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Benefits, barriers, challenges and requirements for the application of digital technologies in agricultural extension in selected regions in Ghana: Perspectives from extension agents

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The application of digital technologies in agriculture is noted for effectively contributing to sustaining agri-food systems and improving food and nutrition security worldwide. However, the adoption of these innovations in agricultural extension systems is low in developing countries. The current study sought to examine the benefits, barriers, challenges, and requirements for deploying digital technologies in agricultural extension in Ghana. The study surveyed 125 frontline extension agents using multi-stage sampling techniques and a questionnaire as the instrument for data collection. Frequencies, percentages, means, standard deviation, principal component analysis, and Kendall's coefficient of concordance were used to analyze the data. It was found that youthful males dominate extension delivery in Ghana. Extension agents regard the benefits of deploying digital technologies in extension as high (Mean = 3.55 ± 0.95). They agreed that the barriers are moderately high (Mean = 3.20 ± 0.91), while the challenges are high (Mean = 3.63 ± 0.95). To improve the application of digital technologies in extension in Ghana, extension agents agreed that the Ministry of Food and Agriculture (MoFA) should initiate strategies to procure digital devices for the Departments of Agriculture to further facilitate the sharing of practical knowledge in the field.

Key words: Agricultural extension delivery, benefits, barriers, challenges, digital technologies, extension agents, Ghana.

INTRODUCTION

The challenges facing agriculture in the 21st century are numerous, the biggest being the production of more food to feed a growing population with a decreasing rural labor force (FAO, 2009). According to the United Nations Department of Economic and Social Affairs (UN-DESA, 2017), the global population of 7.6 billion people will

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increase to 8.6 billion by the end of 2023 and 9.8 billion in 2050. The report suggests that even if global fertility rates continue to fall, the world population is predicted to grow by about 83 million people annually, continuing the upward trend. Despite these challenges, natural resources like fresh water and productive arable land are becoming less available, and rapid urbanization is having a significant impact on patterns of food production and consumption (Trendov et al., 2019). The trend indicates that more food and agricultural raw materials are needed to feed the growing population, supply the enormous bioenergy markets, and support overall development in many developing nations that depend on agriculture.

This can be achieved by adopting more effective and sustainable production practices and adapting to the challenges of climate change (FAO, 2009; Odjegba et al., 2022). Many farmers, especially those in developing nations, cultivate only a few hectares due to a lack of information about modern farming techniques and consequently continue to adopt conventional methods (Accenture Digital Agriculture Service, 2017).

Therefore, more productive, efficient, sustainable, inclusive, transparent, and resilient food production systems are needed to achieve the UN Sustainable Development Goal of a ‘world without hunger’ by 2030 (FAO et al., 2019; WFP, 2020). At the heart of this agri-food systems transformation is the digitalization of agriculture (Trendov et al., 2019). Tsan et al. (2019) defined digitalization for agriculture as “the use of digital technologies, innovations, and data to transform business models and practices across the agricultural value chain and address bottlenecks including productivity, postharvest handling issues, market access, finance, and supply chain management (5).

Digital technologies in agriculture help direct and inform farmers’ choices, promote the economic and effective use of natural resources, lower risks, mitigate the effects of climate uncertainties, and enhance resilience in farming and agri-food value chains (Maru et al., 2018; Ahsan et al., 2023). The dissemination of new technologies among farmers by extension agents can be achieved by using agricultural information and communication technologies and knowledge delivery methods that are transmitted within the agricultural sector (Nyarko and Kozári, 2021; Osumba et al., 2021).

Agricultural production challenges such as extended drought, pest and disease outbreaks, seasonality, geographical dispersion of farming, knowledge irregularities, and high transaction costs are some of the many issues in the agricultural sector that digital technologies can identify and address to facilitate effective farming (Daum, 2018; Martey et al., 2020).

The adoption of cutting-edge digital technologies by extension agents for extension delivery has been limited by the inadequate infrastructure and equipment available to public extension services (Norton and Alwang, 2020).

Collaboration among scientists, researchers, extension agents, and farmers is also lacking (Kassem et al., 2018). However, providing timely and accurate information to farmers on emerging digital technologies that have the potential to transform rural communities and enhance their quality of life can be accomplished with the help of agricultural advisory and extension services (Davis and Franzel, 2018; Kremer and Houngbo, 2020).

Despite the numerous benefits of applying digital technologies in agriculture, their adoption and application in agricultural extension and among extension agents are low, especially in developing countries like Ghana (Nyarko and Kozári, 2021), due to the limited availability of these devices and digital infrastructure (Atengdem et al., 2022). Previous research has shown that several barriers and challenges impede the application of digital technologies in agricultural extension (Daum, 2018; Maru et al., 2018; Trendov et al., 2019; Odjegba et al., 2022). Inadequate supply of digital technologies, knowledge gaps, lack of awareness of new devices, availability of requisite information on devices, and lack of training on digital technologies account for some of the barriers and challenges that affect the adoption of digital technologies in agriculture (Trendov et al., 2019). Poor internet connectivity, high cost of internet data, and insufficient internet speeds are some other barriers and challenges affecting the application of digital technologies in agricultural extension (Nyarko and Kozári, 2021; Ahsan et al., 2023).

Agricultural extension advisory services, which include providing access to new technologies, production inputs, and market information to farmers, as well as advising and training extension personnel for better output and revenue in terms of time, cost, and distance, are important for promoting improvement in agriculture (Tata and McNamara, 2018; Nyarko and Kozári, 2021). Additionally, the application of digital technologies in agricultural extension could directly and indirectly contribute to reducing poverty through the commercialization of agriculture, which can create jobs for the youth (Uzun et al., 2019).

Countries in Sub-Saharan Africa, including Ghana, are building capacity in digital infrastructure that would eventually enable extension personnel to take on new roles as facilitators who lead community organizations, train human resources, identify problems, and educate farmers (Atengdem et al., 2022). Furthermore, agricultural communication and service delivery for rural development are some of the areas where extension agents concentrate their efforts to promote digital transformation (Olajide, 2016). In light of this, there is a need to broaden the scope of research on the application of digital technologies in agricultural extension. Ahsan et al. (2023) recommended that more studies be conducted on the reasons why digital technologies are seldom implemented at the rural level, leading to knowledge gaps. Additionally, more studies are needed to unearth new barriers and challenges to the application of digital technologies in agricultural extension in Ghana.

Previous studies have reported on the application of some digital technologies in Ghana, predominantly in the private sector (Annor-Frempong and Akaba, 2020; Omega et al., 2020), but there is limited application in public extension advisory services (Abdulai et al., 2023; Ayamga et al., 2021). However, none of these studies focused on the benefits, barriers, challenges, and requirements for the application of digital technologies in agricultural extension, especially in public extension advisory services in Ghana. This knowledge gap needs to be filled to provide evidence for policy consideration in the country. The aim of this study was to examine the benefits, barriers, challenges, and requirements for the application of digital technologies in agricultural extension delivery in Ghana. The specific objectives of the study were to examine:

1) Agricultural extension methods used by extension agents for extension delivery,
2) The benefits of deploying digital technologies in agricultural extension,
3) The barriers to the application of digital technologies in agricultural extension,
4) The challenges to the deployment of digital technologies in agricultural extension,
5) Requirements for the application of digital technologies in agricultural extension in Ghana.

MATERIALS AND METHODS

Study area

The study was conducted for a period of one month in April 2023 in four administrative regions in Ghana, namely the Ahafo, Bono East, Central, and Upper East regions. Ghana's economy is agrarian, with this sector contributing close to 20% of gross domestic product in 2022 (GSS, 2023b). The agricultural sector has been the engine of growth and employment creation since independence (The World Bank, 2018). The sector grew by 1.3% in the first quarter of 2023 compared to 1.0% during the fourth quarter of 2022 (Ghana Statistical Service [GSS], 2023a).

For Ghana to become self-sufficient in food production, the work of agricultural extension agents with agricultural stakeholders is essential (Danso-Abbeam et al., 2018). Each extension agent engages with farmers in an operational area, which is a collection of communities where they serve as change agents (Manteaw et al., 2020). The study was conducted in the Asunafo North, Asutifi South, Tano North, and Tano South districts in the Ahafo region; with Awutu Senya West, Ajumako-Eyan-Essiam, Gomoa Central, and Gomoa West districts in the Central region. Additionally, the study included the Techiman Municipal, Kintampo North, Pru West, and Nkoranza South districts in the Bono East region, and the Bawku Municipal, Bolgatanga East, Builsa South, and Kassena Nankana West districts in the Upper East region of Ghana.

Design, population, sampling, and sample size

A descriptive survey design was used to collect quantitative data from agricultural extension agents on the benefits, barriers, challenges, and requirements for the application of digital technologies in agricultural extension from their natural settings and operational areas, without attempting to alter cause-and-effect relationships (Kothari, 2004). This design allowed the researchers to collect data at one point in time from extension agents regarding their opinions on the benefits, barriers, challenges, and requirements for the application of digital technologies in agricultural extension (Prince et al., 2020).

The study population involved all 496 agricultural extension agents from the four administrative regions (Ahafo, Bono East, Central, and Upper East) in Ghana (MoFA-DAES, 2021). A multi-stage sampling technique was utilized to select respondents for the study (Sarantakos, 2013).

The first stage involved stratifying the country into four strata based on ecological zones: Coastal Savannah (Central, Greater Accra, Volta, and Western regions), Forest Zone (Ahafo, Ashanti, Eastern, and Western North regions), Transition Zone (Bono, Bono East, Savannah, and Oti regions), and Guinea Savannah (North East, Northern, Upper East, and Upper West regions) (Wongnaa and Awunyo-Vitor, 2019).

The second stage involved the random selection of one region from each of the four strata. The Ahafo, Central, Bono East, and Upper East regions were randomly selected at this stage. The number of extension agents in these four regions was 496, representing the population of the study (MoFA-DAES, 2021). The third stage of the sampling process involved the random selection of four districts from each of the four regions. The selection of four districts from each of the four regions was due to the disproportionate number of districts in each of the regions.

Respondents for the study were randomly selected from the accessible population of 496 extension agents, representing the fourth stage of the sampling process. Adopting the Krejcie and Morgan (1970) table for determining the appropriate sample size from a given population, the sample size for the study was determined. From the table, the appropriate sample size for the given population of 496 was approximately 217 extension agents.
A list of extension agents was compiled, after which the lottery method was used to randomly select 14 extension agents from each of the 16 randomly selected districts from the four regions, resulting in the selected sample size of 224 extension agents. Figure 1 illustrates the map of Ghana, showing the study areas (regions and districts).

Instrument, pre-testing, and data collection

A questionnaire was adopted as the instrument for the study. The questionnaire was divided into two sections. Section 1 was used to elicit information on the demographic characteristics of the extension agents and the extension delivery methods they used. Extension agents were asked to respond to six questions about the extension delivery methods they mostly adopted, rated on a four-point scale: rarely, sometimes, often, and frequently used. Section 2 of the questionnaire gathered data on the benefits, barriers, challenges, and requirements for applying digital technologies in agricultural extension. The benefits section had 20 items, the challenges section had 10 items, the requirements section had 9 items, and the barriers section had 8 items, all measured on a five-point Likert scale ranging from very low agreement to very high agreement (Krabbe, 2017).

Two agricultural extension experts from the Department of Agricultural Science Education, University of Education, Winneba, assessed the face and content validity of the questionnaire. The experts provided input to ensure that the items on the questionnaire validly measured the objectives of the study. The validated questionnaire was then pre-tested with 10 extension agents in the Greater Accra region of Ghana (Vonglao, 2017). Pre-testing was carried out to examine the validity and reliability of the

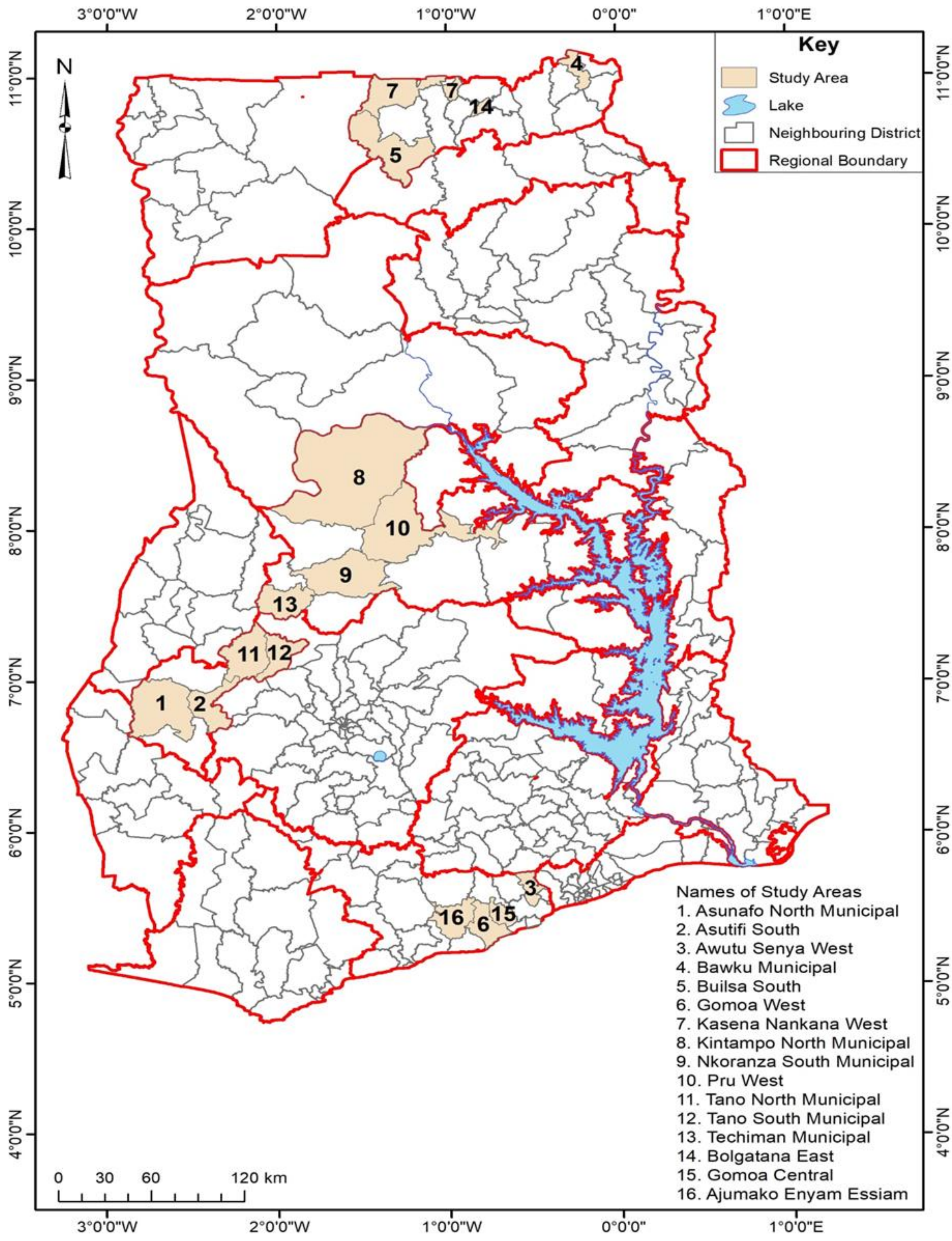

Figure 1. A map of Ghana, showing the study areas (regions and districts).

questionnaire (Bishop and Herron, 2019). The data from the pre-testing exercise was analyzed with the International Business Machine Statistical Package for Social Sciences (IBM SPSS) version 26 to compute McDonald's Omega coefficient of the Likert-type sub-scales (Şimşek and Noyan, 2013). McDonald's Omega coefficients of the pre-tested data ranged from 0.88 to 0.97, indicating that the reliability of the items in the questionnaire was between 88 and 97%. The results showed that the items on the

Table 1. Demographic characteristics of extension agents.

Variable	Frequency	%
Sex		
Male	114	91.2
Female	11	8.8
Age (years)	($\bar{X}$ = 35.67, σ = 7.00)	
21 – 30	25	20.0
31 – 40	76	60.8
41 – 50	16	12.8
50 – 60	8	6.4
Experience	($\bar{X}$ = 8.06, σ = 6.53)	
1 – 10	96	76.8
11 – 20	22	17.6
21 and above	7	5.6
Level of education		
Certificate	22	17.6
Diploma	21	16.8
Bachelor's degree	66	52.8
Master's degree	16	12.8
Positions		
Frontline staff	71	56.8
District/Municipal Agric. Officer	42	33.6
M.I.S officer	9	7.2
Director	3	2.4

n = 125.
Source: Data analysis (2023).

questionnaire had lower standard error, thus demonstrating higher reliability (Hayes and Coutts, 2020).

Prior to data collection, ethical clearance was obtained from the University of Education, Winneba Ethical Review Board. In addition, respondents were asked to confirm their voluntary participation in the research without any compulsion. The questionnaires were administered to the randomly selected respondents through selected agents in their respective offices across the four regions. Respondents were given one month (April 1-30, 2023) to respond to the self-administered questionnaires and return them upon completion. After one month of data collection, 125 out of 224 extension agents returned their completed questionnaires, representing a 56% response rate, which is regarded as appropriate for social science research (Baruch and Holtom, 2008).

Data analysis

Data from the field was prepared for analysis by coding it into the International Business Machine Statistical Package for Social Sciences (IBM SPSS) version 26.0. The demographic characteristics and the extension delivery methods used by extension agents were analyzed using descriptive statistics. The benefits of applying digital technologies were analyzed using means, standard deviation, principal component analysis (PCA), and Kendall's coefficient of concordance. Data on the barriers, challenges, and requirements for applying digital technologies in agricultural extension were analyzed using means, standard deviations, and Kendall's coefficient of concordance. The level of significance was determined at the 0.05 alpha levels.

RESULTS

Demographic characteristics of extension agents

The demographic characteristics of the extension agents are presented in Table 1. More than nine out of every ten extension agents are male (91.2%), while the rest are female (8.8%). The results also show that six in every ten (60.8%) of the agents are aged between 31 and 40 years, with the mean age being 35.67±7.00 years. More than three-quarters (76.8%) of the agents have between one and ten years of working experience, with a mean experience of 8.06±6.53 years. More than half of the extension agents hold bachelor's degrees. Regarding their positions, more than half (56.8%) are frontline staff,

Table 2. Extension delivery methods used by extension agents.

	Rarely [freq (%)]	Sometimes [freq (%)]	Often [freq (%)]	Frequently [freq (%)]
Individual contact (Face-to-Face)	0 (0)	2 (1.6)	35 (28.0)	88 (70.4)
Group contact (FBO meeting)	8 (6.4)	32 (25.6)	71 (56.8)	14 (11.2)
Field demonstrations	19 (15.2)	60 (48.0)	33 (26.4)	13 (10.4)
Farmer field schools (FFS)	48 (38.4)	63 (50.4)	9 (7.2)	5 (4.0)
Community meeting	95 (76.0)	15 (12.0)	8 (6.4)	7 (5.6)
e-Extension	35 (28.8)	49 (39.2)	23 (18.4)	17 (13.6)

n = 125.
Source: Data analysis (2023).

one-third (33.6%) are district and municipal agricultural officers, and a few are management information systems officers (7.2%) and district directors (2.4%).

Extension delivery methods used by extension agents

Table 2 presents the extension delivery methods used by extension agents for information and technology dissemination. Generally, almost all the agents (98.4%) often and frequently use individual contact (face-to-face) extension delivery methods. When it comes to group-contact, that is, using farmer-based organization (FBO) meetings, more than half (56.8%) indicated that they often use the group method. This method is also sometimes used by one-fourth (25.6%) of them, while one-tenth (11.2%) frequently use it. Field demonstrations are sometimes (48.0%), often (26.4%), and frequently (10.4%) used by extension agents. On the other hand, field demonstrations are rarely (15.2%) used by the agents. More than half (50.4%) of the extension agents indicated that they sometimes use farmer field schools. A few often (7.2%) and frequently (4.0%) use farmer field schools for extension delivery, whereas more than one-third (38.4%) rarely use farmer field schools for technology dissemination. More than three-fourths (76.0%) indicated that they rarely use community meetings for information delivery. On the contrary, community meetings are sometimes (12.0%), often (6.4%), and frequently (5.6%) used by one-fourth of the extension agents. The majority (71.2%) of extension agents sometimes, often, and frequently use electronic extension (e-extension) methods. On the other hand, more than one-fourth (28.8%) of the extension agents rarely use e-extension methods.

Benefits of digital technologies in agricultural extension

The benefits derived from applying digital technologies in agricultural extension are presented in Table 3. Generally, extension agents indicated moderate to high agreement regarding the benefits of applying digital technologies in agricultural extension (Mean = 3.55±0.95). The extension agents moderately to highly agree that digital technologies increase communication and market opportunities, allow prompt information sharing, improve supply chain relationships, empower information dissemination, link buyers and sellers, maximize cost efficiency, and optimize resources.

Additionally, they moderately agreed that digital technologies improve the integration of farm equipment, enhance producer health and safety, reduce food wastage, improve land management and fish production, and facilitate the monitoring of waste production.

Factors underlying extension perception and opinion on the benefits of applying digital technologies in agricultural extension

Extension agents' opinions on the benefits of applying digital technologies in agricultural extension were subjected to principal components analysis (PCA) to examine underlying factors in their responses. The suitability of the dataset was assessed before performing PCA. Inspection of the correlation matrix revealed that some coefficients were greater than 0.30 (Pett et al., 2003), indicating the dataset's suitability for PCA. Additionally, the sample size adequacy was assessed using the Kaiser-Meyer-Olkin (KMO) criterion. The KMO value for our dataset was 0.95, which is greater than the recommended threshold of 0.60 by Pallant (2016), signifying sample size adequacy. The Bartlett's Test of Sphericity also revealed statistical significance [χ^2 (190) = 2513.73, $p<0.05$], showing that the correlation matrix supports the factorability of the variables used to measure the benefits of applying digital technologies in agricultural extension (Tabachnick and Fidell, 2013).

The PCA showed that three principal components with eigenvalues greater than one were present in the dataset. The three components (component 1 = 64.65%, component 2 = 7.28%, and component 3 = 5.07%) cumulatively accounted for 76.90% of the variation in the

Table 3. Benefits of digital technologies in agricultural extension.

Statement	Means	Stand. Dev.
Increased communication opportunities	4.06	1.15
Increases market opportunities	3.91	1.19
Allow prompt sharing of information	3.89	1.18
Improving supply chain relationships	3.81	1.14
Give power to information	3.81	1.19
Matching buyers and sellers	3.80	1.16
Maximizing cost efficiency	3.66	1.14
Optimization of resource use	3.63	1.21
Lowering transaction cost of commercial market	3.61	1.16
Market inclusion	3.56	1.26
Adaptation of climate change	3.54	1.22
Increase yield	3.50	1.20
Financial inclusion	3.38	1.18
Improved integration of farm equipment	3.37	1.15
Improved producer health and safety	3.30	1.14
Reduce food waste	3.29	1.20
Improved land management	3.26	1.20
Improving fish farming	3.22	1.24
Monitor waste production	3.18	1.23
Consumer trust	3.17	1.18
Overall mean	3.55	0.95

n = 125. Means were calculated with a scale of 0.45-1.44 = Very low agreement, 1.45-2.44 = Low agreement, 2.45-3.44 = Moderately agreement, 3.45-4.44 = High agreement, 4.45-5.44 = Very high agreement.
Source: Data Analysis (2023).

factors underlying extension agents' opinions on the benefits of deploying digital technologies in agricultural extension. When the Catell (1966) scree-plot was assessed, it showed a breaking point after the second component; hence, two components were adopted for further analysis. The two retained components collectively explained 71.83% of the variance in the benefits of applying digital technologies in agricultural extension, with component 1 predicting 64.65% and component 2 predicting 7.28% of the variation (Appendix).

To determine the rotation adequacy of the PCA, the correlation matrix of the two components was examined using Davis's (1971) convention for determining the magnitude of correlation coefficients. The results showed a very high negative (r =-0.70) inter-correlation between the two components. Therefore, direct oblimin oblique rotation was performed to support the interpretation of the two components (Pallant, 2016). Table 4 depicts the factor loadings, communalities, percent of variance, and covariance. To facilitate the interpretation of the results, the two components were ordered and grouped based on the magnitude of factor loadings.

Agricultural production (component 1) and information communication (component 2) benefits were two suggested interpretations given to the components. The components showed a number of strong loadings. Ten variables each loaded strongly on production benefits and information communication benefits, respectively. Factors loading less than 0.45 (20% of variance) were replaced with zeros. The two components were: agricultural production benefits (e.g., increased yield, improved land management, monitoring waste production, improved integration of farm equipment, and adaptation to climate change) and agricultural information communication (e.g., allowing prompt sharing of information, empowering information dissemination, improving supply chain relationships, maximizing cost efficiency, and increasing market opportunities).

Ranking of agricultural production benefits

The agricultural production benefits of the PCA were ranked with Kendall's coefficient of concordance (W). Table 5 shows that adaptation to climate change (Mean rank = 6.40) is the highest ranked benefit of applying digital technologies in agricultural extension. Increased yield (Mean rank = 6.13) and improved integration of farm equipment (Mean rank = 5.74) are the second and third highest ranked benefits, respectively. Financial inclusion (Mean rank = 5.56) and improved producer health and safety (Mean rank = 5.50) follow in that order. Improved

Table 4. Factor loadings, communalities (h^2), % of variation, covariance for PCA and direct oblimin rotation on benefits of digital technologies in extension.

Statement	Pattern coeffiients		Structure coefficients		h^2
	Comp 1	Comp 2	Comp 1	Comp 2	
Increase yield	0.58		0.72	-0.60	0.53
Improved land management	0.92		0.80	-0.47	0.65
Monitor waste production	0.86		0.87	-0.62	0.76
Improved integration of farm equipment	0.92		0.86	-0.56	0.75
Improving fish farming	0.72		0.81	-0.64	0.66
Adaptation of climate change	0.76		0.87	-0.69	0.77
Improved producer health and safety	0.76		0.86	-0.67	0.75
Consumer trust	0.63		0.81	-0.70	0.69
Reduce food waste	0.79		0.85	-0.63	0.72
Financial inclusion	0.47		0.78	-0.77	0.70
Allow prompt sharing of information		-0.89	0.51	-0.81	0.67
Give power to information		-0.81	0.63	-0.85	0.73
Improving supply chain relationships		-0.63	0.72	-0.82	0.72
Maximizing cost efficiency		-0.66	0.69	-0.82	0.69
Increases market opportunities		-0.88	0.65	-0.91	0.82
Increased communication opportunities		-0.89	0.54	-0.89	0.80
Optimization of resource use		-0.53	0.79	-0.82	0.76
Market inclusion		-0.67	0.72	-0.84	0.74
Matching buyers and sellers		-0.80	0.66	-0.87	0.76
Lowering transaction cost of commercial market		-0.60	0.69	-0.79	0.66
Sum of Squared loadings (SSL)	*11.20*	*11.21*			
Percent of variance	*64.65*	*7.18*			
Percent of covariance	*1.49*	*-1.40*			

n = 125.
Source: Data analysis (2023).

Table 5. Ranking of agricultural production benefits.

Production benefits	Mean Rank	Kendall's W	Chi-Square	df	Asymp. Sig. *
Adaptation to climate change	6.40	0.04	43.77	9	0.00
Increased yield	6.13				
Improved integration of farm equipment	5.74				
Financial inclusion	5.56				
Improved producer health and safety	5.50				
Reduce food waste	5.36				
Improved land management	5.24				
Consumer trust	5.06				
Improving fish farming	5.02				
Monitor waste production	5.00				

n = 125.
Source: Data analysis (2023).

fish farming (Mean rank = 5.02) and monitoring waste production (Mean rank = 5.00) were the least ranked benefits of applying digital technologies in agricultural extension.

The Kendall's coefficient [W = 0.04, χ^2 (9) = 43.77, p <0.05] indicates that extension agents very lowly agree that agricultural production variables such as adaptation to climate change, increased yield, improved integration of farm equipment, financial inclusion, and improved producer health and safety are important production

Table 6. Ranking of agricultural information communication benefits.

Agricultural communication benefits	Mean rank	Kendall's W	Chi-Square	df	Asymp. Sig. *
Increased communication opportunities	6.65	0.07	81.35	9	0.00
Increases market opportunities	6.01				
Allow prompt sharing of information	6.00				
Improving supply chain relationships	5.63				
Give power to information	5.62				
Matching buyers and sellers	5.48				
Maximizing cost efficiency	5.06				
Lowering transaction cost of commercial market	4.86				
Optimization of resource use	4.85				
Market inclusion	4.84				

n = 125.
Source: Data analysis (2023).

benefits of applying digital technologies in agricultural extension in Ghana (Asante et al., 2022). The Kendall's W value of 0.04 suggests that 4% of the variation in the perception of extension agents about applying digital technologies in agricultural extension is explained by the agricultural production benefits (Franceschini and Maisano, 2021).

Ranking of agricultural information communication benefits

The agricultural information communication benefits, which are the second component of the PCA, were also ranked using Kendall's coefficient of concordance to determine the level of agreement among the extension agents on the application of digital technologies in agricultural extension (Table 6). The results show that increased communication (Mean rank = 6.65) and market opportunities (Mean rank = 6.01), allowing prompt sharing of information (Mean rank = 6.00), improving supply chain relationships (Mean rank = 5.63), and giving power to information (Mean rank = 5.62) are the top five ranked variables explaining the information communication benefits of applying digital technologies in agricultural extension.

The results indicated by the Kendall's coefficient [W = 0.07, χ^2 (9) = 81.35, $p<0.05$] show that increased communication and market opportunities, allowing prompt sharing of information, improving supply chain relationships, and giving power to information represent important information and communication benefits of applying digital technologies in agricultural extension to extension agents in Ghana (Omotehinse and Akpaka, 2019). Kendall's W index of 0.07 indicates that the extent of agreement among the extension agents on the information communication benefits of applying digital technologies for agricultural extension is 7%, suggesting very low significant convergence of the information communication benefits among extension agents towards applying digital technologies in extension in Ghana (Zhou et al., 2019).

Barriers to the application of digital technologies in agricultural extension

Table 7 presents the barriers in the opinion of agricultural extension agents that are hampering the application of digital technologies in agricultural extension in Ghana. Generally, extension agents moderately agreed to the barriers hampering the application of digital technologies in agricultural extension (overall mean = 3.20±0.91). Even though the extension agents moderately agreed that limited research, lack of coordination and support from management on the application of digital technologies, and unavailability of needed information, awareness, and knowledge on digital technologies by extension agents are barriers that affect the application of digital technologies, they highly agreed that limited supply of digital technology devices and low internet speed hamper the application of digital technologies in agricultural extension delivery in Ghana.

Ranking of barriers to the application of digital technologies in agricultural extension

The Kendall's coefficient of concordance was utilized to rank the barriers affecting the application of digital technologies in agricultural extension in Ghana (Table 8). The results showed that limited supply of digital technology devices (Mean rank = 5.66) was the highest ranked barrier to the application of digital technologies in agricultural extension. Low internet speed (Mean rank = 5.00) was the second highest ranked barrier, followed by limited research on the application of digital technologies (Mean rank = 4.76). Lack of coordination (Mean rank =

Table 7. Barriers to the application of digital technologies in agricultural extension.

Statements	Means	Stand. Dev.
Limited supply of digital technology devices	3.73	1.30
Low internet speed	3.48	1.22
Limited research on application of digital technologies in Ghana	3.31	1.16
Lack of coordination on the application of digital technologies	3.20	1.04
Lack of support from management on digital technologies	3.07	1.36
Unavailability of needed information on digital technologies	3.01	1.21
Lack of knowledge of digital technologies by extension agents	3.01	1.19
Lack of awareness of digital technologies by extension agents	2.79	1.25
Overall mean	3.20	0.91

n = 125. Means were calculated with a scale of 0.45-1.44 = Very low agreement, 1.45-2.44 = Low agreement, 2.45-3.44 = moderately agreement, 3.45-4.44 = High agreement, 4.45-5.44 = Very high agreement.
Source: Data analysis (2023).

Table 8. Ranking of barriers to the application of digital technologies in agricultural extension.

Barrier	Mean rank	Kendall's W	Chi-Square	df	Asymp. Sig. *
Limited supply of digital technology devices	5.66	0.10	83.24	7	0.00
Low internet speed	5.00				
Limited research on application of digital technologies in Ghana	4.76				
Lack of coordination on the application of digital technologies	4.53				
Lack of support from management on digital technologies	4.21				
Lack of knowledge of digital technologies by agricultural extension agents	4.17				
Unavailability of needed information on digital technologies	4.00				
Lack of awareness of digital technologies by agricultural extension agents	3.68				

n = 125, *p<0.05.
Source: Data analysis (2023).

4.53) and support from management (Mean rank = 4.21) were the fourth and fifth ranked barriers to the application of digital technologies in agricultural extension.

Kendall's coefficient [W = 10, χ^2 (7) = 83.24, p<0.05] indicates that the extension agents were about 10% in agreement on the barriers hampering the application of digital technologies in agricultural extension (Wang et al., 2018).

The results show very low significant agreement among the extension agents on the barriers affecting the application of technologies in Ghana.

Challenges to the application of digital technologies in agricultural extension

Table 9 presents the challenges to the application of digital technologies in agricultural extension delivery in Ghana. Overall, the extension agents had high agreement with the challenges to the application in agricultural extension (overall mean 3.63±0.95). The challenges to the application of digital technologies in agricultural extension that extension agents highly agreed to were the high cost of internet data, high cost of acquiring digital technologies, and the lack of institutional support for the use of digital technologies. Additionally, inadequate funding for digital technologies, the gap between research work and field requirements, and inadequate technical knowledge on the use of digital technologies by farmers were identified as challenges to the application of digital technologies in agricultural extension.

On the other hand, extension agents moderately agreed that difficulty accessing digital technologies and inadequate technical knowledge on the use of digital technologies by extension agents are challenges to the application of digital technologies in agricultural extension.

Ranking of challenges to the application of digital technologies in agricultural extension

The convergence of extension agents' opinion on the challenges that hinder the application of digital technologies was analyzed using Kendall's coefficient of concordance (W). Table 10 shows that the high cost of

Table 9. Challenges to the application of digital technologies in agricultural extension.

Statement	Means	Stand. Dev.
High cost of internet data	3.88	1.23
High cost of acquiring digital technologies	3.87	1.21
Lack of institutional support for the use of digital technologies	3.71	1.20
Inadequate funding for digital technologies	3.71	1.17
Gap between research work and field requirement	3.70	1.20
Inadequate technical knowledge on the use of digital technologies by farmers	3.70	1.30
Inadequate training on digital technologies	3.66	1.21
Insufficient digital technologies	3.46	1.23
Difficulties in accessing digital technologies	3.37	1.23
Inadequate technical knowledge on the use of digital technologies by extension agents	3.19	1.22
Overall mean	3.63	0.95

n = 125.
Source: Data Analysis (2023). Means were calculated with a scale of 0.45-1.44 = Very low agreement, 1.45-2.44 = Low agreement, 2.45-3.44 = moderately agreement, 3.45-4.44 = High agreement, 4.45-5.44 = Very high agreement.

Table 10. Ranking of challenges to the application of digital technologies in agricultural extension.

Challenges	Mean rank	Kendall's W	Chi-Square	df	Asymp. Sig. *
High cost of internet data	6.36	0.07	82.57	9	0.00
High cost of acquiring digital technologies	6.22				
Inadequate technical knowledge on the use of digital technologies by farmers	5.82				
Lack of institutional support for the use of digital technologies	5.68				
Inadequate funding for digital technologies	5.65				
Gap between research work and field requirement	5.61				
Inadequate training on digital technologies	5.59				
Insufficient digital technologies	4.93				
Difficulties in accessing digital technologies	4.86				
Inadequate technical knowledge on the use of digital technologies by extension agents	4.28				

n = 125, *p<0.05.
Source: Data analysis (2023).

internet (Mean rank = 6.36) and acquiring digital technologies (Mean = 6.22), inadequate knowledge on the use of digital technologies by farmers (Mean ranking = 5.82), lack of institutional support (Mean rank = 5.68), inadequate funding for digital technologies (Mean rank = 5.65), and the gap between research work and field requirements are the topmost ranked challenges to the application of digital technologies in agricultural extension delivery in Ghana.

The Kendall's coefficient of 0.07 signifies that there was a very low degree of agreement (7%) among the extension agents [W = 0.07, χ^2 (9) = 82.57, p<0.05] on their convergence of the challenges to the application of digital technologies in agricultural extension delivery in Ghana (Jayalath, 2019). Even though the computed Kendall's coefficient is very low, the significance indicates that the extension agents perceive the challenges to the application of digital technologies as necessary factors influencing the adoption of digital technologies in Ghana hence, should be given the needed attention.

Requirements for application of digital technologies in agricultural extension

The requirements for the application of digital technologies in agricultural extension in Ghana are presented in Table 11. The extension agents highly agreed with the requirements for adopting digital technologies in agricultural extension (overall mean = 3.76±1.3). In light of this development, the extension agents highly agreed that there is a need for the Ministry of Food and Agriculture to purchase digital technology devices for the Departments of Agriculture to enhance their practical knowledge from fieldwork. Additionally, training on digital technologies for smallholder farmers is

Table 11. Requirements for application of digital technologies in agricultural extension.

Statement	Means	Stand. Dev.
Need to purchase digital technology devices for the Departments of Agriculture	4.00	1.18
Need for practical knowledge from field work	3.85	1.11
Training on digital technologies for smallholder farmers to increase productivity	3.83	1.25
Cooperation between government and private organisations for local development of digital technologies	3.80	1.22
Cooperation between government and private organisations for digital technologies dissemination	3.79	1.18
Stakeholder engagements on the necessity of digital technologies in Ghana	3.72	1.16
Linkage between research institutions and field-level extension	3.71	1.18
Policy on application of digital technologies needed	3.62	1.19
Need to develop only agriculture related digital technologies	3.55	1.24
Overall mean	3.76	1.03

n = 125. Means were calculated with a scale of 0.45-1.44 = Very low agreement, 1.45-2.44 = Low agreement, 2.45-3.44 = moderately agreement, 3.45-4.44 = High agreement, 4.45-5.44 = Very high agreement.
Source: Data Analysis (2023).

Table 12. Ranking of requirements for the application of digital technologies in agricultural extension.

Requirement	Mean rank	Kendall's W	Chi-Square	df	Asymp. Sig. *
Need to purchase digital technology devices for the Departments of Agriculture	5.71	0.04	37.53	8	0.00
Need for practical knowledge from field work	5.16				
Training on digital technologies for smallholder farmers to increase productivity	5.15				
Cooperation between government and private organisations for local development of digital technologies	5.12				
Cooperation between government and private organisations for digital technologies dissemination	5.04				
Linkage between research institutions and field-level extension	4.98				
Stakeholder engagements on the necessity of digital technologies in Ghana	4.80				
Policy on application of digital technologies needed	4.58				
Need to develop only agriculture related digital technologies	4.47				

n = 125, *p<0.05.
Source: Data analysis (2023).

needed to increase productivity. Furthermore, cooperation between government and private organizations is needed for the development and dissemination of digital technologies, as well as stakeholder engagements on the necessity of digital technologies in the Ghanaian agricultural sector in order to establish the linkage between research institutions and field-level extension.

Ranking of requirements for the application of digital technologies in agricultural extension

To assess the extent of agreement among extension agents regarding the collective effect of the variables required to improve the application of digital technologies in agricultural extension in Ghana, the Kendall's coefficient of concordance W was utilized. The results, as presented in Table 12, indicate that there is a need for the Ministry of Food and Agriculture to purchase digital technology devices for the Departments of Agriculture (Mean rank = 5.71) to enhance practical knowledge from fieldwork (Mean rank = 5.16), which are the first and second highest ranked variables by the extension agents. Training on digital technologies for smallholder farmers to increase productivity (Mean rank = 5.15) is the third highest ranked requirement for the application of digital technologies in agricultural extension according to the extension agents. The fourth, fifth, and sixth ranked requirements are cooperation between government and private organizations for the development (Mean rank = 5.12) and dissemination (Mean = 5.04) of digital technologies, as well as the establishment of the linkage between research institutions and field-level extension (Mean rank = 4.98). The Kendall's coefficient [W = 0.04, χ^2 (8) = 37.53, p<0.05] indicates that the extension agents were 4% in concordance with the requirements for the application of digital technologies in agricultural extension in Ghana. The findings show variations in the assessment of extension delivery about the requirement for application of novel technologies in extension. That notwithstanding, the results attest to the significance of the convergence of the strategies needed to improve the uptake of digital technologies in agricultural extension among extension agents in Ghana.

DISCUSSION

The study on the benefits, barriers, challenges, and requirements for application of digital technologies in agricultural extension in Ghana provides empirical evidence in response to the suggestion of Ahsan et al. (2023) for more research work on the reasons why digital technologies are hardly implemented in rural areas by extension agents, leading to knowledge gaps. The authors also indicated that such studies should focus on bringing out more barriers and challenges to the application of digital technologies in different geographical regions to advance the science on the adoption of digital technologies in agricultural extension. Previous research has shown that the application of digital technologies is being implemented in agricultural extension in Ghana (Annor-Frempong and Akaba, 2020; Omega et al., 2020; Ayamga et al., 2021; Abdulai et al., 2023). None of these studies, however, focused on the barriers and challenges to the low adoption of digital technologies in agricultural extension, and the requirements for increased adoption of the new technologies in Ghana's agricultural sector. The results provide empirical evidence to prove that extension agents are aware of the high benefits of applying digital technologies in agricultural extension. Annor-Frempong and Akaba (2020) reported high benefits of applying a digital technology like drone for spraying pesticides to control Fall Armyworm in Northern Ghana. Two key factors underscore extension agents' perception of the high benefits of adopting digital technologies in agricultural extension. These are agricultural production benefits and agricultural information communication benefits. The findings support the assertion of Abdulai et al. (2023) that in practice both digital hardware and software technologies are applied directly to farm production systems (Kremer and Houngbo, 2020), and services solutions for information advisory services (Norton and Alwang, 2020). On the agricultural production systems, extension agents indicated that digital technologies are highly beneficial because they provide solutions for climate change adaptation, increased yield, and improved integration of farm equipment. The results are consistent with previous research that showed that digital technologies are improving crop yields, enhancing integration of farm equipment, and supporting efforts at tackling the effect of climate change in agricultural production (Kremer and Houngbo, 2020; Maru et al., 2018; Trendov et al., 2019). Effective information communication is at the heart of agricultural extension delivery (Van den Ban and Hawkins, 1996; FAO, 2019). It is, therefore, not surprising that extension agents highlighted the benefits of applying digital technologies in agricultural extension to include increased information communication opportunities, market opportunities, and prompt sharing of information with farmers. Abdulai et al. (2023) posit that the proliferation and ubiquity of smartphones and their associated applications have enhanced information delivery from extension agents to farmers in Ghana. Transformation of agriculture and food systems using digital technologies in developing countries, which focuses on small-scale farmers' decision-making during crop production and marketing, has demonstrated the advantages of integrating digital technologies in agriculture (Ahsan et al., 2023). Customized digital tools like mobile applications are being used by extension agents and farmers to access targeted information such as climate and weather data, expected yield, and commodity price information for enhanced data-driven decisions and recommendations (Davis and Franzel, 2018; Maru et al., 2018; Odjegba et al., 2022). Precision agriculture application models and smartphone-based extension advisory services have positively affected farmers' adoption of sustainable agricultural technologies in developing countries (Freeland et al., 2012; Kassem et al., 2018; Kremer and Houngbo, 2020). Therefore, their implementation to aid adoption decision-making in agricultural extension in developing countries should be encouraged (Abdulai et al., 2023; Ahsan et al., 2023).

However, to achieve sustainability in agricultural production, the barriers and challenges affecting the application of digital technologies in agricultural extension need to be adequately addressed through policy interventions and guidelines for deploying digital infrastructure in Ghana (Baig et al., 2019; Dhehibi et al., 2020). Our results indicate that extension agents moderately agreed with the barriers impeding the application of digital technologies in agricultural extension in Ghana. Key among the obstacles obstructing the application of novel devices are limited supply of digital tools and devices, low internet speed, low research on the application of digital technologies, and lack of coordination on the application of digital technologies among stakeholders in the agricultural sector. Apart from the barriers, the extension agents agreed that the challenges affecting the application of digital technologies in agricultural extension are high.

These challenges include, but are not limited to, the high cost of internet data, acquiring digital technologies, and inadequate technical knowledge of the use of digital technologies by farmers.

It is worth noting that countries in Sub-Saharan Africa have had difficulty overcoming obstacles such as constrained technical resources, ineffective extension systems, and poorly integrated food supply chains (El Bilali and Allahyari, 2018). Our results point to the fact that extension agents agreed that the requirements for deploying digital technologies in agricultural extension in Ghana are high. Extension agents agreed that to scale up digital technologies in agricultural extension in the country, there is a need to purchase digital devices for the Departments of Agriculture to enhance practical knowledge from the field. Training on digital technologies for smallholder farmers is also required to increase productivity, as well as cooperation between government and private organizations for local development and dissemination of digital technologies among agricultural stakeholders.

Positive outcomes resulting from the implementation of digital technologies for climate adaptation and resilient farming have been documented through collaborations and connections among various stakeholders in agriculture (Kassem et al., 2018; Sylla et al., 2019; Trendov et al., 2019; Ahsan et al., 2023). Government web-based platforms, drones, sensors, remote sensing, geographic information system technologies, and smartphone applications have undergone testing in the field and trial phases with smallholder farmers in Ghana (Abdulai et al., 2023; Annor-Frempong and Akaba, 2020; Omega et al., 2020). In developing nations like Ghana, employing such technology-driven development and linkage decision mechanisms between researchers and extension agents could empower smallholder households and communities toward establishing a digital ecosystem for long-term sustainability in food systems development (Atengdem et al., 2022; Abdulai et al., 2023; Ahsan et al., 2023).

Male extension agents predominantly occupy frontline extension roles in Ghana, with the majority falling within the age range of 31 to 60 years. This observation aligns with previous studies which also reported a higher representation of male frontline extension agents compared to females (Akpotosu et al., 2017; Manteaw et al., 2020). Additionally, our results indicate that frontline extension agents commonly employ face-to-face extension delivery methods as their primary mode of interaction with farmers. Other methods utilized include group contact, field demonstrations, farmer field schools, and e-extension services. Notably, community meetings are seldom used for technology dissemination by extension agents. These findings are consistent with previous research, such as the study by Manteaw et al. (2020), which concluded that extension information and technology dissemination predominantly occur through on-farm interactions like face-to-face engagements, group trainings, and field demonstrations in Ghana. To effectively fulfill extension objectives, extension agents employ these various delivery methods to engage farmers in discussions concerning digital technologies, assisting them in addressing production and information challenges (FAO, 2019; Trendov et al., 2019). Our research draws upon the Everett Roger's Diffusion of Innovation Theory, a communication theory that elucidates how extension agents adopt and disseminate novel technologies through various communication channels like face-to-face interactions, group contact, field demonstrations, farmer field schools, and e-extension methods (Rogers, 2003). The findings underscore the significance of innovation characteristics, such as relative advantage, compatibility, complexity, trialability, and observability, in determining the benefits of adopting digital technologies in agricultural extension (Talukder et al., 2019). Furthermore, our results highlight that barriers and challenges within the social system significantly impact the application of digital technologies in agricultural extension.

Thus, it is incumbent upon extension organizations and stakeholders to collaborate in eliminating these obstacles to enhance the adoption of digital technologies in extension (Dearing and Cox, 2018).

This study provides valuable empirical data on the benefits, barriers, challenges, and requirements for the application of digital technologies in agricultural extension across four regions in Ghana. The development of digital technology and collaborative decision-making between researchers and extension agents has the potential to empower smallholder farmers and strengthen rural communities, fostering a sustainable digital ecosystem in the country. By shedding light on these aspects, our findings offer insights that can inform policymakers in crafting policies related to the adoption of digital technologies for agricultural extension in Ghana, particularly regarding potential barriers, challenges, and key requirements for scaling up digital technologies in public extension services.

However, it is essential to acknowledge some limitations of this study. Firstly, our reliance on self-reported opinions and responses from extension agents collected at a specific point in time may limit the generalizability of the findings, as opinions may evolve over time with further interactions with digital technologies. Additionally, our study was confined to extension agents in only four out of the sixteen regions in Ghana, which restricts the broader applicability of the findings to all extension agents in the country. Moreover, the low response rate and participation of extension agents in the study necessitate caution in interpreting the results. Future research endeavors should aim to engage other stakeholders involved in extension, such as farmers, researchers, and policymakers, to gain a comprehensive understanding of the benefits, barriers, challenges, and requirements associated with the application of digital technologies in agricultural extension. Furthermore, exploring factors that facilitate effective coordination among researchers, extension agents, and farmers for the enhanced deployment of digital technologies in agricultural extension in Ghana would be a valuable avenue for future investigation.

Conclusions

The study conducted in the four regions of Ghana illustrates that extension agents generally express moderate to high agreement regarding the benefits associated with the adoption of digital technologies in extension services. These benefits are broadly categorized into agricultural production and information communication benefits, encompassing factors such as climate change adaptation, increased yield, improved equipment integration, enhanced information communication, and expanded market opportunities. Leveraging these benefits, particularly on climate change adaptation, yield enhancement, and improved communication, could be pivotal for promoting the adoption of digital technologies in Ghana's agricultural sector.

However, extension agents also recognize various institutional, structural, and physical barriers that hinder the effective application of digital technologies in agricultural extension. These barriers include inadequate supply of digital tools, slow internet speed, limited research, and lack of coordination among stakeholders, high costs associated with internet data and acquiring digital technologies, and insufficient technical knowledge among farmers. It is imperative for the Government of Ghana, in collaboration with relevant stakeholders, to address these barriers to facilitate the seamless integration of digital technologies into agricultural extension services.

To advance the scale-up of digital technologies in Ghana, the Ministry of Food and Agriculture should spearhead initiatives to procure digital devices for agricultural departments, enhance the capacity of extension agents through training programs, and foster stronger collaboration between the government and private sector organizations for the development and dissemination of digital technologies. Additionally, considering the predominance of young male frontline extension agents in Ghana, leveraging diverse extension delivery methods such as face-to-face interactions, group contacts, field demonstrations, farmer field schools, and e-extension services could effectively facilitate the dissemination and training on digital technologies among smallholder farmers.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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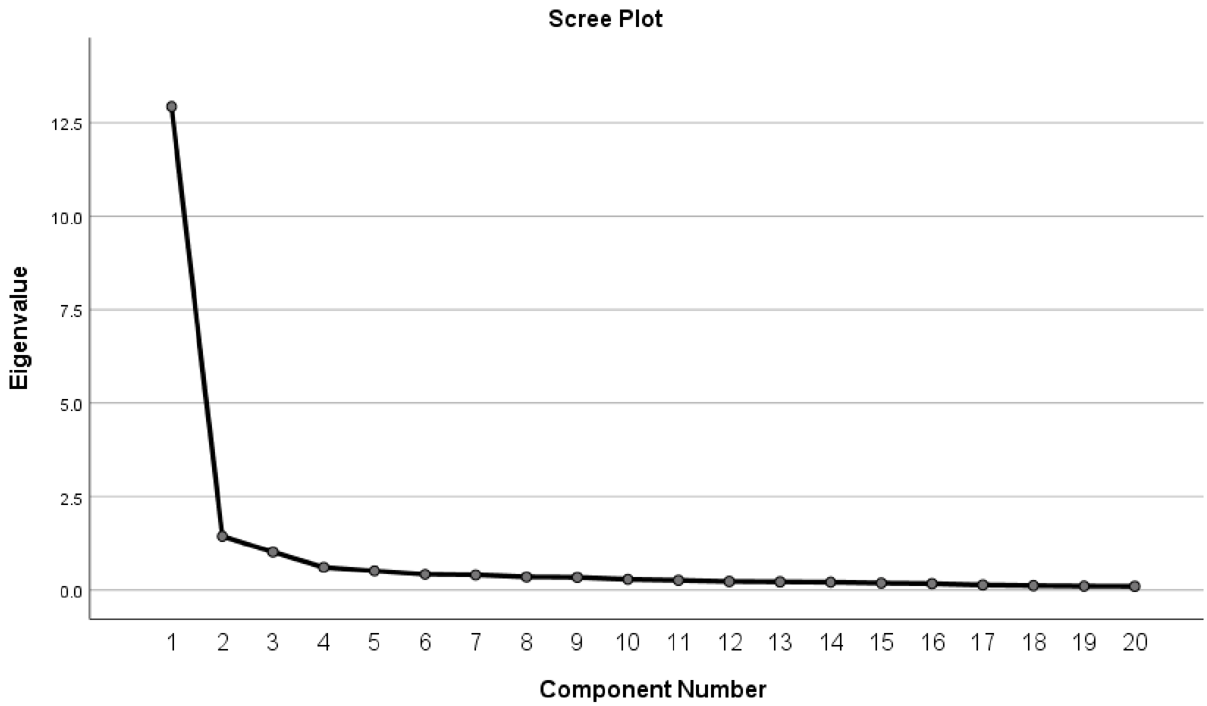
Appendix


Scree Plot
Eigenvalue
12.5
10.0
7.5
5.0
2.5
0.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Component Number