrument and data collection procedures

The questionnaire for the study was developed by modifying past research questionnaires developed by (Weng et al., 2018; Sánche & Hueros, 2010) in addition to developing new questions by the researcher. The questions were a combination of dichotomous, Likert scale, nominal, and open-ended. As part of establishing content and face validity, a pilot study was carried out prior to the main data collection. The questionnaire generated was evaluated by a team of experts consisting of Senior technical extension officers at the department of extension, researchers, and social science lecturer at the Hungarian University of Agriculture and Life Sciences. The panel members have more than ten years of experience in their respective fields. Twenty farmers participated in the pilot study. Additionally, to establish reliability, a pilot study was conducted with fifteen farmers.

The questionnaire contained closed-ended questions. Reliability is the measure of internal consistency of the constructs in a study and is considered reliable when the Alpha value is greater than .70 (Hair et al., 2013). The questionnaire contained closed-ended questions. The overall reliability of the model was .871. Based on the pilot study results, some of the questions that were not clear to the respondents were modified.

The questionnaire was self-administered with the assistance of three enumerators who resided in the regions the study was carried out. Before administering the questionnaire, the enumerators were given three days of training on how to assist respondents, especially those who could not read or write in the English language. Also, Enumerators were taken through each question to ensure they understood them before the commencement of the data collection. The enumerators assisted the respondents by interpreting the questions for them to select their preferred answers. The farmers who could answer the questionnaire on their own were given the questionnaire to fill out and return later. The second phase of the survey was conducted between August and November 2021.
The final survey was conducted between July and September 2022.
During the survey, 414 questionnaires were distributed, but 408 were returned, and after crossing-checking, five were excluded due to multiple responses to questions that require one response. Therefore, a total of 403 questionnaires were accepted for the analysis.

3.5 Data analysis

The qualitative data were analyzed by coding the interview responses to generate major themes. Direct quotations of key expressions were used while withholding the names of the participants.
The quantitative data were entered into the Statistical Package for the Social Sciencess (SPSS) software version 27 and Microsoft excel. The quantitative data collected from the respondents includes demographic variables such as gender, age, income, educational levels, marital status, ownership of ICT devices, holding size, household size, and variables related to digital device access and availability. The demographic data were analyzed using descriptive statistics displayed in tables and graphs. Microsoft Excel was also used to analyzed and classified farmers into the various innovation adoption categories. Logistic regression was used to establish relationships among variables. The outputs were presented in tables and figures and interpreted based on the statistical output, reviewed literature, and objectives of the study.

3.5.1 Calculation of adopter categories

The study adopted the Hurt et al. (1977) innovativeness determination scales to classify the respondents into the five main innovative categories proposed by Rogers. The scale was a valid Likert scale appropriate for a self-administered questionnaire or face-to-face interviews. The purpose of the scale is to measure individuals' degrees of innovativeness. The scale does not focus on the technologies but rather the individual attitudes towards the technology or the innovation. The scale has been used in past studies (like Kaushik & Rahman, 2016; Chao et al., 2012) to demonstrate its psychometric characteristics. The scale contains twenty items created based on Roger's innovativeness categories. For instance, "I am challenged by ambiguities and unsolved problems" is considered an innovator or early adopter, while "I am suspicious of new ideas" is considered a late majority or a laggard. The scale is measured on five Likert scales, with 1 representing strongly disagree and 5 representing strongly agree.

The adopter categories of the respondents were calculated based on the innovativeness scales developed by Hurt et al (1977).

The formula proposed was Adopter (II) = 42 + TPA -TNA.

TPA represents total positive attributes; TNA represents total negative attributes, while 42 is a constant value of the scale of the innovation.

First step: the TPA was obtained by summation of 1, 2, 3, 5, 8, 9, 11, 12, 14, 16, 18, and 19.

Second step: the TNA was obtained through the summation of 4, 6, 7, 10, 13, 15, 17, and 20.

Third step: TPA was added to 42 and then subtracted TNA from the total to obtain the value for the adopter category of the individual. This was done for all the respondents using Microsoft excel.

Scores interpretation:

A score above 80 is categorised as an innovator.

A score between 69 and 80 is categorised as Early Adopter

A score between 57 and 68 is categorised as Early Majority.

A score between 46 and 56 is categorised as Late Majority

A score below 46 is classified as a laggard,

The scores were presented with a graph.

3.5.2 Econometric Model employed

The binary logistic regression was employed to model the various factors influencing farmers' intention to use the DAIP. The binary logistic regression became the preferred model over others because, according to the diffusion of innovation theory, innovation adoption or use has a binary response; either farmers accept to use or reject the innovation (Rogers, 2003). Logistic regression is a linear regression model that employs a logistic function to model the likelihood of binary observation bounded between 0 and 1 (Belyadi & Haghighat, 2021). It is a probabilistic model that uses dichotomous variables to establish the relationship between a categorical dependent variable and one or more independent variables. Past studies (like (Uddin et al., 2014; Fosu-Mensah et al., 2012) have used the logit model to model farmers' innovation adaption strategies.

In this study, the model is adapted to model the effects of farmers' demographic factors, farm factors, ICT tool access, or possession on their intention to use a new DAIS. Table 2 is a description of the variables.

The likelihood that a farmer will use the DAIS in the study area is represented by R_i. Therefore,

$$Prob(Y_i = 1) = R_i = F(T_i) = F(\alpha + \sum \beta_i X_i) = \frac{1}{1+e^{-T_i}} \quad (1)$$

Xi denoted the independent variable; α and β are variables to be determined. Also, the likelihood that a farmer will not use the DAIP is denoted by 1- R_i. Equation 2 can therefore be represented by

$$Prob(Y_i = 0) = 1 - Prob(Y_i = 1) = (1 - R_i) = \frac{1}{1+e^{-T_i}} \quad (2)$$

From equations 1 and 2, equation 3 can be written as

$$\frac{Prob(Y_i = 1)}{Prob(Y_i = 0)} = \frac{R}{1-R_i)} = e^{T_i} \quad (3)$$

R_i is the probability that Y_i takes the value 1, and 1-R_i is the probability that Y_i is 0, where e is the constant of the exponent. When a log is taken with equation 3, it gives equation 4.

$$T_i = \text{In}\left(\frac{R_i}{1 - R_i}\right) = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \cdots \beta_k X_{Ki} + U_i \quad (4)$$

3.5.3 Variables description and measurement techniques

Table 2 gives detailed descriptions of the variables used in this study and their measurement techniques. Independent variables were gender, education, age, income, household size, land ownership, extension visits, membership of farmer association, and forth, while the dependent variable was ready to use digital agricultural technology.

Table 2. Variables description and measurement techniques

Variables	Type	Measure	Variable type
Ready to use	Categorical	0=No, 1=Yes	Dependent variable
Gender	Categorical	0=male, 1=female	Independent variables
Age	Continuous	Years	
Education	Categorical	0 = No formal edu., 1= Educated	
Income	Categorical	0= Below Ghs10,000, 1=above ghs10,000	
Holdings size	Categorical	0= Less than 2ha, 1= 2ha and above	
Land ownership	Categorical	0= Rented, 1= Owned	
Extension visits	Categorical	0= No visits, 1= visited	
Membership of a farmer association	Categorical	0= No membership, 1= Membership	
Mobile phone ownership	Categorical	0= No. 1= Yes	
Network access	Categorical	0= No access, 1= Have access	
Privacy threats	Categorical	0= No, 1= Yes	
Access to electricity	Categorical	0= No, 1= Yes	
Perceived ease of use	Categorical	0= will not be ease, 1=Will be ease	

(Author's own construction, 2022)

Table 2 gives details of the measure of the variable and their categorization in for the study. The logistic regression model was adopted for the study hence binary responses were such as 1 is equal to yes, and 0 equal to No were adopted.

4. RESULTS AND DISCUSSIONS

This chapter presents the results of the qualitative and quantitative data analyzed. The result is based on the objectives of the study and the research questions. It consists of demographic variables, digital technologies available to farmers, the challenges they face in accessing digital technologies, farmers information needs, and the proposed digital agricultural services.

4.1 The socioeconomic characteristics of respondents in the study area

The results of the demographic characteristics of the respondents in this study are displayed in table 3. It can be observed from table 3 that the majority (55.1%) of the respondents were above 35 years of age, while fewer than half of the population were below 36 years. This shows that the study areas have less youthful farmer populations. Also, the gender distribution shows that 52.1% of the respondents were males, while 47.9% were females. Regarding respondents' educational attainment, a significant majority (54.6%) of them have attained some formal education, while a considerable number (45.4%) have not attained any form of formal education. This implies that the results from this study represent the views of educated and uneducated farmers.

Moreover, the marital status of the respondents shows that 31% are single, while 69% are married. Table 3 further shows that the respondents with household size below 5 are 27.8%, while a household with above 3 members is 72. 2%. This implies that farmers in the area have large household sizes. Also, regarding respondents' annual income and its sources, table 3 shows that most of the respondents' annual income was above GHS10,000 while nearly half had an annual income below GHS10,000.

Additionally, it can be observed that the main source of respondents' income is farming (53.1%), while other sources represent a fraction (46.9%) of their income. Furthermore, the land ownership status of the respondents shows that a significant number (57.2%) of them do not own the land they work on, while a noticeable number (42.8%) own the land. Also, nearly 88% of the respondents indicated that they inherited their lands, while about 12% purchased theirs. Finally, 68.8% of the respondents have a land size below 2.1 hectares, while 31.3% have a land size of 2 hectares and above, which implies that smallholder farmers dominate the study areas.

The results of the demographic characteristics of the respondents in this study have given broader background information on smallholder farmers in the Ketu Municipalities. It was observed that the majority of the smallholder farmers in the areas under study were above the youthful age cohort. This indicates that farming and agricultural-related activities are less participated by the youth. This implies that smallholder agriculture in the areas is in the hands of the aged population. The result, therefore, confirms the growing trend of aging labour population in agriculture in developing countries. A similar result was observed by Udimal et al. (2017) and Adebiyi & Okunlola (2013) in their study of rice and cocoa farmers in Nigeria and Ghana. While their studies focused on farmers in specific crops, the current study considered all smallholder farmers. The implication of this result is that digital technology use in agriculture in the study areas is likely to be affected negatively since young farmers are known to adopt and use new technologies more than older farmers.

Table 3. The socioeconomic characteristics of respondents in the study area

Factor		Frequency	Percentage
Age	Above 35 Below 36	222 181	55.1 44.9
Gender	Male Female	210 193	52.1 47.9
Education	Educated Not educated	220 183	54.6 45.4
Marital status	Single Married	125 278	31 69
Household size	Below 5 Above 4	112 291	27.8 72.2
Income	Below Ghs 10,001 Above Ghs 10,000	207 196	51.4 48.6
Income source	Farming Other business	214 189	53.1 46.9
Land ownership	Own land Rented land	89 119	42.8 57.2
Ownership sources	Inheritance Purchased	78 11	87.6 12.4
Land size	Below 2.1 hectares Above 2 hectares	143 65	68.8 31.3

(Authors' survey, 2022)

Also, it was observed that males dominate agriculture production in the study areas more than females. This finding is consistent with the past study findings by Oyekale (2021) and Asravor (2018), who documented that male-populated agricultural activities in Ghana. They both attributed their findings to the nature of agricultural practice in Ghana. In the present study, the respondents explained that men usually engaged in the main production activities while women played supporting roles by doing light activities such as harvesting, processing, and sales of farm produce. The present findings can be attributed to the division of labour in the study area.

The study also identified that more than half of the respondents were educated. This is a novel revelation because past studies such as Bruce (2015) and Al-Hassan (2008) have found and classified smallholder farmers are highly illiterate and that smallholder farmers in Ghana can neither read nor write in English and in their native languages. This is welcoming news for the agricultural extension services in the area since the adoption and use of digital technology need some levels of basic education; therefore, having more educated farmers in the study areas may promote digital agricultural technology information access.

Furthermore, it was observed that the majority of the smallholder farmers were married as compared to the single farmers. This result implies that marriage is an important sociodemographic variable in the study areas. The present finding is consistent with the past study by Nouman et al. (2013), who found marriage to be high among rural farmers in Pakistan. Marriage is considered very sacred in most societies in Ghana. In most rural areas, it is a key determinant of one's success or responsibility. Therefore, people sometimes marry early to justify their social status in their communities. This could account for the increase in marriage among the respondents in the area.

Moreover, it was found that smallholder farmers in the study areas have large household sizes. This means that household heads in the study areas have many dependents. The reason for this result could stem from the sociocultural practice in Ghana in general. Culturally, Ghanaians practice the extended family system, where one's nuclear family can live together with the external family (uncles, aunties, nieces, grandparents) who may be under the care of the household head. Additionally, smallholder farmers usually depend on family labour for their agricultural activities; as such, most of them give birth to many children with the hope that they will support their production activities. Polygamy is also an acceptable form of marriage in Ghana. This practice also leads to increase in household size. These reasons could explain why farmers have large household sizes in the study areas.

The results also revealed that most smallholder farmers had annual incomes above GHS 10,000 (1200 euros). This result implies that more than half of the smallholder farmers earn above the national minimum wage of 584 euros per annum. This is a bit surprising because past studies have established that smallholder farmers in developing countries, especially in Africa, live in poverty and cannot afford 1 euro a day. The reason for the current result could be the diverse farmer groups involved in this study. For example, fish, livestock, and rice farmers earn more money per harvest or sale than arable crop farmers. Their inclusion in this study may justify the increase in the annual income of smallholder farmers in the study areas. However, this new result suggests that poverty should not be generalised among farmers in a particular geographical location.

Regarding land ownership of smallholder farmers, the study found that a significant majority of the farmers rent the land they operate on. The interpretation of this result is that smallholder farmers in the areas may find it difficult to make long-term investments or establish permanent crops on their lands since majority of them do not own the farmland. It will therefore be necessary for them to use digital technologies that can help them access timely information to increase their productivity within a short time to gain profit from their investments. Similarly, the study found that inheritance is the main source of land ownership in the study areas. This finding could be linked to the land ownership systems in Ghana. Lands in Ghana are largely owned by families (customary lands). Families usually do not sell the lands; they rather share among family members. This practice could account for the increase in inheritance as the main source of land ownership in the study areas.

Finally, the result of the demographic characteristics of smallholder farmers showed that more than 67% of farmers in the study area farm on land less than 2 hectares in size, which implies that smallholder farmers in the area have small holdings. The present finding concords with past studies by Giller et al. (2021) and Anang et al. (2020), who also found that smallholder farmers in their studies farmed on lands below 2 hectares. They attributed their findings to a lack of credit. The present study observed that smallholder farmers in the study areas practice the customary land tenure system, where families control and allocate lands to family members. In this system, farmers' farm sizes are dependent on the size of the family and the land available. Farmers in families with large family sizes usually get small lands, whereas farmers in families with small membership with large land get bigger lands. This could explain why many smallholder farmers have a land size below 2 hectares in the area.

4.2 Farming type, farmer group, training, and extension visits smallholder farmers receive

Table 4 displays the type of farming respondents engage in the study areas. Among the types of farming, crop production was the highest, with 50.9% of the respondents practicing, followed by animal production, with 25.6% of the respondents engaged in it, 14.9% engaged in agro-processing, while fishing and fish farming were the least, accounted for 8.9% of respondents practicing it.

Furthermore, table 4 displays details on the agricultural extension and advisory services respondents receive in the study area. It could be observed that the majority, 60.8% of the respondents, indicated that they do not receive regular extension visits, while 39.2% indicated that they receive regular extension visits. Additionally, 96% of the respondents responded that they did not participate in any extension services ICT training programme, while 4% responded that they participated in the extension services ICT training programme. The present findings of a high number of farmers not receiving extension visits could be linked to the extension agents staffing problem in many parts of Ghana. Past studies (like (Anang et al., 2020; Bonve et al., 2012) have echoed that the extension services in Ghana have inadequate extension agents; as a result, only few staff take care of the numerous farmers in the study in various regions. This could explain why some farmers received extension visits in a season and others did not receive them. A study by Idrisa (2012) also found that more than 67% of the respondents who participated in their survey study in Nigeria had fewer or no extension contact in a season.

Table 4. Farming type, farmer group, training, and extension visits smallholder farmers receive

Type of farming	Animal Fisheries Crops Agro-processing	103 35 205 60	25.6 8.7 50.9 14.9
ICT training	Participate No participation	16 387	4.0 96.0
Extension visits	No visit Hard visits	245 158	60.8 39.2
Farmer group membership	No membership Membership	278 125	69 31

(Authors' survey, 2022)

Finally, table 4 shows that most respondents (69%) did not belong to a farmer group in the study areas. Having fewer farmers belonging to a farmer group or association in the study areas could affect information dissemination because farmer groups could be a powerful tool for disseminating new technologies.

4.3 Digital agriculture platforms commonly used by smallholder farmers.

In order to get a better view of digital or ICT environment in the study areas, the study enquired about respondents' knowledge, experience, and use of digital platforms. The type of telecommunication network services and possession or usage of digital technology tools were also soughed. Tables 5 to 10 give the responses received from respondents concerning the digital technology experiences in the areas under study.

Use of digital extension services by respondents

In table 5, respondents were asked if they have ever used any digital agricultural services to access production and agricultural services in their area.

Table 5. Use of digital extension service by respondents

Use of digital extension	Frequency	Percentage
Yes	68	16.9
No	335	83.1
Total	403	100

(Authors' survey, 2022)

The majority (83.1%) of the respondents in the study area responded no, indicating they have never received or accessed agricultural information through any digital agricultural platform, while 16.9% responded yes to accessing agricultural information through digital agricultural platforms. This implies that the use of digital platforms to communicate agricultural information is still at a juvenile stage in the study area. It will therefore require much education to stimulate farmers interest in using digital agricultural platforms introduced in the area.

4.4 The List of digital platforms used by smallholder farmers

Among the respondents who have used DAIPs in the study areas, table 6 displays the names of the common DAIPs used in the study area.

Table 6. List of digital platforms used by smallholder farmers

Digital platforms	frequency	percentage
ESOKO	20	29.4
Farmerline	12	17.6
MOFA e-learning	36	52.9

(Authors' survey, 2022)

Among the named DAIPs, Esoko (29.4%) and MOFA e-learning (52.9%) were the most used among the respondents, while Farmerline (17.6%) was the least named DAIP used by respondents. From the three named DAIPs, Esoko, and Farmerline are private owned, while MOFA's e-extension is public ownership. The result shows more than 50% of the respondents have used the public digital extension service more than private ones. The reason for this could be related to the issue of affordability. While public agricultural services are usually free to farmers, private services charge service provision fees.

4.5 The different services offered by the major digital agricultural platforms in the study areas

Table 7 is a display of all the various services offered by the main identified DAIPs in the study area. It can be observed from the table that some of the agricultural services are offered by all the DAIPs while others are offered by a few of them. For instance, crop production information, marketing, and weather forecast were provided by all three major DAIPs, i.e., Esoko, Farmerline, and MOFA e-agriculture. However, the observation of the individual DAIPs revealed details on how the various services under them are offered.

Table 7. The different services offered by the major digital agricultural platforms in the study areas.

Service	Esoko	Farmerline	MOFA E-Agriculture
Crop production	√	√	√
Animal production	', √	'	√
Fisheries	"	√	√
Marketing	√	√	√
Processing	"	"	√
Weather	√	√	√
SMS	√	√	"
Voice recording	√	√	"
Call centre assistance	√		√"
How-to-do demo videos	"	"	***√, very old***
Link to other service providers	"	"	√
Service in Ewe	"		√"
Service in other local languages	√	√	√

NB: √ means service offer or active;" means not offer, √" means offered but inactive. (Authors' survey, 2022)

The Esoko DIAP provides tailored agricultural production advisory services such as pests and diseases management, agronomic practices, soil management, commodity market updates, and weather information to farmers. It was noted that Esoko operates web-based information services and call centre assistance services to farmers. The web services provide information on agricultural commodity prices, whereas their call centre (farmer helpline) focuses more on agricultural advisory services. Esoko subscribers receive timely updates through SMS and call centre assistance services. The services are offered in English and Twi languages. Esoko platforms provide information mainly to crop producers who have subscribed to their services. It can be seen from table 7 that the Esoko platforms do not tackle fishery services, animal production, and agro-processing services. Additionally, Esoko's website does not link users to other agricultural service providers. Self-taught demonstration videos are also lacking in their services.

Furthermore, table 7 shows that Farmerline line's service provision is almost the same as Esoko. It was noted that they also offer services to farmers in the areas of crop production, agricultural inputs, commodities distribution, and linking consumers to producers. Their services are accessed through web service and the mergdata app. The web service offers opportunity for consumers and producers to purchase agriculture commodities and farm inputs. The mergdata app utilises the internet, cloud computing, and mobile phone technologies to provide agricultural advisory services, weather updates, and market information to farmers through SMS and audio voice recording. It was noted that, unlike Esoko, farmerline extends its services to fish farming; however, it does not operate a call centre support service. Farmerline services are provided in English, Twi, and Hausa languages. It does not operate in the Ewe language; it does not have self-tutorial videos, or link to other agricultural service providers on its app and website. The website services are only offered in English.

Furthermore, from the survey and observation of the MOFA e-agriculture platforms, it was noted that the MOFA system combines web-based services with mobile apps and call centre support services. Farmers have options to choose which service that works better for them. The platforms cover all the major agriculture production (animal production, fish farming crop production, market, and product distribution) areas practiced by farmers in the study areas. However, the e-agriculture system, in general, does not provide SMS and audio voice message services. Also, the e-extension mobile app was designed exclusively for extension technical officers' use. The web-based platform that is supposed to serve as a knowledge centre for extension agents, farmers, researchers, and other players in the agricultural value chain only operates in English; no other local language option is available. Additionally, it was noted found from the respondents that the mobile application and the call centre support services are not active. Information such as demonstration videos, market data, and weather on the website is outdated.

All the listed DAIPs but MOFA e-learning are private own DAIPs and offer agricultural information services mainly to crop producers with little or no services to animal and fish farmers. Private enterprises usually invest in areas where the return on investment is high, therefore, having the private DAIPs focusing more on the crop sectors suggests that there is a higher profitability in the crop production than in the animal production in the areas. However, smallholder farmers make up the majority of farmers in Ghana, their system of farming combines two or more farming methods; as such, a digital service to them should be able to cover all the major agricultural areas. Additionally, considering their low-income status, coupled with resource constraints on their side, digital agricultural services to them should be opened to all of them without restrictions of any kind; to promote technology adoption and use among them. Additionally, smallholder farmers also vary in technology use, information access, and needs, therefore, to promote equal access to agricultural information by all smallholder farmers in the areas, it will be important to have a DAIS that combines web-based services or mobile app with a call centre support service to serve all the farmers information needs, regardless of their productivity type or levels.

4.6 Challenges of using the major digital agricultural platforms

Table 8 gives details of the major challenges that respondents face using the various digital agricultural platforms available in their areas. Among the challenges, the language barrier was the most cited, followed by cost of accessing the services, limitedness of services, outdated information, and unavailability of services and information.

Table 8. Challenges of using digital platforms.

Challenge	Percentage	rank	DAIP Type
Language barrier	96.5	1st	All
Cost of accessing	93.5	2nd	Esoko, Farmerline
Limitedness of services	91.4	3r	Esoko, Farmerline
Service failure	86.1	4th	MOFA
Unavailability of information or services	86.1	4th	MOFA
Outdated information	78.9	5th	MOFA-extension

(Authors' survey, 2022)

According to the respondents, most of the information delivered to them was in English or the Twi, which many do not understand well. They, therefore, find it difficult to fully comprehend and apply the contents without the help of others. The language barrier problem pervert among all the DAIPs in the areas, as shown in table 8 one respondent stated that "when you click on the Esoko and farmerline websites, everything is written in English, no other language is available to choose from; meanwhile many of us here are Ewes, and that is the language we understand very well." Language forms an important component of product adoption and usage. Products or services that offer information in languages that potential users understand influence the degree that such products will be used (Asenso-Okyere & Mekonnen, 2012). Digital agricultural information or services adoption rate, like many other products, is influenced by the language in which the service is offered. DAIPs that offer services in languages that smallholder farmers understand may increase their confidence in the service and use them.

Aside the language barrier that cuts across all the DAISs, the study identifies two distinctive challenges between the public-supported DAIS and the private DAIP. While respondents have service and system performance as the main challenges with the public-supported DAIP, the private DAIPs have cost as their main challenge to users.

Ayim et al. (2022) and Kayumova (2017) found a similar challenge with the adoption of ICT innovation among rural farmers. Likewise, Okoroji (2019) documented that perceived cost of mobile phone services negatively affected farmers' use of mobile phone applications in agriculture.

Furthermore, cost was stated as the main challenge to the use of services of DAIPs such as Esoko and farmerline. Respondents explained that the services offered by the private DAIPs require subscriptions, aside the data and the call credit that farmers use to access the information. Most smallholder farmers find this subscription fee too expensive and thus deter them from subscribing to their services. Cost is arguably a major determiner of farmers acceptance or rejection of any innovation. If new technologies come with an outrageous cost, the possibility of it being backlash by users is high. However, private DAISs are for-profit services delivery enterprises, unlike the government funded DAISs, which depend on the service charges to provide continuous service to the farmers. To be able to offer free or discounted services to smallholder farmers in the area, they would need sponsorship or supports from government agencies or NGOs to roll out such services.

Also, in terms of the limitedness of services, the respondents explained that the DAIPs like Esoko, farmerline provide services mainly to crop farmers without extending their services to livestock and other animal producers. It was observed that many of the smallholder farmers in the areas produce crops and raise farm animals, they, therefore, prefer a service that can provide both crop and animal production information.

Other challenges, such as outdated information, and unavailability of information and services, were found to be higher in the services offered by the MOFA e-extension DAIP. Respondents explained that the website of the MOFA e-extension provides information that is as old as three or five years. This information they consider irrelevant in the current time. Others also explained that the call does not go through when they call the MOFA e-extension short code for assistance. Those who are able to search for information online also explained that many of the interfaces on the webpage were empty. "When you click on the livestock information, nothing shows up, the interface is empty" (a crop farmer in an interview). Other links to input dealers also leads you to nowhere" (farmer 5). A study by Fawole and Olajide (2012) also identified service failure and lack of maintenance as the main impediment to farmers use of new ICTs in agriculture.

The study has revealed that smallholder farmers face a series of problems in their quest to use digital agricultural platforms in the study areas. The study areas are predominantly Ewe-speaking zones, therefore, services offered to farmers should first of all, consider their language. Also, considering the resource constraints of smallholder farmers in the study area, a DAIS that offers a subsidised or free, current, and integrated agricultural information will be well fit in the area.

4.7 Common digital technology devices owned and used by respondents.

The possibility of accessing digital agricultural information by smallholder farmers depends not only on existing policies but also on the ownership and access to digital devices.
Table 9 shows the result of the main digital devices used by respondents in the study areas; it can be observed that mobile phone without internet access was the highest (77.7%) digital device owned by respondents, followed closely by radio (74.4%), television (38.5%), smartphone (12.9), a personal computer was the least owned digital device by respondents.

Table 9. Common digital technology devices owned and used by respondents

Digital device	frequency	percentage
Mobile phone (simple)	313	77.7
Radio	300	74.4
Television	155	38.5
Smartphone	52	12.9
Personal computer	2	0.5

(Authors' survey, 2022)

The result of this study suggests that mobile phones have become the most preferred digital tool used by smallholder farmers in Ghana. Hence, a mobile phone can be the best medium to reach a large number of smallholder farmers with agricultural innovations.

The current findings corroborate with the study of Krell et al. (2021), who observed that more than 90% of respondents in their study own mobile phones compared to other ICT devices. Contrary to the current findings, Fawole and Olajide (2012) observed in their research that among the rural farmers in Nigeria, radio and televisions were the most widely used ICT devices compared to mobile phones. It should be noted however that Fawole and Olajide's study was carried out in 2012, whereas the current study was conducted in 2022. This suggests that time and geographical location play important roles in digital technology adoption and usage.

The increase in mobile phone use over other digital devices, such as radio and television, could stem from the increased availability and affordability of mobile phones in Ghana. Mobile phone services have relentlessly penetrated all the nooks and crannies of Ghanaian society, most especially the rural areas; this has made mobile phone services available to all class of rural dwellers and at a price range that meet almost everyone's budget. Furthermore, the introduction of mobile money (momo) to Ghana in early 2002 made mobile phones use more relevant in Ghana than any other ICT device, especially in the rural areas. These could explain the increased ownership of mobile phones by farmers.

Smartphones and personal computers are somewhat expensive compared to simple mobile phones. Also, their usage requires basic ICT knowledge, which most smallholder farmers lack in the area; this could account for the reasons why they were the least owned digital technology devices among smallholder farmers.
It can therefore be concluded that mobile phone usage among smallholder farmers in the Ketu Municipalities is gaining much foothold over the old ICT tools like radio and television. Therefore, digital agricultural information services that are compatible with simple mobile phones will be more useful to smallholder farmers in the study area.

4.8 Mobile networks accessible to respondents

The data in table 10 presents the three top mobile telecommunication networks respondents have access to and use frequently in the study areas. Among the networks, MTN was the most used by the respondents. 63.3% of the respondents indicated they use MTN, 31.8% use the Vodafone network, and 5% subscribe to Airtel/Tigo.

Table 10. Mobile networks accessible to respondents

Network	**frequency**	**percentage**
Vodafone	128	31.8
MTN	255	63.3
Airtel/Tigo	20	5.0

(Authors' survey, 2022)

Respondents explained that MTN has the most stable and the largest network coverage in the area; that makes it the topmost preferred mobile network service provider in the area. Respondents also explained that the remaining networks have unstable services, especially in the villages where farmers are located.

4.9 Smallholder farmers information needs

To develop a robust digital agricultural information system, farmers information needs to be considered. The proper identification of farmers information needs will guide the development of a sustainable digital information system for extension communication. Although some of the information farmers need may be the same across the different farmer groups, the time and the nature of the information needs may vary. In this this study, different farmer groups were interviewed to gather the most pressing information needs in their respective fields of operation. These farmers were crop producers, livestock farmers, fish farmers/fisher folks, and agro-processors. Based on the interview and the focus group discussions, the information needs identified are discussed below.

4.9.1 Weather information

Information on weather forecasts was among the predominant information needs that were common to all the participants. Information on weather forecasts was very important to the farmers because many of the respondents explained that farming in the areas depends largely on rainfall.

"The pattern of the rain has changed significantly these days, as a result, information on weather is very important to us; because when you apply fertiliser on the crops without rain, the fertiliser does not reach the plant roots, they even kill the plant when the temperature is very high" (a crop farmer 09, in a focus group discussion). "This area lacks an irrigation scheme to support our farming activities in the minor season; we only depend on rainfall. Land preparation which starts the main farming activities, depends largely on rainfall, therefore prolonged drought with high temperature delays our land preparation for the season" (a crop farmer 05, in a focus group discussion).

In an area where farmers depend solely on rainfall, the nursing of seeds, transplanting seedlings, application of agrochemicals, and performing other important cultural practices on the fields are usually determined by the timing of the rainfall. Therefore, without the appropriate weather information, it is difficult for smallholder farmers to determine when to start tilling their lands. A study by Bachhav (2012) in India found that rural farmers in India require information such as weather updates to make planting decisions.

"Sometimes, it is difficult to know the rainfall pattern to decide whether to go fishing or not. We normally depend on the chief fisherman for weather updates a day before we prepare for sea. The information sometimes comes late. I think getting regular weather forecast will be very helpful for us" (Fish farmer 02 in a focus group discussion). "I get daily weather updates from Accra (the capital city) and share the information with the fishermen so they can prepare adequately before going to the sea. The updates are not regular, which affects our operations" (a chief fisherman in a focus group discussion).

It was revealed during the focus group discussion that important information, such as weather conditions, is often shared with the chief fisherman, who in turn shares it with other fisher folks. The reason given for only chief fisher folk receiving information for other fisher folks was that he is the elected representative of the fisher folks in the area. To reduce information asymmetry, every fisher folk or farmer should have equal access to information concerning their activities directly. This could be achieved through a digital agricultural information system that gives farmers equal information access.

4.9.2 Agricultural input information

Agricultural inputs form one of the key elements in agricultural production. Without inputs, nothing can be grown and there will not be food for humans and animals.

"Before the beginning of the new season, I look for new seeds, especially the ones that can withstand stress because at the start of the season, the time for rains prolongs" (a maize farmer).

"At times, we are compelled to use old seeds saved from the previous season when there is no information on new seeds; therefore, getting timely information on new seed varieties will help me to prepare ahead of time for the planting season" (a vegetable farmer).

"In this area, we find it difficult to know the actual prices of fertilizer, especially the NPK. Some sell it at GHS80, and others also sell it at GHS95. If you are not lucky, you will buy the expensive one before you hear the actual price. The extension fertiliser, too, comes very late. If you can get correct and timely price information on fertilizer, it will help us" (vegetable farmer).

"Premixed fuel is the only fuel we use for our outboard motors fishing, however, it is very difficult to get in this area, when the one we have finished, it is very difficult for us to know when the next consignment will arrive. Sometimes we walk long distance to the filling stations, we get there, and there is no fuel, the sellers will tell us to come back next day, we go and still there is no fuel" (a fish farmer 43, in a focus group discussion).

“When you hear that there is fuel around, before those of us from far places get there, those close to the selling point had purchased everything. Timely information on premix fuel distribution is urgently needed in this area” (a fisher folk 49, in a focus group discussion).

Fish farming and fishing are very important to the economy of Ghana; fish constitute a larger proportion of animal protein consumed in Ghana, therefore, the ability to provide information that farmers need to increase their production will not only generate income but also increase animal protein consumption in Ghana. Extension services can help fish farmers and fisher folks get regular updates on fishing information through digital technologies.

Also, agricultural inputs can be seeds, seedlings, vegetative parts, agrochemicals, fuel, and the like. Farmers, therefore, need information on their availability, quantities, and their prices ton their production activities. Many of the smallholder farmers in the study areas were observed to live in small villages where there are no agrochemical shops, when they need farm inputs, they will have to travel to nearby towns or cities to purchase them. Considering the travel distance and the cost involved, it will be important for farmers to get current information on input availability to plan their activities accordingly. A digital agricultural system that can provide smallholder farmers with input information will help them plan their activities and save them from being duped by unscrupulous individuals who sell farm input at exorbitant prices to farmers.

4.9.3 Subsidies

Subsidy was one of the topics that came up during the focus group discussion. According to the participants, information on the availability of government subsidy is important to their decision-making. They explained that government provides subsidies on specified farm inputs under a policy called "Planting for Food and Jobs (PFJ)." One farmer explained that the government subsidy programme helps them to save money on farm inputs; however, the inputs arrive very late in the season.

"The planting for Food seeds and fertilizers come in very late. The planting materials usually arrive in the middle of the farming season when the planting period is almost over. The NPK fertiliser too delays. The officers at the agriculture centre do not provide adequate information on their supplying" (farmer 19, in a focus group discussion).

Government subsidy programs are meant to support farmers by reducing their cost of production. The participants in the focus group discussion detailed how urgent information on these subsidies is to them. Agricultural extension service that distributes these subsidies will need a system that will help them to communicate effectively with farmers without any barrier.

4.9.4 Farm credit

Access to farm credit became an important theme during the engagement with famers in the focus group discussion. Participants highlighted their difficulties in their quest to access farm credits to support their production.

“We find it difficult to obtain information on farm credits at the beginning of the farming season; we are therefore forced to borrow money from our fellow farmers who charge us more interest on the little money received” (Focus group discussion). “I learnt some of the agrochemical companies provide farm inputs on credit to farmers at the beginning of the production season and demand payment at the end of the season, but in this area, we do not get such information” (Maize farmer in a focus group discussion).

"The banks demand so many documents before considering giving you their money. Sometimes it is even difficult to know the exact documents they need, and if you are not able to provide all the documents they requested, you are denied the loan" (farmer 19, in a focus group discussion).

"Some of the banks will ask us to form groups and save money with them for about six months, after which they will give us loans, the process takes a long time, and they don't always give you the money; those who will give you too sometimes give you less money than you requested" (farmers 27, in a focus group discussion).

It can be deduced from responses that farmers lack information on the procedure, documentation, knowledge, processes, and procedures to follow to access farm credits. This could be best addressed with the appropriate platforms that offer timely financial education and information to farmers. The current study result is consistent with a study by Awotide (2015), who found that timely credit information had a positive influence on cassava productivity. Smallholder farmers who lack knowledge on credit acquisition are not able to secure loans from established credit firms to support their farming activities, which sometimes forces many of them to either borrow from friends at a high-interest rate or subscribe to low-quality inputs, which sometimes affects their optimum levels of production. This suggests that smallholder farmers in the study areas require timely information on available credit so that they can plan their operations ahead of time. The extension services can support smallholder farmers through a robust digital agricultural platform that provides constant updates on available credits and financial services that the financial institutions such as microfinance, rural banks, and commercial banks in smallholder farmers' communities provide to them and the basic requirement they need to meet to access these credits. Also, information on government subsidies or soft loans available to farmers can be shared with farmers on a regular basis.

4.9.5 Feed and feeding information

Feeding and feed information was a common topic found among the information needs of livestock and fish farmers. In animal production, feeding the animals with the right feeds and at the right time helps them grow faster and healthy. Participants indicated their need for training on feed formulation, feed ingredient price, and the appropriate ingredients needed to formulate feeds for animals.

"Feed for the animals is very expensive, and it is also difficult to get quality formulated feeds in this area, we therefore, formulate our own feeds. We need information on the ingredients that are good for formulating pigs and poultry feed" (smallholder farmer 34, in a focus group discussion). "I learned how to formulate feeds from my colleague farmers; I think the extension services need to organise regular training on animal feeding for us to learn the improved ways of preparing animal feed" (a smallholder farmer 43, in a focus group discussion).

"It is difficult to get fresh leaves such as grasses to feed the sheep, goats, and cattle in the dry season; getting information on alternative feed during that period is very important" (a ruminant farmer, in a focus group discussion).

4.9.6 Market for produce

During the focus group discussion on the information needs of the farmers. Farmers mentioned the difficulties they face in getting readily available markets for their produce. They narrated how during the peak seasons; their farm produce is sometimes left on the field to root due to the lack of buyers. Some also detailed the low prices they are sometimes forced to sell their perishable products due to the unavailability of markets for their products. Below are some examples of the experience shared by farmers:

"The major challenge I face as a farmer is to know the actual sale price for farm produce. In my area, we do not get information about market prices for farm produces, the buyers decide the prices for us, and if you fail to sell at the price they offer, your fellow farmer will accept, so you will end up having your fresh produce rotting." (a vegetable farmer).

"Season, I sold my tomatoes at a cheap price to buyers from the city, one week later, I got the information that the price was higher than what I was offered." (a crop farmer).

"As farmers, we can all agree to one price when we have advance information on the sales prices for the commodities. Luckily, I joined the vegetable sellers' association, so the group gave us updates on market prices for some of the vegetables we produce here; this helps me know how to bargain with the buyers." (Vegetable farmer 10).

“I sent my tomatoes to the market hoping to get a good price only for me to realise that there were few buyers. The price they offered me was so bad, but I had no choice than to accept it because I could not afford to pay another transportation fare to return the tomatoes to the house.” (Another vegetable farmer).

"Sometimes the animals that we rear reach maturity, but due to unavailability of the market, I keep them which add extra cost on me." (Livestock farmer).

“I think getting frequent information on prices of all products in this area will be helpful to all of us. Because we do not have such information, we are always cheated by the middlemen.” (Farmer 01).

“It is important to know when farmers harvest their produces, this helps us to gather resources to buy and store them in large quantities” (an agro-processor, in a focus group discussion).

Timely market information is very crucial in agricultural production. Farmers can make very good decisions when they get advanced information, such as the current price of produce, availability of buyers, and market dynamics. A study by Elly and Silayo (2013) found that close to 70% of farmers in their study required market and production information. A robust system that provides farmers opportunities to access frequent market updates will help smallholder farmers to plan when to sell their products to gain good prices.

4.9.7 Pests and diseases information

Many farmers cited pests and diseases as the areas they need information about most. Pests and diseases affect agricultural production in several ways and at different stages. The participants indicated their need for information on different pests and diseases that affect their field of operation.

"I look for information on how to treat simple diseases that occur in my poultry, it is difficult to get the veterinary officers to visit my farm when there is an emergency, so when I know how to control or treat simple diseases myself, I can save them from dying" (a poultry farmer).

"I do visit the extension office to seek information on disease outbreaks on my farm; sometimes I go there with some of the affected plants for them to see and recommend chemicals that can be used to treat them." (Farmers 12).

"I have local fowls that I keep and sometimes sell to earn extra income. Unfortunately, these fowls have been attacked by Newcastle disease seasonally, and this results in mass death of the fowls. My colleague farmers recommended drugs to be used, but the drugs are not effective in controlling the disease. Therefore, getting regular information on appropriate medicine and the time to administer them is very important to me" (a poultry farmer).

"When I see an abnormality in the animals, I contact the veterinary officer to know what to do; unfortunately, it takes a long time to get him to answer me" (smallholder farmer 30, in a focus group discussion).

"Recently, I have been seeing different pests attacking my maize on the farm, some of these pests are very destructive, and it is difficult to control them. I have been looking for the correct pesticides to apply to control them. The pesticides I have cannot control them well."

"The fall armyworms, and other strange diseases have been identified in our area. We really need information on the effective ways to control these diseases." (a crop farmer).

The information from participants indicates that farmers in the study areas lack the appropriate medium to source information on different pests and diseases that they face in their production. They also brought to light the emerging pests and diseases they see on their farms which pose a threat to their crops, animals, fish, and other agricultural products. Similar information needs were found in a study conducted by Babu et al. (2012). They observed that farmers in developing countries like India information needs were pest and disease management, pesticide application, and seed treatment.

4.9.8 Postharvest practices

Postharvest management is important topic that came up during the focus group interview with respondents. The different farmer groups who participated in the interview gave an account of the losses they incurred due to their lack of training and information on handling, processing, and storing their products.

"The local maize that I used to grow could stay for many months after harvesting without going bad. But the Agric seeds (hybrid maize seeds) easily go bad a few weeks after harvesting when not treated. I need information about the proper ways of storing the Agric maize after harvesting." (Maize farmer).

"I learnt there are new machines and equipment that can be used to store vegetables like tomatoes, okro, and garden eggs. When we get some of these machines, it will help us to store our vegetables to wait for a good price". (a vegetable farmer).

"Packaging is increasingly becoming popular in local agricultural product processing; we, the vegetable processors, need training and how to improve food packaging to be able to compete with the sellers at Accra (The capital city)." (An agro-processor).

"The products I send to the market easily get a bruise and decoloured shortly after the car offloads them on the market. The drivers mishandle them, it easily affects the shelf life. Period education on how to transport our farm produce to the market is important to us.

The participants opened the various forms of challenges and information, or training needs they want to reduce the losses they incur after harvesting their products. Issues related to processing, packaging, transportation, and storage were the major postharvest needs that respondents stated. Past studies have bemoaned the increasing loss that occurs in agriculture after harvesting farm produces. For instance, Ambuko (2017) argued that more than 30% of agricultural products produced in Africa are lost through postharvest handling. It was further stated that the loss is even higher (50%) in fruits and vegetables.

Postharvest loss reduction is critical to increasing farmers income, market participation, food security, and improving farmers welfare. The observations from this study imply that the extension services need to create a system that will enable farmers to access information, communicate, and learn about different ways of handling agricultural produce safely.

The study identified that due to the heterogeneity of farming activities in the areas, information needs vary among the farmers. While crop producers need information on the type of fertilizer to apply to their crops, animal producers and fish farmers seek information on new feeds and vaccines. This means that different farmer group requires different information. Having these diverse information needs means that an integrated agricultural information system will be needed to serve these diverse farmer groups in the study areas. Furthermore, the study found that farmers require this information at a different point in time in the production seasons, i.e., some information is required before the start of the season, others are required at the start of the season, within, and toward the end of the season. This indicates that farmers require periodic information throughout the production periods. Additionally, considering the volatility and the unstructured agriculture marketing systems in Ghana, smallholder farmers need assistance to find the available markets, prevailing prices, and information that will enhance their work efficiency.

Furthermore, based on the study result, farmers information needs in the study areas could be classified under technical information needs, economic information needs, and regulatory or service information needs. Technical information is the information that relates directly to farmers daily operational activities in their respective fields. This includes pest and disease control, animal husbandry practices, feeding management, weather information, soil management, and so forth. The business information needs, on the other hand, include input prices, farm credit, available market for farm produce, and others, while the regulatory and service information involves government policies, subsidies, transportation, and credit availability. Smallholder farmers need all this information to plan and manage their enterprises. Considering the current trend of climate change and the new digital revolution in the agriculture sector, coupled with government policies to ensure food security, food quality, and sustainability in agriculture, smallholder farmers in all sectors of the agricultural value chain need timely and reliable information to make decisions. This can be achieved through the use of digital agricultural information services that farmers can access easily.

4.10 Sources of Agriculture Information

Smallholder farmers in the study areas obtain information from different sources; these sources are either formal or informal. During the interview, participants were asked to list the sources they obtained information from to make decisions on their production activities. Table 4 displays the sources listed by farmers. It could be seen that colleague farmers served as the highest source of information to many farmers in the study areas.,29.2% rated them as the main source of information. This result is not surprising because the extension services in the areas are understaffed, as a result, they are not able to cover all the farmers in the operational areas. The farmers, therefore, had to depend on their colleague farmers whom they considered to be doing well in their field of operation, to assist them. Also, it was learned that farmers in the study areas work in groups; this is common among the fish farmers and the fisher folks. They usually obtain information from the head of the association, whom they refer to as the "chief fisherman." This chief fisherman acts as a liaison officer between the fishier folks and external institutions like the extension services. This could account for the reason why information from colleague sources is rated high. The observed result confirms an earlier study by Bachhav (2012) and Opara (2008), who found in their studies in India and Nigeria that 67% and 71% of the respondents respectively obtained agricultural information from their fellow farmers.

Although relying on colleague farmers as sources of agricultural information have proven to speed up information dissemination and technology adoption, however, if the channel is not well developed to ensure competent and well-trained individuals are in charge, fake and unreliable information may be shared among farmers, which may have a long-lasting consequence in the agricultural value chain. It is, therefore, important for the extension services to establish a system where farmers can seek or verify information received from informal sources other than the established systems.

Table 11. Sources of agricultural information

Source	Frequency	percentage
Colleague farmers	21	29.2
Extension services	16	22.2
Farmer groups/association	10	13.9
Agro-input dealers	8	11.1
Radio	7	9.7
Information centres	6	8.3
Print media	4	5.6

(Authors' survey, 2022)

Furthermore, the results show that extension services form the second-highest source of agricultural information for farmers. More than 22% of the respondents rated extension services as the main source of information to them. This indicates that the extension services play a significant role in farmers information delivery in the areas, despite the dearth of technical staff in the service. The current result is consistent with the study of Crawford et al. (2015), who found that agricultural organizations and extension services served as the major sources of information for organic farmers in North Carolina counties. However, their study covered specific farmer groups (organic), while the current study covered different smallholder farmers. Additionally, Opara (2008) found that more than 88 percent of the farmers in the Imo State obtained their agricultural information from the agricultural extension service. The result of the current study is a demonstration of the importance of agricultural extension services in information dissemination to smallholder farmers. Therefore, any public policy or investment that seeks to improve extension coverage will invaluably have a significant increase in the use of digital technology among smallholder farmers.

The other important sources of information for farmers found in this study were farmer groups (13.9%), agro-input dealers (11.1%), radio (9.7), information centres (8.3%), and print media (5.6%). The respondents explained that they usually seek technical information such as management of pests and diseases, feed formulation, pruning of farms, and the like from colleague farmers and extension agents. At the same time, marketing and credit information is sought from fellow farmers and farmer associations. It was further explained that colleague farmers know the informal sources of marketing agricultural produce more than the extension agents.

The study further observed that information on farm inputs such as fertilizers, pesticides, feeds, fishing gears, and others was obtained from input dealers, extension agents, and colleague farmers, while subsidy information was obtained from the extension agents.

4.11 Adopter categories of Smallholder farmers

The respondents in this study were classified into the various innovation adoption categories based on the Rogers (2003) Diffusion of Innovation Theory (refer to fig 1). Rogers' innovation adopter categories have five main groups that every adopter or user of new technology belongs to (Rogers, 2003). It can be seen from figure 15 that the innovation adopter category that the majority (35%) of the smallholder farmers belong to in the study areas is the early majority, followed slightly by the late majority (34%), the laggards (14.4%), the early adopters (13.9%) and lastly, by the innovators category (2.7%). The obtained results with many farmers belonging to the early majority, late majority, and laggards adopter categories imply that most of the smallholder farmers in the Ketu Municiparities are skeptical about new digital technologies and may want to see evidence such as pictures, videos, reviews, and testimonies from other farmers using similar technologies before making adoption or usage decisions. They may also wait till an appreciable majority of the population use new technologies before they may consider using them too. It would be important for extension agents in the areas to combine different communication strategies when introducing new technologies to the farmers in the areas.

Also, figure 15 further shows that the early majority and the late majority cumulatively constitute close to 70% of the total respondents in the study areas. This means that farmers in the early majority and the late majority play a key role in determining digital technology use and diffusion in the study areas. This suggests that organizations, individuals, and extension services that introduce new technologies or innovations to farmers must develop multi-facet marketing or communication techniques when engaging smallholder farmers in new technologies adoption; it will help get all levels of farmers groups to accept the new products.

Furthermore, comparing the current study results with the percentage results of the Rogers innovation adopter category chart (refer to fig 1), the present study identified an increased trend in innovativeness among the farmers. For instance, in Rogers' innovativeness category, innovators were 2.5% as against 2.7% in the present study; 13.5 in the early majority as against 13.9 in the present study, and laggards were 16% in Roger's theory as against 14.4% in the present study. These findings mean that innovativeness is not static and may vary by geographical location, culture, people, and demographics. Therefore, a macro-level study result (as in Rogers' study) may differ from a micro-level study (as in the current study).

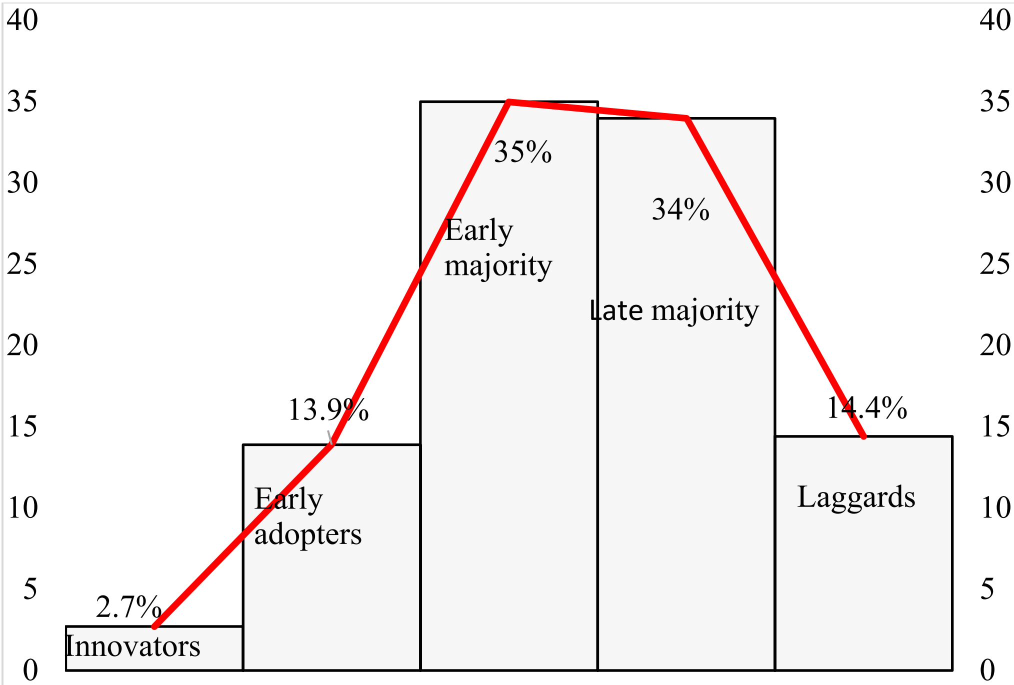

Figure 15: Innovation adopter categories of smallholder farmers. (Authors' survey, 2022)

4.12 Relationship between socioeconomic characteristics of respondents, access to the services, and intention to use digital agricultural services.

The results of the logistic regression model that tests the effect of the predictor variables and the response variable are displayed in table 12. The statistically significant of the chi-square test in the model was 42%, and the suitability of the model to predict the observation correctly was 85.1%, which is an indication that the data fit the model.
From table 12, it can be observed that the gender of the respondents shows a coefficient of 1.540 with an odd ratio of 4.667 and an insignificant value of 0.133, which implies that there is no statistical difference between men and women regarding the decision to use the DAIS in the study areas. It also suggests that in areas where literacy is high (like the current study area), gender disparity in resource use is lessened. The current finding is in contrast with the study results of Sousa et al. (2016), who found that male farmers in Mali and Burkina Faso use technologies in agriculture more than women, and Kante (2018), who observed that female farmers in their study used ICTs to access agricultural input information more than male farmers in Sikasso.

Furthermore, it can be seen from the statistical analysis that the age of the respondents was negative and significant with the intention to use DAIS. Age showed a coefficient of -0.843 and was significant at 0.035, meaning that a unit increase in a farmer's age is likely to cause a decrease in their intention to use DAIS at an odd ratio of 0.431. The current finding concord with the study result of Papadavid et al (2017), who found that in the EU, farmers who were younger were more diversified, used technologies, and applied more eco-friendly agricultural methods than older farmers. The current finding implies that as smallholder farmers advance in age, they turn to show less interest in digital technology use as compared to younger smallholder farmers. This is so because as farmers get older, risk aversion increases among them, hence they do not invest in complex technologies. Young farmers, on the other hand, are inquisitive and tech-savvy, as such, they may want to explore digital technologies. The present result suggests that more local content digital technologies are needed to attract older farmers' attention.

Also, it can be observed from table 12 that the level of formal education of the respondents was significant factor in respondents' intention to use DAIS. This means that smallholder farmers who are more educated have a better ability to process information and search for technologies applicable to their area of production than farmers who are less educated. The estimated marginal effect of this variable shows 1 year increase in education will cause a marginal increase in using DAIS at 39%.

Also, regarding respondents' income and their intention to use DAIS, the model analysis shows that there was no significant relationship between farmers annual income and their intention to use DAIS. This means that farmers with low annual income and those with high annual income have no different use intention of DAIP. The current result contracts with previous study findings by (Gajewski et al., 2022; Bukchin & Kerret, 2020; Diiro & Sam, 2015), who established an association between multiple incomes and risk-taking; assets possession, and use of new technologies; as well as drip irrigation adoption among farmers. The previous studies focused on farmers adoption of new technologies introduced to them without the farmers' input. However, the present studies are centred on a technology that the farmers needs are incorporated. This could be the reason for the difference in the results. The findings from this study, therefore, add to the academic debate that higher technologies that are developed by including farmers' opinions eliminate disparities between farmers that can afford them and those that cannot afford them.

Moreover, the study shows that the household of respondents was significant to the use of digital platforms in the study area. Smallholder farmers with large household sizes are likely to use the DAIS more than smallholder farmers with smaller household sizes. The explanation for this could be that farmers with large household sizes may have more social responsibilities, such as paying school fees and hospital bills of their extra household members, which may shrink their savings; as such, they see the DAIP as to help them getting information without spending extra money on private digital agricultural services. The smallholder farmers with small household sizes, on the other hand, may be able to save extra money to pay for private digital agricultural services due to their small household size.

The result in table 12 further shows that land ownership was negatively significant with the intention to use DAIS by smallholder farmers. The coefficient of land ownership was -0.840, indicating that holding all independent variables constant, a-unit increase in land ownership will cause a decrease in a farmer's intention to use DAIS at an odd ratio of 0.432. This implies that smallholder farmers who rent land for farming will use digital technologies more than smallholder farmers who own their own lands. Land is very scarce and expensive in many farming areas, therefore farmers may want to put into good use the small lands available to gain maximum benefits out of them; as a result, they may be interested in technologies that will help them manage and gain the most out of their investment within the period of their holdings. Contrary to smallholder farmers who own their own lands, their occupancy is not constrained by time, therefore they may not be in haste to use technologies to work within a specified time frame.

Table 12. Relationship between socioeconomic characteristics of respondents, access to the services, and intention to use digital agricultural services

Factor	Coefficient	S. E	Wald	Sig.	Odd ratio
Gender	1.540	1.026	2.252	0.133	4.667
Age	-0.843	0.299	4.401	0.035	0.431
Education	0.957	0.709	1.821	0.001	0.3973
Income	0.183	1.079	0.029	0.865	1.201
Household size	0. 842	0.399	4.453	0. 035	0.431
Landownership	-0.840	0.297	8.007	0.005	0.432
Extension visits	-0.553	0.298	3.460	0.045	0.575
Membership of association	0.-300	0.310	0.936	0.033	0.741
Mobile phone	0.742	0.314	76.271	0.000	0.064
Perceived Usefulness	0.270	0.317	106.550	0.000	.3080
Perceived ease of use	0.319	0.717	10.454	0.001	0.634
Privacy	0.810	0.228	63.126	0.000	6.112
Electricity access	0.547	0.350	52.962	0.000	0.076
Network access	-0.686	1.379	0.247	0.619	0.504
		DF	Sig.		
Chi-square	42.9	14	0.000		
-2 Likelihood test	273				
Pseudo R^2	0.609				
Overall prediction	85.1				
Total observation	403				

(Authors' survey, 2022)

Furthermore, it is well documented in literature the role of extension in technology adoption. In the current study, extension visits were found to be negatively significant with digital technology use among smallholder farmers. Table 12 shows that a unit increase in extension visits decreases farmers intention to use DAIS at an odd ratio of 0.575. The present finding means that farmers who receive more extension contact will be reluctant to use new digital technologies due to the fact that the extension agent provides them with the information they need. The extension service will therefore need to educate smallholder farmers on the importance of digital technologies in extension information delivery. Contrary to this finding, a study by Wossen et al. (2017) on extension and cassava technology adoption in Nigeria found that farmers extension access enhanced the adoption of improved cassava varieties by up to 12.3% in Nigeria and that participation in on-farm demonstration training gives farmers opportunities to learn and experiment with new technologies. Wossen and co. research focused on product technology, while the current study centred on information technology.

Furthermore, smallholder farmers intention to use DAIS decrease with a decrease in membership of a farmer group. Table 12 shows that a unit increase in non-membership of a farmer group will cause a decrease in farmers intention to use DAIS at an odd ratio of 0.741. It means that smallholder farmers who are members of farmer associations will use digital agricultural technology more than smallholder farmers who are not members of any farmer association. The import of this result is that farmer associations or groups promote digital technology adoption among their members. The current result aligns with the findings of Abdul-Rahaman and Abdulai (2021), who observed that FBO membership increased smallholder rice farmers mobile money use in Ghana. Similarly, Umar (2015) opined that the more farmers and extension officers participate in associations, the more they expose to opportunities leading to their increased use of ICTs. Farmer associations in the study area, such as Farmer Based Organisations (FBOs), often organise farmer educative programmes to promote collective action by ensuring members have access to good technologies, inputs, and current information by linking them to extension specialists, markets, and others agricultural enterprises; this help members to get advance knowledge on new trends in the agricultural sector than the smallholder farmers who are not members of these association. Additionally, many of the private digital agricultural service providers prefer working with farmer associations over individual farmers. These could explain the reason why smallholder farmers who are members of farmer associations have positive intentions to use digital agriculture information systems than those who are not members of any farmer association. This suggests that farmers should be encouraged to join the farmer associations in the study area so they can obtain the benefits that the associations offer to their members.

Also, regarding respondents' mobile phone use and their intention to use the DAIS. Table 12 shows that as mobile phone ownership increases, the intention to use DAIS also increases. That is, a unit increase in mobile phone ownership increases farmers' intention to use DAIP at an odd ratio of 0.067 and significant at 0.000. This result is not surprising because studies such as (Kabbiri et al., 2018; Aker & Mbiti, 2010) have found that mobile phone use in Sub-Saharan Africa in Ghana has surpassed the rest of the world's mobile phone use. Also, since the DAIS requires farmers to call through phones, it is obvious that farmers who have mobile phones will stand in a better position to access the services than those who do not have mobile phones.

Moreover, the model analysis shows that perceived usefulness was positively significant with the intention to use the DAIS. Perceived usefulness gave a coefficient of 0.270, an odd ratio of 0.308, and significant at 0.000. It implies that smallholder farmers who perceive the DAIS to be useful will use it more than farmers who perceive it as less useful. The present finding is consistent with the study result of Ulhag et al. (2022), who found that shrimp farmers who perceived ICT useful increased their adoption in shrimp farming. The present findings suggest that farmers perceptions play important role in their final decision to adopt new technologies. Positive perception of technologies can be increased when farmers are involved in the planning and development stages of new technologies meant for them.

Furthermore, table 12 shows that perceived ease of use was positive and significant with farmers intention to use DAIS. PEOU had an odd ratio of 0.634, a coefficient of 0.319, and significant at 0.001. it suggests that farmers who perceived the DAIS to be ease to use will invariably use it, holding all things constant. Smallholder farmers in the study area are used to using mobile phones for making calls and seeking information from other organisations. The DAIS uses the same concept of call-making; therefore, it uses is not different from traditional phone calls. That could explain the positive intention to use DAIS by many farmers. This means that technologies that are developed using concepts that farmers are used to will not face adoption and usage difficulties.

Also, table 12 shows that privacy concern was positively significant with smallholder farmers intention to use DAIS. It means that the more smallholder sees the DAIS not be a threat to their privacy, the more they will use it.

Moreover, access to electricity was also positive and significant with the intention to use DAIS. Farmers who have access to electricity will use DAIS more than farmers who do not have access to electricity. The odd ratio of electricity was 0.076 and with a coefficient of 0.547. electricity plays an important role in mobile phones, and other electronics use. Thus, farmers who lack access to this social amenity may not be able to use mobile phones or other electronic devices that will help them access the DAIS.

Finally, network access was found to be insignificant with the intention to use DAIS. This is a surprise because mobile phone use goes hand in hand with mobile network access; it was therefore expected that mobile network access increase intention to use DAIS. However, farmers network access varies based on the location of their farms and homes. Some may have good mobile network reception in their farmers and may have poor network at home. Others may also have good network reception at home and poor network reception on the farm. This could be the reason why both farmers with network access and those without mobile network access showed no significant difference in the intention to use DAIS.

4.13 The proposed Decentralized Digital Agricultural Information Services (DDAIS)

Based on the literature review and the study results, a digital agricultural information service called Decentralized Digital Agricultural Information Services (DDAIS) is proposed. This model will help serve the different farmer groups in the Municipalities. It will also help increase extension coverage in the areas. Farmers will get up-to-date agricultural information to speed up their decision-making on production. The DDAIS will be operated in the Ewe language, the dominant language in the study areas. The service can be accessed using a simple mobile phone.

The logistic regression model results showed that farmers willingness to use the Decentralized Digital Agricultural Information Services (DDAIS) was 85%. This shows that the system would not face accessibility challenges. Farmers find it important and relevant.

The Decentralized Digital Agricultural Information Services (DDAIS**)** will provide two services. An Information Desk (ID) and Voice Audio text Messages (VAM). The information desk will function as a customer support service.

The figure below is a demonstration of how the DDAIS will function. The DDAIS will have a toll-free number that farmers will dial to access the services. The extension agents will operate the system at a centralized location. The system consists of a concierge that calls will route through to the extension agents, so when a farmer calls, a list of options will be provided through the interactive voice response (IVR) unit. The caller will have options to press 1 for crops, 2 for animals, 3 for fisheries, 4 for inputs, 5 for general extension services. The system also contains automatic Call Distribution (ACD) systems and Computer Telephone Integration (CTI) systems. The ACD will route the farmers' call to the available extension agent based on their area of experts. There is a CTI that will link the call to an accounting system that will show on the computer screen to enable the agent to see the caller ID and other relevant details. This also will provide the AEA an opportunity to take notes and document vital information.

The second service will be voice audio text messages. Regular recorded short voice audios will be sent to farmers to inform them of new developments in agriculture. The IVR message interface will store the prerecorded messages distributed to farmers.

4.13.1 Functions of major parts

Voice Log Server: The voice log server contains the voice mail memory; it stores recorded conversations between farmers and the extension agent. Prerecorded audio will also be stored in the voice mail memory.

IVR/Dialer CTI Server: The IVR will house all prerecorded voice instructions that provide instructions to callers.

Custom Call Control: The Custom Call Control is embedded in the call log server cables; it helps the operators to control calls that route through the concierge.

Device Arc Server: The device arc server is connected to the switch to communicate with other units such as, the voice log the and IVR system. Among these is the Database Access Control: the system that contains, monitors, and houses all the farmers' data. This helps the extension services to document data and all details of farmers.

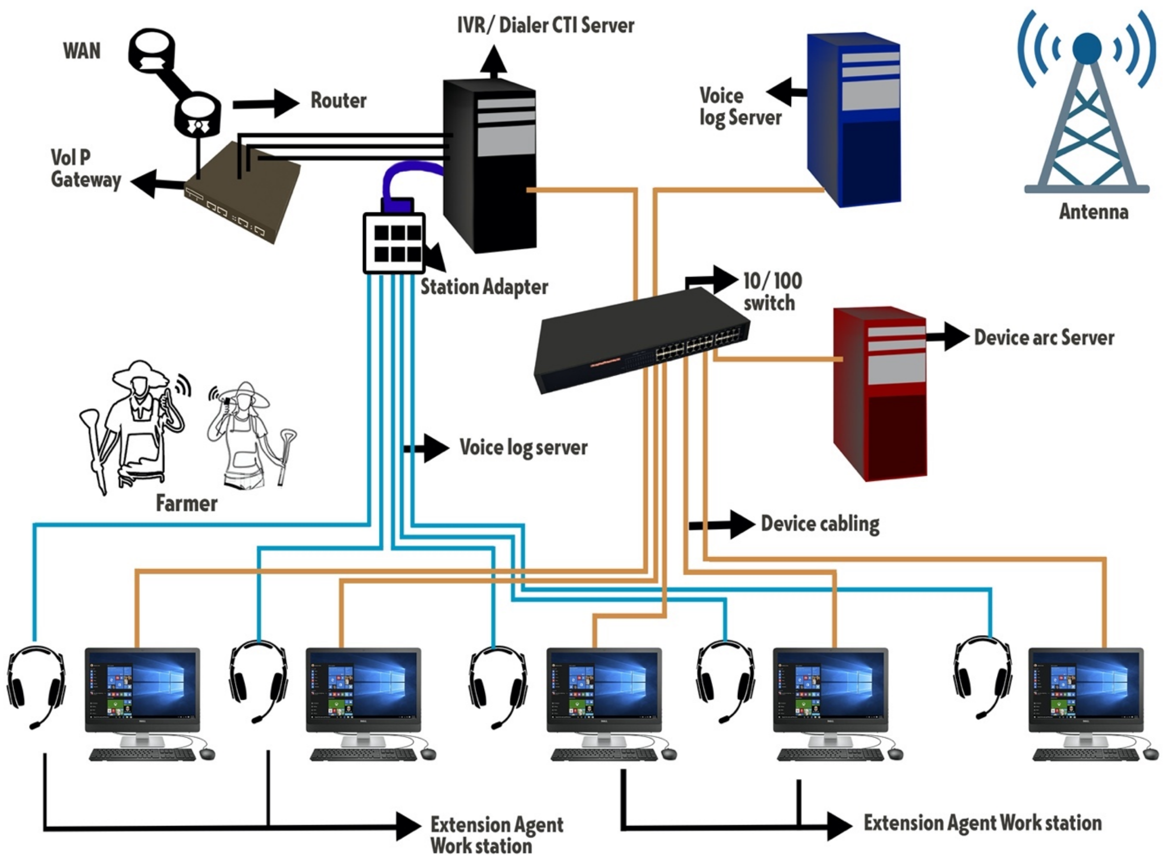

Figure 16. The proposed Decentralized Digital Agricultural Information Services (DDAIS) model. (Sources: author's own sketch, 2022)

4.13.2 Justification

The proposed digital agricultural information model is unique because it will be offering services in the local language spoken by the majority of the farmers. Additionally, it will be operated by extension agents in the region the farmers operate; therefore, tailored agricultural information and local knowledge will be offered. The service will be free to all farmers. It will help all commercial and small-scale farmers get timely agriculture information, which will lead to increased technology adoption among farmers, high farm output, and increased farm income.

The proposed model may not have a social acceptance challenge because many farmers are used to receiving text messages and calling customer services for an assistant.

The DDAES will complement the extension delivery services by reducing the workloads on extension agents. Many farmers will also be covered within a short period since voice messages can be sent to many farmers at a time.

The DDAES extension model is the future of agriculture extension delivery in Ghana.

Limitation

The anticipated challenge with this system will be accessibility. While the model is expected to increase extension coverage, farmers who do not have mobile phones will not be able to access the service. Although our study results showed that the majority of the farmers in the areas have access to mobile phones than any other ICT device, the few farmers who do not have mobile phones may not be able to access the service. Also, farmers who live in areas without mobile network coverage may find it difficult to access the service. The farmers who do not speak Ewe may find it difficult to use the service since it will be fully operated in the Ewe language.

The Department of Agriculture in the areas must locate the farmers who do not have mobile phones and those who live in no mobile network zones and offer regular extension services to them to enable them to have equal access to information.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions of Findings

This chapter covers the conclusions and recommendations, including a summary of findings, new research findings, policy implications, and recommendations based on the research questions. The main purpose of the study was two folds. First, identify and evaluate the factors impacting smallholder farmers' digital technologies use, and then propose a digital agricultural information service to enhance smallholder farmers and extension communication in the Ketu.

The results obtained from the study showed demographic factors such as gender, age, education, marital status, and family size; economic factors such as income, land ownership, income source, land size, type of farming, and farming experience; institutional factors such as extension visits, farmer association membership, and extension training participation; language barrier, and cost of accessing service were the main factors influencing smallholder farmers digital agricultural technologies adoption and usage in the Ketu municipalities.

Demographic factor analysis

The study has made an interesting revelation in the demographic distribution of smallholder farmers in the Ketu municipalities. According to the study, the aging working cohorts largely control agricultural activities in the municipalities. This is evidenced by the high percentage distribution of older farmers than youthful farmers in the study result. This finding is a testament to the general notion that the youth are not attracted to the agricultural sector job and that the sector is gradually filling by the aging cohorts. The study findings revealed that males dominate smallholder agricultural activities more than females in the areas. Moreover, it was found from the study that a large number of the smallholder farmers in the study areas were married, which indicates that marriage is an important sociocultural practice in the Municipalities.

Furthermore, the findings showed that more than half of the smallholder farmers in the municipalities are educated, contrary to past study findings. This means that the majority of the farmers in the area have literacy and numeracy skills. They can keep simple records and perform basic arithmetic. This revelation is novel in the study of smallholder farmers in Ghana because past studies have consistently classified smallholder farmers in Ghana as illiterate who cannot read or write in their native languages. Therefore, the present findings show that the education trend among smallholder farmers is changing. Additionally, the study has revealed that smallholder farmers in the Municipalities have large household sizes. This was evidenced by the majority of the farmers having more than four household members. It implies that smallholder farmers in the areas have more dependents.

Moreover, the study has shown that more than half of the smallholder farmers in the study earned more than GHS10,000 (1,200 Euros) annually, implying that their annual income is higher than the national minimum wage. This result is a great revelation in the study of smallholder farmers because past studies on smallholder farmers have found and classified them as poor and living below the national minimum wage threshold. The study further revealed that most smallholder farmers in the municipalities inherited the land they owned. Inheritance can therefore be said to be the main source of land ownership in the area.

According to the study results, crop production is the most practiced agricultural activity in the Municipalities. This was evidenced by the results showing crop production being the highest practiced by most farmers, followed by livestock production, while fishing and fish farming were the least in the areas. New entrant farmers can look at livestock production or fish farming as an entry point to the farming sector in the municipalities since fewer farmers are in that sector market, and profitability will be high.

The findings also revealed that most smallholder farmers in the municipalities do not have access to extension services. According to the results, nearly three-quarters of the farmers did not receive extension service throughout the production season. This shows that agricultural extension coverage is very low in the municipalities; greater majority of farmers who are supposed to get agricultural advisory services from the extension services were left without services. The study revealed that farmers relied on their colleague farmers and other farmer associations as their main sources of information. Although relying on colleague farmers as sources of agricultural information have proven to speed up information dissemination and technology adoption, however, if the channel is not well developed to ensure competent and well-trained individuals are in charge, fake and unreliable information may be shared among farmers, which may have a long-lasting consequence in the agricultural value chain. Therefore, It is important for the extension services to establish a system where farmers can seek or verify information from informal sources other than the established systems.

Smallholder farmers' information needs

The study has identified eight key themes of information needs of smallholder farmers in the study areas. These themes were weather information, agricultural input, subsidies, farm credit, feed and feeding information, market for produce, pests, and diseases, and postharvest practices. These information needs depend largely on the type of agricultural activities the farmers undertake, as opposed to the general classification of smallholder farmers' information needs in past research without recourse to the variations. For instance, the current study found that the priority of crop farmers' information needs differs from that of livestock farmers, fish farmers, and agro-processors. Crop producers require information on the weather forecast, availability of inputs and their associated prices, government subsidies, pests and disease management, and credit availability. Livestock farmers, on the other hand, require information on feeds, vaccines, farm credits, pests, and diseases. The study also documented that weather conditions, feeds and feeding management, premix fuel, and credit were the dominant information needs among smallholder fish farmers and fish folks. Moreover, agro-processors and marketers' information needs were farm location, harvesting period, the quantity of produce or livestock available, packaging and labeling, and availability of transportation. The study further revealed that farmers require this information at different points in the production seasons; certain information is required before the start of the season, and others are required at the start, within, and toward the end of the season. The study has identified varieties of agricultural information needs among the smallholder farmers in the Ketu

Municipalities. This information ranged from technical (production) and market (sales) to regulatory (subsidies) information.

Considering the current trend of climate change and the new digital revolution in the agriculture sector, coupled with government policies to ensure food security, food quality, and sustainability in agriculture, smallholder farmers in all sectors of the agricultural value chain need timely and reliable information to make decisions. This can be achieved through effective digital agricultural information services that farmers can access easily.

Main digital agricultural technologies used by smallholder farmers

The study has revealed that mobile phone is the most information communication tool used by smallholder farmers in the municipalities. A simple mobile phone without internet features was the top ICT tool used by almost all the farmers (77.7%). This is a novel finding in farmer-extension communication research because past research findings have shown that radio is the most ICT tool used by smallholder farmers in developing countries. The current finding suggests that mobile phones have become the most preferred digital tool used by smallholder farmers in Ghana. Hence, mobile phones can be the best medium to reach a large number of smallholder farmers with agricultural innovations in the municipalities. Therefore, digital agricultural information services that are compatible with simple mobile phones will be more useful to smallholder farmers in the study area.
The study also found that smallholder farmers have access to different mobile network services in the municipalities. This makes it possible for them to use mobiles for their farmers.

Challenges of accessing existing digital agricultural information service

The study also has shown that many farmers in the municipalities have never used any form of digital agricultural information service before. The identified digital agricultural services outside the municipalities that few farmers have tried before were Farmerline, Esoko, and E-extension. Among these digital platforms, MOFA e-extension operated as a public service at the national level; however, it lacked services such as voice audio and SMS. Farmers also find it difficult to access its services due to unavailability. Esoko and Farmerline were operated by private firms, the study showed that they do not cover most of the agricultural activities undertaken in the municipalities. Their services are not offered in the dominant language spoken in the study municipalities; also, they require subscriptions that many farmers cannot afford.

The study has also found that language barrier was the most challenge that many farmers faced accessing the existing digital agricultural information services. All the existing service providers offered their services mainly in English and Twi, which are not well-spoken by farmers in the areas. Ewe, which is the dominant language in the area, is not used. The study also revealed that cost of accessing the service, limitedness of services, service failure, and unavailability of contents or information were the major challenges smallholder farmers faced with the existing digital agricultural services.

The innovation adoption categories that smallholder farmers belong to

The study has found that most smallholder farmers in the Municipalities belong to the early and late majority categories of innovation adoption. This implies that smallholder farmers in the areas are passive to new technology use. They may want to see evidence such as pictures, videos, reviews, and testimonies from other farmers using similar technologies before making adoption or usage decisions.

The present study has discovered an increasing trend of innovativeness among smallholder farmers, and the observed trend is different from Rogers' diffusion of innovation trends. For instance, in Rogers' innovativeness category, innovators were 2.5% as against 2.7% in the present study; 13.5 in the early majority as against 13.9 in the present study, and laggards were 16% in Roger's theory as against 14.4% in the present study. These findings mean innovativeness is not static and may vary by geographical location, culture, people, and demographics.

Demographic and socioeconomic variables of smallholder farmers and their relationship with intention to use DDAIS

The findings from the study showed no statistical difference between men's and women's probability of using DDAIS in the municipalities. Thus, men and women have equal chances of accessing digital information services. Also, land ownership negatively affected farmers' intention to use DDAIS. Farmers who own their lands in the study areas are less likely to use DDAIS.

Moreover, increasing extension visits to smallholder, farmers decrease their probability of using DDAIS. Thus, smallholder farmers who receive constant extension visits from the extension services will not border themselves so much to access agricultural information using digital services. The study further revealed that an increase in smallholder farmers' participation in farmers' associations decreases their intention to use DDAIS.

Also, farmers' access to mobile phones increases their probability of using DDAIS. Farmers in the study areas will likely use the DDAIS due to their increased mobile phone use.

Also, smallholder farmers with large household sizes are more likely to use the DDAIS than smallholder farmers with smaller household sizes.

Perceived usefulness increases smallholder farmers' likelihood to use DDAIS. Smallholder farmers who perceived DDAIS to be useful to them have a higher probability of using them. Additionally, perceived ease of use increases smallholder farmers' likelihood to use DDAIS. Smallholder farmers who perceived DDAIS to be easy have a higher probability of using it.

According to the study, privacy concern increases the probability of using DDAIS. The more farmers see the DDAIS as secure and protect their privacy, the higher their intention to use it.

Also, farmers who have access to electricity will use DDAIS more than farmers who do not have access to electricity. Similarly, smallholder farmers with access to mobile networks have more positive intentions to use DDAIS than those without network access.

5.2 New scientific results

Based on the research design and the data collected from the research areas. The current research has made the following novel findings in smallholder farmers' digital agricultural technology use in Ghana.

1. Many research have adapted the Rogers diffusion of innovation theory to classify and explain farmers innovativeness. All the past studies found smallholder farmers as less innovative. However, the new scientific results from the current research showed an increase in innovativeness among smallholder farmers. There were fewer laggards but more innovator farmer cohorts in the Ketu Municipalities. The current trend of innovativeness among smallholder farmers is slightly different from the original diffusion of innovation categorization by Rogers. Our findings demonstrate that innovativeness among farmers is not static; it changes over time in response to technological advancement and demographic changes.
2. Our research has also found a positive shift in smallholder farmers demographic characteristics in the Ketu Municipalities. The new scientific result showed that more than half of the smallholder farmers in the Ketu Municipalities are educated, contrary to past research findings. Also, many of the smallholder farmers annual income from farming has increased above the national annual minimum wage. That is, more than half of the farmers annual income was above GHS10,000 (1,200 Euro). The findings are novel in the study of smallholder farmers in Ghana because past research have consistently classified smallholder farmers in Ghana as illiterate who cannot read or write in their native languages and also earn below the national minimum wage threshold. The current findings, therefore, give hope for smallholder agriculture in Ghana.
3. The research has revealed that mobile phone is the most used ICT device by smallholder farmers in the Ketu Municipalities. It was found that more than three-quarters of the farmers used simple mobile phones without internet features. This finding is novel because past research has identified radio as the most ICT device used by smallholder farmers in Ghana.
4. The research has found that perceived usefulness, perceived ease of use, privacy concern, and access to mobile phones are the main factors that increase smallholder farmers' intention to use DDAIS. Also, the new scientific results from the current research showed that smallholder farmers in the Ketu Municipalities have the capacity to access and are willing to use digital agricultural information services. Based on these new scientific results, We have proposed and designed a digital agricultural information model called Decentralized Digital Agricultural Information Services (DDAIS) to be implemented in the Ketu Municipalities to enhance smallholder farmers and extension communication.

5.3 Policy implications and recommendations

The findings from this research serve as a guide to the local government regarding municipal agriculture policy development. Different farmer groups have different needs; therefore, in formulating policies for farmers, one cannot assume that smallholder farmers are homogenous; thus, a general policy can be developed for them. Areas specific problem is also different from other areas. Agriculture policy for the entire Ghana would need to be localised to meet the needs of the areas. This study gives insight to policymakers to implement decentralised agriculture policy that meets farmers needs in the geographical areas they find themselves. Livestock farmers, crop producers, fish farmers/fishermen information needs are different. Therefore, policymakers need to be guided.

The study also helps the extension services to know the current trend of digital technology use in Ghana and the need to develop programmes and training that meet the current trends of farmers information access in the country.

Future studies will dwell on the empirical evidence from this study to develop a more robust digital agriculture system that meets the presence of information needs while paving the way for future innovations in agricultural communication in Ghana.

Based on the qualitative and quantitative research techniques employed and the findings from the current study, the following recommendation is proposed.

The Decentralised Digital Agriculture Information Services should be implemented in the Ketu municipalities by the Department of Agriculture Extension Services (DAES). This will help provide extension advisory services to all farmers in the municipalities. Our study result indicates that many farmers use mobile phones; therefore, taking advantage of the proliferation of mobile to implement the DDAIS will reduce the asymmetry in extension service access in the municipalities. The DAES should partner with the mobile telecommunication companies that offer good service in the area to roll out this programme.

Also, the extension services would need to sensitize farmers with the existence of the DDAIS when it is first introduced, farmers need to be informed of the importance of the services, the safety measures put in place to protect their privacy, how the system operates and the benefits that the farmers will derive from its implementations because our study shows that many of the farmers are categorised into Late and Early majority of innovation adoption.

The extension services should adopt a participatory approach to programme planning and development where farmers are fully involved in the decision-making of the programmes and services meant for them. Doing this will increase farmers perceived usefulness and perceived ease of use of extension programmes. They will also feel being part of the whole extension system, resulting in increased adoption, use, and sustainability of extension programmes. Our study has proven that participatory approaches increase farmers perceived ease of use and perceived usefulness.

The extension services should partner with other NGOs, private institutions, and the local government to introduce more youth-centered and gender-inclusive agriculture programmes in the study areas. This will make agriculture more attractive to the youth in the area. Programmes such as school and community gardening can be implemented to give hands-on experience to students and youth in the communities. A special financial support programme for women and youth can be implemented as an entry support fund. This will motivate women and youth to actively participate in production agriculture, which may serve as a remedy for the aging farmer population in the municipalities.

Moreover, extension services and organisations that introduce new technologies or innovations to farmers must develop multifaced communication strategies when engaging smallholder farmers in new technology adoption. Evidence-based marketing or communication strategies coupled with oral communication and pamphlet distribution should be adopted. It will help meet the different means that smallholder farmers access information, considering the different innovation adoption groups that farmers belong to in the Ketu Municipality.

Future studies have to explore the factors contributing to the changes in demographic factors, such as an increase in farmer education, income, and innovativeness in the study area.

The current study is limited to the Ketu Municipalities, it is therefore recommended that future studies replicate the study by including other regions in Ghana and also increase the sample size to see if the same trend of smallholder farmers demographics and digital agriculture use exists.

6. SUMMARY OF THE THESIS

Smallholder farmers in Ghana depend largely on extension services for advisory services on new technologies, government policies, and developments in the agricultural sector. However, the public extension services in Ghana are understaffed. The ratio of extension agents to farmers is about 1:1500, which is higher than the Food and Agriculture Organization's recommended ratio of 1:400. As a result, fewer farmers are covered by the available extension agents, leaving many farmers unattended. Also, for a long time, Ghana has been practicing the home and farm visit extension approach, which involves physical meetings with farmers in groups or individually. Nevertheless, the recent global Coronavirus (COVID-19) pandemic has proven that these forms of extension approach to physical meetings cannot always be assured.

Moreover, the mobile and telecommunication industries in Ghana are well positioned in the Sub-Saharan sub-region to support farmers' information access. The subscription and use of mobile phones and other Information Communication Technology (ICT) devices have increased tremendously in Ghana since the introduction of the first mobile phone in the country in 1992. These new trends in the communication industry can be an engine for agricultural extension services to link researchers, advisory services, and farmers together to promote effective communication and information dissemination.

The study aimed to identify and evaluate the factors impacting smallholder farmers' digital technologies use and then to propose a digital agricultural information service to enhance smallholder farmers and extension communication in the Ketu Municipalities. Specifically, the study sought to:

5. Identify and evaluate the digital agricultural technologies commonly used by respondents.
6. Assess smallholder farmers' information needs in the areas.
7. Analyse smallholder farmers' demographic and socioeconomic variables and their relationship with the intention to use digital agricultural services.
8. Identify the innovation adoption categories that smallholder farmers belong to and the factors impacting their digital agricultural technology use intention.

Also, the following research questions laid the basis for the study.

6. What is the status of digital agricultural services in the Ketu Municipalities currently?
7. What information do the different smallholder farmers in the Ketu Municipalities need to support their production?
8. Which demographic and socioeconomic characteristics of smallholder farmers impact their intention to use digital agricultural technologies in the area?
9. Which innovation adoption categories do smallholder farmers belong to in the Ketu Municipalities?
10. Which digital extension model will best serve the diverse smallholder farmers in the Ketu municipalities?

A review of literature on topics such as the importance of digital technologies in agriculture, Barriers to digital agricultural adoption, traditional media and modern media, the difference between traditional media and new media, mobile phones and agriculture information access, the importance of mobile phones in agriculture, existing digital agricultural services facilitating agricultural information access in developing countries, farmer information needs, the role of agricultural extension in innovation transfer, and role of digital extension service were conducted to support the research problem and the objectives. Dwelling on the diffusion of innovation theory and the technology adoption model. The study adopted an exploratory sequential research approach where qualitative data was collected first, followed by quantitative data. The study used multistage sampling techniques to select the sample for the quantitative data collection. The towns in each Municipality were grouped into three zones based on the operational areas zoning used by the agricultural extension department. Altogether, six zones were created in the study areas. Simple random and purposive sampling techniques were used to select the respondents in each zone. A total of 414 smallholder farmers formed the main sample size for the study. The qualitative data were collected through focus group discussions and one-on-one interviews, while the quantitative data was collected through a survey. The qualitative data were analyzed by coding the interview responses to generate major themes. The quantitative data were also analyzed using descriptive statistics and the logistic regression model was used to establish the relationships among the dependents and the independent variables. Also, the study adopted the Hurt et al. (1977) innovativeness determination scales to classify the respondents into the five main innovative categories proposed by Rogers.

The results of the demographic characteristics of the respondents in the study gave broader background information on smallholder farmers in the Ketu Municipalities. It was observed that most of the smallholder farmers in the areas under study were above the youthful age cohort, which indicates that the youth are less participated in farming and agricultural-related activities. Smallholder agriculture in the areas is in the hands of the aged population. The result, therefore, confirms the growing trend of the aging labour population in agriculture in developing countries. A similar result was observed by Udimal et al. (2017) and Adebiyi & Okunlola (2013) in their study of rice and cocoa farmers in Nigeria and Ghana. While their studies focused on farmers in specific crops, the current study considered all smallholder farmers. The implication of this result is that digital technology use in agriculture in the study areas is likely to be affected negatively since young farmers are known to adopt and use new technologies more than older farmers. Also, it was observed that males dominate agriculture production in the study areas more than females. This finding is consistent with the past study by Oyekale (2021) and Asravor (2018), who documented male-populated agricultural activities in Ghana. They both attributed their findings to the nature of agricultural practice in Ghana. In the present study, the respondents explained that men usually engaged in the main production activities while women played supporting roles by doing light activities such as harvesting, processing, and sales of farm produce. The present findings can be attributed to the division of labour in the study area.

The study also identified that more than half of the respondents were educated. This is a novel revelation because past studies such as Bruce (2015) and Al-Hassan (2008) have found and classified smallholder farmers are highly illiterate and that smallholder farmers in Ghana can neither read nor write in English and in their native languages. This is welcoming news for the agricultural extension services in the area since the adoption and use of digital technology need some levels of basic education; therefore, having more educated farmers in the study areas may promote digital agricultural technology information access.

The results also revealed that most smallholder farmers had annual incomes above GHS 10,000 (1200 euros). This result implies that more than half of the smallholder farmers earn above the national minimum wage of 584 euros per annum. This is a bit surprising because past studies have established that smallholder farmers in developing countries, especially in Africa, live in poverty and cannot afford 1 euro a day. The reason for the current result could be the diverse farmer groups involved in this study. For example, fish, livestock, and rice farmers earn more money per harvest or sale than arable crop farmers. Their inclusion in this study may justify the increase in the annual income of smallholder farmers in the study areas. However, this new result suggests that poverty should not be generalised among farmers in a particular geographical location. The study found that a significant majority of the farmers rent the land they operate on. The interpretation of this result is that smallholder farmers in the areas may find it difficult to make long-term investments or establish permanent crops on their lands since majority of them do not own the farmland. It will therefore be necessary for them to use digital technologies that can help them access timely information to increase their productivity within a short time to gain profit from their investments. Similarly, the study found that inheritance is the main source of land ownership in the study areas. This finding could be linked to the land ownership systems in Ghana. Lands in Ghana are largely owned by families (customary lands). Families usually do not sell the lands; they rather share among family members. This practice could account for the increase in inheritance as the main source of land ownership in the study areas.

Regarding farmers use of digital agricultural services in the study areas, majority (83.1%) of the respondents indicated that they have never accessed agricultural information through any digital agricultural platform, while 16.9% indicated that they have accessed agricultural information through digital agricultural platforms. The implication of the result is that the use of digital platforms to communicate agricultural information is still at a juvenile stage in the study area. It will therefore require much education to stimulate farmers interest in using digital agricultural platforms introduced in the area.

The popular digital agricultural services used by a few farmers were Farmerline (private service), Esoko (private service), and E-extension (public service). The public digital agricultural service lacked services such as voice audio and SMS. It was operated at the national level and has been out of operation, so farmers cannot access any of it. The private digital agricultural services do not provide services in areas the majority of farmers in the Ketu municipalities operate. Their services are mainly offered in Twi and English, which the majority of farmers do not understand. Therefore, language barriers, cost of accessing services, limitedness of services, service failure, outdated information, and unavailability of contents were the major challenges farmers faced with the existing digital agricultural services.

All the private DAIS offer agricultural information services mainly to crop producers with little or no services to animal and fish farmers. Private enterprises usually invest in areas where the return on investment is high, therefore, having the private DAIS focusing more on the crop sectors suggests that there is a higher profitability in the crop production than in the animal production in the areas. However, smallholder farmers make up the majority of farmers in Ghana, their system of farming combines two or more farming methods; as such, a digital service to them should be able to cover all the major agricultural areas. Additionally, considering their low-income status, coupled with resource constraints on their side, digital agricultural services to them should be opened to all of them without restrictions of any kind; to promote technology adoption and use among them. Additionally, smallholder farmers also vary in technology use, information access, and needs, therefore, to promote equal access to agricultural information by all smallholder farmers in the areas, it will be important to have a DAIS that combines web-based services or mobile app with a call centre support service to serve all the farmers information needs, regardless of their productivity type or levels.

The possibility of accessing digital agricultural information by smallholder farmers depends on existing policies and the ownership and access to digital devices. The result of the main digital devices used by respondents in the study areas showed that mobile phone without internet access was the highest (77.7%) digital device owned and used by smallholder farmers in the study areas. This result suggests that mobile phones have become the most preferred digital tool used by smallholder farmers in Ghana. Hence, a mobile phone can be the best medium to reach a large number of smallholder farmers with agricultural innovations.

The current findings corroborate with the study of Krell et al. (2021), who observed that more than 90% of respondents in their study own mobile phones compared to other ICT devices. Contrary to the current findings, Fawole and Olajide (2012) observed in their research that among the rural farmers in Nigeria, radio and televisions were the most widely used ICT devices compared to mobile phones. It should be noted, however, that Fawole and Olajide's study was carried out in 2012, whereas the current study was conducted in 2022. This suggests that time and geographical location play important roles in digital technology adoption and usage.

The study identified that information needs vary among farmers due to the heterogeneity of farming activities in the areas. While crop producers need information on the type of fertilizer to apply to their crops, animal producers and fish farmers seek information on new feeds and vaccines. This means that different farmer group requires different information. Having these diverse information needs means that an integrated agricultural information system will be needed to serve these diverse farmer groups in the study areas. Furthermore, the study found that farmers require this information at different points in time in the production seasons, i.e., some information is required before the start of the season, others are required at the start of the season, within, and toward the end of the season. This indicates that farmers require periodic information throughout the production periods. Additionally, considering the volatility and the unstructured agriculture marketing systems in Ghana, smallholder farmers need assistance to find the available markets, prevailing prices, and information that will enhance their work efficiency.

Moreover, the study found that the majority of smallholder farmers in the study areas belong to the early majority and late majority category of innovation adoption. This means that farmers in the early majority and the late majority play key roles in determining digital technology use and diffusion in the study areas. This suggests that organizations, individuals, and extension services that introduce new technologies or innovations to farmers must develop multi-facet marketing or communication techniques when engaging smallholder farmers in new technologies adoption; it will help get all levels of farmers groups to accept the new products.

Also, comparing the current study results with the percentage results of the Rogers innovation adopter category chart (refer to Fig 1), the present study identified an increased trend in innovativeness among the farmers. For instance, in Rogers' innovativeness category, innovators were 2.5% as against 2.7% in the present study; 13.5 in the early majority as against 13.9 in the present study, and laggards were 16% in Roger's theory as against 14.4% in the present study. These findings mean that innovativeness is not static and may vary by geographical location, culture, people, and demographics. Therefore, a macro-level study result (as in Rogers' study) may differ from a micro-level study (as in the current study).

Furthermore, the model analysis shows that perceived usefulness was positively significant with the intention to use the DDAIS. Perceived usefulness gave a coefficient of 0.270, an odd ratio of 0.308, and significant at 0.000. Also, perceived ease of use was positive and significant with farmers intention to use DDAIS. PEOU had an odd ratio of 0.634, a coefficient of 0.319, and significant at 0.001. it suggests that farmers who perceived the DDAIS to be ease to use will invariably use it, holding all things constant. Additionally, smallholder farmers who perceive the DDAIS to be useful will use it more than farmers who perceive it as less useful. The present findings suggest that farmers perceptions play an important role in their final decision to adopt new technologies. Positive perception of technologies can be increased when farmers are involved in the planning and development stages of new technologies meant for them. Access to mobile phone also increase smallholder farmers likelihood to use DDAIS.

The following new scientific results were obtained from the study;

1. Many research have adapted the Rogers diffusion of innovation theory model to classify and explain farmers innovativeness. All the past studies found smallholder farmers as less innovative. However, the new scientific results from the current research showed an increase in innovativeness among smallholder farmers. There were fewer laggards but more innovator farmer cohorts in the Ketu Municipalities. The current trend of innovativeness among smallholder farmers is slightly different from the original diffusion of innovation categorization by Rogers. Our findings demonstrate that innovativeness among farmers is not static; it changes over time in response to technological advancement and demographic changes.
2. Our research has also found a positive shift in smallholder farmers demographic characteristics in the Ketu Municipalities. The new scientific result showed that more than half of the smallholder farmers in the Ketu Municipalities are educated, contrary to past research findings. Also, many of the smallholder farmers annual income from farming has increased above the national annual minimum wage. That is, more than half of the farmers annual income was above GHS10,000 (1,200 Euro). The findings are novel in the study of smallholder farmers in Ghana because past research have consistently classified smallholder farmers in Ghana as illiterate who cannot read or write in their native languages and also earn below the national minimum wage threshold. The current findings, therefore, give hope for smallholder agriculture in Ghana.

3. The research has revealed that mobile phone is the most used ICT device by smallholder farmers in the Ketu Municipalities. It was found that more than three-quarters of the farmers used simple mobile phones without internet features. This finding is novel because past research have identified radio as the most ICT device used by smallholder farmers in Ghana.
4. The research has found that perceived usefulness, perceived ease of use, privacy concern, and access to mobile phones are the main factors that increase smallholder farmers' intention to use DDAIS.

The findings from the study have shown that the majority of the smallholder farmers in the Ketu Municipalities have the capacity to access and are willing to use digital agricultural information services. We, therefore, propose the implementation of a digital agricultural information model called Decentralized Digital Agricultural Information Services (DDAIS) in the Ketu Municipalities to enhance smallholder farmers and extension communication. The study results indicate that many farmers use mobile phones, therefore, taking advantage of the proliferation of mobile to implement the DDAIS will reduce the asymmetry in extension service access in the municipalities. The DAES should partner with the mobile telecommunication companies that offer good service in the area to roll out this programme.

The current study results give insight to policymakers to implement decentralised agriculture policy that meets farmers needs in the geographical areas they find themselves. Livestock farmers, crop producers, fish farmers/fishermen information needs are different. Therefore, policymakers need to be guided.

The study also helps the extension services to know the current trend of digital technology use in Ghana and the need to develop programmes and training that meet the current trends of farmers information access in the country.

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APPEDIX I
Questionnaire for smallholder farmers

Participants Consent

Dear respondents and participants,

My name is Daniel Ayisi Nyarko, a graduate student at the Hungarian University of Agriculture and Life Sciences. I am currently carrying a study on ***Digital Agricultural Information Model for Smallholder Farmers and Extension Communication,*** which seeks to assessing the digital information environment in the Ketu municipalities and develop a digital agricultural extension service that will support smallholder farmers information access. I humbly appeal to you to assist me by responding to this survey. The questionnaires are structured that it would not take much time to finish. The outcome of this study will assist the extension services in Municipalities to provide timely information to farmers. It will also help them to develop the appropriate communication strategies to orient smallholder farmers technological innovation adoption. Note that your responses will only be known to the research team, and we assure you that no information regarding your identity will be included in the report. Participation in this interview or survey in purely voluntary, if you are not willing to participate, there will be no loss of benefits or penalty assigned to you as a farmer.

In case you have any questions, you can contact the lead researcher at;

Nyarko.Ayisi.Daniel@phd-mate.hu

Thank you.

Questions

PART ONE

A. Information needs, sources of information and preferred sources of information.

1. Could you tell me in order of importance the most important information need in your area of production?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

2. Which sources have you been getting this information?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

3. Do you get them regularly?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

4. How credible do you see these sources to be?

……………………………………………………………………………………………………

5. Do you think getting them from different sources will help you in your farming decision making?

……………………………………………………………………………………………………
……………………………………………………………………………………………………

PART TWO

B. The states of digital agricultural services in the Ketu Municipalities

6. Have you used any digital extension services before?
   a. Yes b. No

Please if yes, continue from ***question 7***. If you no, please continue from ***question 14.***

7. Which among these have you used before?
   a. Esoko
   b. Farmerline
   c. MOFA E-extension
   d. Others (………………………………………………………)
8. Who was the provider of the digital agricultural services?
   a. Government b. private c. Both government and Private
9. What services do they offer? (Please select all that apply to you)
   a. Crop services
   b. Animal services
   c. Fisheries services
   d. Agro processing service
   e. Input services
   f. Agricultural credit services
   g. Agricultural mechanization
10. Which of the services did you sought? (Please select all that apply to you)
    a. Crop services
    b. Animal services
    c. Fisheries services
    d. Agro processing service
    e. Input services
    f. Agricultural credit services
    g. Agricultural mechanization
11. What languages do they operate?
    a. English b. Twi c. Ewe d. Others …………………………
12. What language did you use to communicate with them?
    a. English b. Twi C. Ewe d. Others …………………………

13. Can you list the major challenges that you faced when accessing the services of the named digital agriculture services?

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

C. Factors influencing smallholder farmers digital technology use.

14. Below are lists of mobile network services in Ghana, kindly select from the list the ones available in your area.
    a. MTN
    b. Vodafone
    c. Airtel-Tigo
    d. Glo
    e. None
15. Which of the mobile networks available do you use? kindly select from the list the ones available in your area.
    a. MTN
    b. Vodafone
    c. Airtel-Tigo
    d. Glo
    e. None
16. Do you have internet service in your community?
    a. Yes b. No
17. If yes, which among the two do you have in your community?
    a. Mobile broadband service b. Cable internet service
18. Do you have public internet café in your community?
    a. Yes b. No
19. Do you have access to internet?
    a. Yes b. No
20. If yes, which of the following do you have access to?
    a. Mobile broadband b. Cable internet
21. Is there public ICT training center in your community?
    a. Yes b. No
22. Do you have access to electricity?
    Yes 0. No
23. Below are lists of ICT devices commonly used in Ghana, kindly select from the list the ones you use regularly.
    a. Mobile phone (serviced)
    b. Smartphone
    c. Computer
    d. Radio
    e. TV
    f. None

24. Which among these devices do you own personally?
    a. Mobile phone (simple)
    b. Smartphone
    c. Computer
    d. Radio
    e. TV
    f. None

D. Technical capacities do smallholder farmers and extension service.

25. Have you participated in any ICT training in the last 1 year**?**
    a. Yes b. No
26. If yes, who organized the training?
    a. The extension service b. others
27. How did you learn how to operate the current device you are using?
    a. From family and friends b. through training

E. Demographic and socioeconomic variables

28. How do you identify yourself?
    a. Male b. Female c. Others
29. Which age category do you belong?
    a. Below 36-year b. 36 years and above
30. What is your highest educational attainment?
    ………………………….
31. What is your marital status?
    a. Married b. Single
32. What is your household size?

33. What is your annual household income range?
    a. Below GHS10,000 b. above GHS10,001
34. What is your main source of income?
    a. Farming
    b. Farming and other business
35. What type of farm do you practice? Please select all that apply to you.
    a. Livestock b. crops c. Fisheries d. Agro processing
36. How long have you been farming?
    a. Less than 5 years b. 6 to 10 years c. 11 to 20 years d. above 21 to 30 years
37. What is the total size of your holding?
    …………………………………..

38. Do you own the land you work on currently?
    a. Yes b. No
39. Are you a member of any farmer group or association?

a. Yes b. No

40. How many times do you receive extension visits in four months?
    a. 1 b. 2 c. 3 d. 4 e. 5 or more
41. Have you participated in any ICT training organised by the extension services in last 12 months?
    a. Yes b. No

F. Respondents' innovativeness variables

From question 1 to 20, please indicate the degree to which you agree or disagree to each statement by writing **only one number** against each question from **1, 2, 3, 4, 5**.

Where **1 = Strongly Disagree; 2 = Disagree; 3 = Neutral; 4 = Agree; 5 = Strongly Agree.**

There are no right or wrong answers, just record your first impression.

_______ 1. My peers often ask me for advice or information regarding new innovations in farming.

_______ 2. I enjoy trying new innovations or technologies in agriculture.

_______ 3. I seek out new methods to do things in farming.

_______ 4. I am generally cautious about accepting new innovations introduced in farming.

_______ 5. I frequently improvise methods for solving a problem in my farming operations when an answer is not apparent.

_______ 6. I am sceptical of new inventions and new ways of thinking.

_______ 7. I rarely trust new ideas or methods until I can see whether the vast majority of farmers around me accept them.

_______ 8. I feel that I am very influential member of my colleague farmers.

_______ 9. I consider myself to be creative and original in my thinking and behaviour.

_______10. I am aware that I am usually one of the last people in our farming group to accept new innovation.

_______11. I can inventive new ideas or method to improve agriculture production.

_______12. I enjoy taking part in the leadership responsibilities of the groups and associations I belong to in my area.

_______13. I am reluctant about adopting new ways of farming until I see them working for people around me.

_______14. I find it stimulating to be original in my thinking and behaviour.

_______15. I tend to feel that the old way of farming is the best way.

_______16. I am challenged by ambiguities and unsolved problems.

_______17. I must see other people using new innovations before I will consider them.

_______18. I am receptive to new farming practices.

_______19. I am usually challenged by unanswered questions.

_______20. I often find myself sceptical of new ideas and practices.

PART THREE

Respondents' perception on proposed decentralised digital agricultural information service.

Perceived ease of use

Please indicate your agreement or disagreement to following statements by indicating **yes** or **no.**

1. The decentralised digital agricultural extension information system contents will be easy to understand.
   a. Disagree b. Agree
2. The decentralised digital agricultural extension information system will be easy to access.
   a. Disagree b. Agree
3. I can call for information anytime I am on the farm.
   a. Disagree b. Agree
4. I will understand the information provided.
   a. Disagree b. Agree
5. I can operate the decentralised digital agricultural extension information system without support.
   a. Disagree b. Agree

Perceived usefulness

6. The decentralised digital agricultural extension information system will be very useful to my area of production.
   a. Disagree b. Agree
7. Using the decentralised digital agricultural extension information system will save me time.
   a. Disagree b. Agree
8. Using the decentralised digital agricultural extension information system will increase my productivity.
   a. Disagree b. Agree

9. Using the decentralised digital agricultural extension information system will increase my profitability.
    a. Disagree b. Agree

Language

10. Decentralized digital agricultural extension information system that offers services in local language is important to me.
    a. Disagree b. Agree
11. Decentralized digital agricultural extension information system in local language will be easy to use.
    a. Disagree b. Agree
12. Decentralized digital agricultural extension information system in local language will be easy to useful to my operations.
    a. Disagree b. Agree
13. Decentralized digital agricultural extension information system without subscription fee is all that I need.
    a. Disagree b. Agree
14. Decentralized digital agricultural extension information system without subscription fee will be useful.
    a. Disagree b. Agree
15. Decentralized digital agricultural extension information system without subscription fee will be easy to use.
    a. Disagree b. Agree

Data privacy

16. Using the decentralized digital agricultural extension information system will expose my production techniques to other farmers.
    a. Disagree b. Agree
17. The operators of the decentralised digital agricultural extension information system may sell data.
    a. Disagree b. Agree
18. Using the decentralized digital agricultural extension information system will expose me to the spirit world.
    a. Disagree b. Agree

Service (animal, crops, fisheries, inputs, processing)

19. Digital agricultural information service that provides services on animal, fisheries, inputs, processing, and crop production will be useful to me.
    a. Disagree b. Agree
20. Digital agricultural information service that provides services on animal, fisheries, inputs, processing, and crop production will increase my knowledge on farm practice.
    a. Disagree b. Agree
21. Digital agricultural information service that provides services on animal, fisheries, inputs, processing, and crop production will help me save money.
    a. Disagree b. Agree

22. Digital agricultural information service that provides services on animal, fisheries, inputs, processing, and crop production will be easy to use.
    a. Disagree b. Agree

Information

23. It will provide exact information I get from extension agents during visits.
    a. Disagree b. Agree
24. The information will be genuine.
    a. Disagree b. Agree
25. The information will be suitable for my current needs,
    a. Disagree b. Agree
26. considering I have access to such system I will.
    a. Disagree b. Agree
27. I will recommend it to my colleagues to use.
    a. Disagree b. Agree

APPENDIX II

Figure 17. Focus group meeting with crop producers.
(Source: Field data, 2021).

Figure 18. Focus group meeting with agro-processors. (Source: Field data, 2021).

Figure 19. A visit to a farmer's cocoa farm. (Source: Field data, 2021*)***.**

Figure 20. Focus group meeting with livestock farmers. (Source: Field data, 2021).

Figure 21. Focus group meeting with fishermen and fish farmers. (Source: Field data, 2021)