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Digital Agricultural Extension and Small-Ruminant Farming in Northern Ghana

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Abstract

This study examined the determinants and constraints of mobile phone-enabled agricultural extension services among small-ruminant farmers in Northern Ghana. Cross-sectional data were collected from 406 farmers through purposive and simple random sampling methods. The data is analysed using descriptive statistics, binary logistic regression, and Kendall's coefficient of concordance. The results show that gender, household size, farmer-based organisation (FBO) membership, and small-ruminant-rearing experience significantly influenced access to mobile-enabled extension on small ruminant production. Male farmers had 16.20 times the odds of access compared with female farmers. Each additional household member was associated with 1.91 times the odds of access, while FBO members had 3.11 times the odds compared with non-members. Each additional year of small-ruminant-rearing experience was associated with 2.35 times the odds of access. Kendall's ranking identified inadequate electricity coverage as the most important constraint, followed by high device costs, device management costs, difficulty understanding SMS messages, and limited knowledge of mobile phones. The study recommends gender-responsive digital extension, rural electrification, local-language voice services, and integration of mobile and conventional extension systems to enhance the knowledge of small ruminant farmers in the Northern Region of Ghana.

Keywords: Constraints, Determinants, Extension, Mobile Phone, Northern Ghana, Ruminants, Smallholder Farmers

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INTRODUCTION

Agricultural extension and advisory services are fundamental to smallholder agriculture because they connect farmers with the knowledge, technologies, and management practices to improve productivity and sustain rural livelihoods. For livestock farmers, the value of timely advisory services is particularly important because animal-health and management problems can develop rapidly, lowering reproductive performance and financial losses. Yet, the ability of extension systems to provide timely and regular advice remains constrained in many rural areas of Ghana. These constraints are especially consequential in Northern Ghana, where agriculture and livestock are central to household livelihoods and where dispersed rural settlements can make frequent face-to-face extension contact difficult. Recent evidence from the Ministry of Food and Agriculture (MoFA, 2025) shows that the farmer-to-extension agent ratio in Ghana is over 1,500, raising fundamental policy concerns. But how can livestock-dependent households obtain timely and reliable advisory services when conventional extension systems cannot reach them frequently enough?

This issue is particularly relevant to small-ruminant farmers in Ghana's Northern Region, especially in districts with high levels of ruminant production and dedicated livestock marketplaces that operate on market days. In these settings, mobile-enabled extension can provide farmers with timely information to support their production and animal-health decisions. These include major districts such as Savelugu, Gushegu and Tolon in the Northern region.

Sheep and goats are not merely productive assets; they form part of the livelihood and coping strategies of households in these districts. Their significance is especially pronounced in periods of seasonal food scarcity, bad crop yields, or unforeseen household expenses. Livestock can be a source of food or sold to buy food when household food supplies from crop production are exhausted. Similarly, households may sell animals to meet immediate needs for health care, school fees, clothing, farm inputs or other basic needs. Small ruminants therefore can be a form of precautionary saving and financial insurance for households with highly seasonal incomes and vulnerable to agricultural shocks (Adams et al., 2021; MoFA, 2019).

Small-ruminant production requires regular decisions concerning feeding, breeding, housing, disease prevention, vaccination, treatment and marketing. However, farmers in these districts face inadequate or delayed access to reliable technical advice. This leaves farmers poorly positioned to identify disease symptoms and respond to emerging animal-health risks. Livestock losses consequently have implications beyond the value of the individual animal. For example, ruminant farmers with inadequate access to extension suffer losses such as death, illness or poor productivity of sheep and goats, an important source of food and emergency liquidity precisely when household resources are under pressure.

The challenge is intensified by the structural limitations of conventional extension delivery in rural Northern Ghana. Farmers living far from extension offices in these districts receive visits infrequently. In addition, limited transport and operational resources constrain the ability of extension personnel to respond rapidly to livestock-health problems. Information and communication technologies, particularly mobile phones, offer a potential means of complementing conventional extension. They can potentially improve the speed with which farmers seek advice on animal health, feeding, breeding and markets and can extend advisory reach to communities that are difficult to serve regularly. Empirical evidence such as Folitse et al. (2019) showed that farmer characteristics influenced the mobile phone use of Ghanaian small-scale poultry farmers. However, digital agricultural services are increasingly viewed in

sub-Saharan Africa as potentially important channels for dissemination of agricultural information. However, connectivity, affordability, technological literacy and digital skills remain barriers to inclusive access (Fabregas et al., 2022; Choruma et al., 2024).

Nevertheless, farmers in the Northern region differ in their ability to obtain, operate and use digital technologies for agricultural purposes. Differences in education, income, gender, network connectivity and existing relationships with extension providers can influence whether mobile technology becomes a meaningful source of agricultural advice.

That notwithstanding, the growing interest in digital agricultural extension specifically concerning small-ruminant farmers in rural Northern Ghana remains limited. There is insufficient empirical understanding of which characteristics of farmers in the Northern region determine whether small-ruminant farmers can access mobile-enabled extension. In addition to which practical constraints prevent them from using mobile technology for livestock advisory purposes. This study therefore examines mobile-enabled agricultural extension among small-ruminant farmers in rural Northern Ghana. Specifically, it identifies the socioeconomic and institutional factors associated with farmers' access to mobile-enabled extension services and assesses the major constraints affecting their use of mobile technology for agricultural advisory purposes. Binary logistic regression is employed to examine the factors associated with access, while Kendall's coefficient of concordance is used to assess farmers' agreement in ranking the constraints they face. By focusing on small-ruminant producers, the study extends the emerging literature on digital agriculture beyond general smallholder populations and provides evidence on how mobile technology can complement conventional livestock extension. The findings are intended to inform extension agencies and livestock-development programmes seeking to improve advisory reach, reduce information-related constraints. Again, strengthen the contribution of small ruminants to household food security, income generation and resilience in rural Northern Ghana.

LITERATURE REVIEW

Theoretical Framework

The study is anchored in a Digital Access and Capability Framework, which combines insights from the digital-divide perspective with the capability approach to technology use. The central proposition is that access to digital agricultural extension is not determined by technology availability alone but by farmers' ability to convert available digital resources into meaningful agricultural information and advisory benefits.

The digital-divide literature distinguishes between inequalities in access to digital technologies and inequalities in the ability to use those technologies effectively. Recent research on digitalisation of agriculture in sub-Saharan Africa has shown that smallholders are unable to benefit equally from digital technologies because of limited connectivity, affordability, digital literacy levels, infrastructure and gender disparities (Choruma et al., 2024). Likewise, Abdulai et al. (2023) in Northern Ghana find that digital agricultural service use is associated with digital access (mobile-phone access, ability to make calls), farmer-group membership, gender, and pre-existing extension services. These findings imply that the probability of accessing mobile-enabled extension depends on both digital resources and farmers' socioeconomic and institutional capabilities. Thus, two farmers with similar access to mobile phones may have substantially different capacities to obtain and use agricultural information. Unequal digital

competencies and political-economic conditions behind digital agricultural extension can reproduce existing inequalities in access to agricultural knowledge (Abdulai, 2024).

The framework therefore conceptualises mobile-enabled extension access as the outcome of three interacting dimensions. The first is technological access, comprising mobile-phone ownership, network connectivity, electricity and affordability. The second is individual capability, including education, age, gender, income, digital competence and ability to operate mobile services. The third is institutional and social embeddedness, including extension contact, farmer-group membership, access to agricultural training and relationships with extension providers. These dimensions jointly influence the probability that a small-ruminant farmer can access mobile-enabled agricultural extension.

This framework is consistent with the digital-extension user journey proposed by Fabregas et al. (2022), which distinguishes between accessing the digital interface, accessing relevant information and ultimately using that information to change behaviour. The present study focuses primarily on the first access stage, while recognising that effective access is conditioned by capabilities and institutional relationships. Accordingly, the empirical model tests whether farmer characteristics, technological resources and institutional factors significantly influence the likelihood of accessing mobile-enabled extension services, while the constraint analysis identifies the practical barriers that may prevent farmers from converting digital access into effective advisory use.

MATERIALS AND METHODS

Study Area

The study was conducted in the Northern Region of Ghana. An area where agriculture remains central to rural livelihoods and where access to agricultural services is often shaped by distance, infrastructure and the availability of communication technologies. The region covers approximately 70,384 km² and forms part of Ghana's Guinea Savannah agro-ecological zone. The agricultural nature of the Northern Region makes it particularly relevant considering the study on mobile-enabled extension services. Farming households are widely distributed across rural communities, while extension staff and other agricultural service providers often have to serve large numbers of farmers across fairly large geographical areas. The study is limited to Gushegu, Savelugu Municipal and Tolon District, three predominantly agrarian districts that provide a good setting to explore the relationship between mobile-phone technology and agricultural extension access. The Ministry of Food and Agriculture's agricultural statistics show that there are high numbers of agricultural households, including 8,110 in Tolon, 14,669 in the former Savelugu-Nanton district and 11,150 in Gushegu (MoFA, 2018). Livestock keeping, including sheep and goat production, is one of the livelihood systems of the rural households (GSS, 2021). The selection of Gushegu, Savelugu and Tolon is therefore both substantively and empirically relevant. Given the geographical spread of farming communities and the importance of livestock production.

Sampling Method and Procedure

A multi-stage sampling procedure was employed to select small-ruminant farmers for the study. The multi-stage approach was appropriate because the target population was geographically dispersed and a complete list of all small-ruminant farmers in the Northern Region was not readily available. In the first stage, purposive sampling was employed to

identify the relevant districts/municipalities and farming communities based on the concentration of small-ruminant production and the relevance of agricultural extension activities. In the second stage, selected communities were identified within the sampled districts. In the third stage, small-ruminant farmers were randomly selected with the assistance of agricultural extension personnel and the community-level farmer networks. Finally, eligible farmers were selected and interviewed using a structured questionnaire. The eligibility criterion was that respondents had to be actively engaged in small-ruminant production and have sufficient experience with farming and/or mobile-phone use to provide information on access to agricultural extension services. Both farmers who accessed extension information through mobile phones and those who did not were included. Including both groups was important because the logistic regression required variation in the dependent variable to identify characteristics associated with mobile-enabled extension access.

Sample Size and Data Collection Procedure

A total of 406 small-ruminant farmers were selected and responded to the study questions. The sample size was determined through Fisher's sample size formula. The estimated population of farmers for each district was based on the Ghana Statistical Service 2012 population and housing census report. These data were used to determine the sample size of respondents for each district and community (see Appendix for details). The final sample of 406 farmers was interviewed face-to-face at the household level in 12 communities. The selected communities were based on the dominance of ruminant farmers and the suitability of random sampling of respondents to cater for the calculated sample sizes for each community.

The primary data were collected using a structured questionnaire administered to the sampled small ruminant farmers. The structured questionnaire was vetted by the research supervisor and approved before data collection with respondents. Consent of respondents was sought before questionnaire administration, and the ethics of confidentiality were adhered to in the process. The consent form was read to non-literate farmers, while literate farmers were given copies to read before agreeing to take part in the interviews. However, secondary data on livestock farmers were obtained from the state agency website and the office of the Department of Agriculture in the three districts.

Data Analysis

The data analysis combined descriptive statistics and inferential statistics through binary logistic regression and Kendall's coefficient of concordance. Descriptive statistics were first used to summarise the characteristics of the respondents. Frequencies, percentages, means and other appropriate measures were used to describe socio-economic variables of farmers. Binary logistic regression was subsequently employed to estimate the determinants of access to mobile phone-enabled agricultural extension services. Kendall's coefficient of concordance (W) was used to assess the degree of agreement among farmers in ranking the constraints affecting mobile-phone use for agricultural extension.

Analytical Framework

The analytical framework was designed to address two complementary dimensions of mobile phone-enabled agricultural extension among small-ruminant farmers. It examines factors that determine whether farmers access extension services through mobile phones and the relative importance of constraints that limit their effective use of mobile technology for extension. The details of variables considered in analysing the study objectives are highlighted in Table 1. The

next sections explain the framework for determinants of mobile-enabled extension access and constraints faced by farmers.

Table 1: Description of Explanatory Variables

Explanatory variable	Description of Measurement	Expected Outcome
Gender (dummy)	Gender of farmer (1 = Male, 0 = Female)	+
Age (years)	Age of household head (years)	+
Education (dummy)	Education of farmer (1= literate, 0; Otherwise)	+
Household size (number)	Number of people living in Household (Number)	+
FBO membership (dummy)	Farmer belong to FBO (1=Yes, 0=No)	+
Small-ruminant-rearing experience (years)	Number of years rearing small ruminants (years)	-
General farming experience (years)	Number of years in farming (years)	+/-
Mobile-phone operating knowledge (dummy)	Mobile phone operating knowledge (1=Yes, 0=No)	+
Years of mobile-phone use (years)	Number of years using a mobile phone (years)	+
Credit access (dummy)	Farmer access to credit (1= Yes, 0-No)	-

Binary Logistic Regression Model

This study evaluates the determinants of farmers' access to mobile-enabled agricultural extension services as a binary decision. Thus, whether a farmer accesses extension services via mobile phone ($Y_i = 1$) or not ($Y_i = 0$). This binary dependent variable justifies using a binary logistic regression model. The framework assumes that a farmer's decision is driven by an unobserved propensity Y_i^*. The latent-response specification is:

$$Y_i^* = Z_i + \varepsilon_i \quad (1)$$

where Z_i is the systematic component determined by explanatory variables, and ε_i is the stochastic error term. The observed binary outcome Y_i is linked to the latent propensity by:

$$Y_i = \begin{cases} 1 & \text{if } Y_i^* > 0 \\ 0 & \text{if } Y_i^* \leq 0 \end{cases}$$

Assuming a logistic distribution for ε_i, the probability $P_i = P(Y_i = 1)$ that farmer i accesses mobile-enabled extension is expressed as:

$$P(Y_i = 1) = \frac{\exp(Z_i)}{1+\exp(Z_i)} = \frac{1}{1+\exp(-Z_i)} \quad (2)$$

The corresponding probability of non-access is $1 - P(Y_i = 1) = \frac{1}{1+\exp(Z_i)}$. Taking the ratio of the two probabilities yields the odds of access:

$$\frac{P(Y_i=1)}{1-P(Y_i=1)} = \exp(Z_i) \quad (3)$$

Applying the natural logarithm to the odds yields the logit transformation:

$$\ln\left[\frac{P(Y_i=1)}{1-P(Y_i=1)}\right] = Z_i = \beta_0 + \sum_{k=1}^{K} \beta_k X_{ki} + \varepsilon_i$$

where β_0 is the intercept, β_k represents the estimated parameter for vector X_{ki} of farmer, household, institutional, and technological characteristics, and ε_i is the residual error term.

The Odds Ratios (OR) are **o**btained by exponentiating the parameter estimates:

$$\text{OR}_k = \exp(\beta_k) \quad (4)$$

Where OR> 1 indicates a positive association with the odds of access, OR < 1 indicates a negative association, and OR = 1 indicates no effect.

The average Marginal Effects across the sample size N measure the direct changes in predicted probability is expressed as:

$$\text{AME}_k = \frac{1}{N}\sum_{i=1}^{N} P_i(1-P_i)\beta_k \quad (5)$$

While the continuous and discrete variables are computed in equations (6) and (7), respectively.

$$\frac{\partial P(Y_i=1)}{\partial X_{ki}} = P(Y_i=1)\left[1-P(Y_i=1)\right]\beta_k \quad (6)$$

$$\Delta P = P(Y_i = 1 \mid X_{ki} = 1) - P(Y_i = 1 \mid X_{ki} = 0) \quad (7)$$

Kendall's Coefficient of Concordance (*W*)

To evaluate structural constraints restricting mobile technology usage, respondents evaluated nine ($n = 9$) potential operational challenges on a 5-point Likert scale ($L_{ij} \in \{1,2,3,4,5\}$), ranging from *1* = Not a constraint to 5 = Very high constraint.

Rank Sum and Mean Likert Derivations

Let R_{ij}represent the rank assigned by the respondent $i(i = 1,\ldots,m)$ to constraint $j(j = 1,\ldots,n)$. The aggregate rank sum (R_j) and mean rank ($\bar{R}_j$) for constraint *j*are calculated as:

$$R_j = \sum_{i=1}^{m} R_{ij} \quad \text{and} \quad \bar{R}_j = \frac{R_j}{m}$$

The mean Likert severity score ($\bar{L}_j$) across *N*total respondents is defined as:

$$\bar{L}_j = \frac{1}{N}\sum_{i=1}^{N} L_{ij}$$

Test of Concordance (W)

To quantify the level of agreement among the smallholder farmers, Kendall's Coefficient of Concordance (W) is specified (Franceschini & Maisano 2021; Kendall & Smith, 1939; Kendall, 1970):

$$W = \frac{12S}{m^2\left(n^3 - n\right)} \quad (8)$$

where $S$is the sum of squared deviations of rank sums (R_j) from their mean ($\bar{R}$):

$$S = \sum_{j=1}^{n}\left(R_j - \bar{R}\right)^2 \quad \text{with} \quad \bar{R} = \frac{1}{n}\sum_{j=1}^{n} R_j = \frac{m\,(n+1)}{2}$$

The coefficient ranges between $0 \le W \le 1$, where $W = 0$ indicates complete randomness/non-concordance and $W = 1$ denotes unanimous agreement. When rank ties occur, $W$is adjusted using the tie-correction factor T_i:

$$W = \frac{12S}{m^2\left(n^3 - n\right) - m\sum_{i=1}^{m} T_i} \quad (9)$$

where $T_i = \sum_k \left(t_k^3 - t_k\right)$, and $t_k$represents the number of tied ranks in group k.

RESULTS AND DISCUSSIONS

Descriptive Statistics

The descriptive statistics in Table 2 show that the sample consists largely of male ruminant farmers: the mean for gender (77.1%) shows that ruminant farmers in the selected district are male-dominated. This is not different from many communities across the region due to the labour- and cost-intensive nature of rearing livestock, for which many women cannot afford the resources.

Table 2: Descriptive Statistics of Farmers

Explanatory variable	Mean	Standard Deviation
Gender (dummy)	0.771	0.421
Marital status (dummy)	0.645	0.479
Age (years)	34.00	12.12
Education level (dummy)	0.426	0.495
Household size (number)	8.210	2.31
Farmer-based organisation membership (dummy)	0.485	0.500

Ruminant rearing experience (years)	5.801	2.566
Farming experience (years)	14.101	7.210
Gushegu (district-dummy)	0.335	0.473
Savelugu (district-reference)	0.333	0.472
Tolon (district-dummy)	0.333	0.472

Source: Authors' Analyses, 2026

The results also show that, on average, 64.5% of farmers are married, compared with 33.5% single. Spouses at the community level usually support farm production in addition to animal rearing in the Northern region. Marriage gives you an advantage in providing farm labour and other activities to raise ruminants. These characteristics is quite related in mobile-enabled extension access because farmers' roles in household decisions, control, and access to information differ across marital groups (Miine et al., 2023).

Also, farmers are 34 years old on average, indicating a relatively young and economically active group, ruminant-dominated farming population. Moreover, younger farmers are generally assumed to be more comfortable with newer technologies, especially accessing extension through mobile phones. The average farming experience was 14.10 years, while farmers' mean ruminant-rearing experience is 5.80 years. This suggests that many respondents have broader farming experience but fewer years specifically in ruminant production. This could also be inferred to mean that mobile-enabled extension could help farmers strengthen livestock-specific knowledge, including animal health, feeding, breeding and disease prevention.

The average household size is 8 members, indicating that many households may have family labour available for livestock activities. This also shows a relatively large size compared with the Northern regional average of 5 persons (GSS, 2021). Farmer-based organisation membership has a mean of 0.485, implying that less than half of the farmers belong to farmer based organization which has the potential to increase access to information. Again, about 42.6% of farmers are literate compared to the non-literate, typical of the low literacy level of farming communities in the Northern region (GSS, 2021). District representation is nearly equal across Gushegu, Savelugu and Tolon, at about one-third each, supporting comparisons across the study locations.

Determinants of Mobile-Enabled Extension Access: Binary Logistic Regression

To identify the factors associated with farmers' access to agricultural extension services through mobile phones, a binary logistic regression model was estimated. Access to extension services by farmers through mobile phones was used as a proxy for estimating the determinants of mobile-enabled extension. Table 3 shows that the estimated model is statistically significant at the 1% level, as indicated by the likelihood-ratio statistic of $LR\chi^2(10) = 56.72$.

Table 3: Binary logistic regression estimates of mobile-enabled extension access

Explanatory variable	Coefficient	Std. Error	Odds ratio	95% CI for odds ratio	Marginal effect
Constant	-0.324	1.353	0.723	[0.051, 10.256]	—
Gender (dummy)	2.785	1.103	16.196**	[1.865, 140.735]	0.102**

Age (years)	-0.259	0.283	0.771	[0.443, 1.344]	-0.016
Education (dummy)	0.172	0.18	1.188	[0.835, 1.690]	0.011
Household size (numbers)	0.646	0.325	1.908**	[1.009, 3.607]	0.041**
FBO membership (dummy)	1.134	0.576	3.107**	[1.005, 9.611]	0.071**
Small-ruminant-rearing experience (years)	0.854	0.356	2.349**	[1.169, 4.720]	0.054**
General farming experience (years)	-0.372	0.342	0.689	[0.353, 1.348]	-0.023
Mobile-phone operating knowledge (dummy)	-1.015	0.79	0.363	[0.077, 1.705]	-0.064
Years of mobile-phone use (years)	0.414	0.23	1.514*	[0.964, 2.375]	0.026*
Credit access (dummy)	0.692	0.533	1.997	[0.703, 5.678]	0.044
Number of observations	406				
LR χ^2 (10)	56.72	<0.001			
Pseudo R^2	0.243				
Log likelihood	−88.49				
AUC/ROC	0.842				
Correctly classified	92.36%				

Source: Authors' Analyses, 2026 Significance levels: *** p < 0.01, ** p < 0.05, * p < 0.1

This indicates that the explanatory variables jointly improve the prediction of mobile-enabled extension access relative to the intercept-only model. The pseudo-R^2 of 0.243 indicates that farmer households', institutional, and digital characteristics explain meaningful variation in mobile-enabled extension access. More importantly, the model achieves an Area Under the Receiver Operating Characteristic Curve (AUC) of 0.842, indicating good discrimination between farmers who access extension services via mobile phones and those who do not. Again, the model correctly classifies 92.36% of observations. In addition, the multicollinearity among key variables was negligible (VIFs < 5), ensuring stable parameter estimates.

The results show an average of 0.102 male farmers, which means that being male is associated with a 10.2 percentage point higher probability of accessing mobile-enabled extension. This is in line with Miine et al. (2023), who found that a higher proportion of male farmers adopted digital agricultural solutions, including those that facilitate access to extension services. Similarly, Abdulai et al. (2023) also identified gender as a significant factor in farmers' participation in digital agricultural services in Northern Ghana. Household size is positive and

statistically significant, with an average marginal effect of 0.041, implying that an increase in household size is associated with an increase of about 4.1 percentage points in the probability of accessing extension via mobile phone. A possible explanation is that large households may have more human resources to access and interpret information. The finding is consistent with Addison et al. (2024), who found a significant positive effect of the number of economically active members of a household on the use of digital technologies in agriculture in rural Ghana. The result thus implies that access to digital extension may be a partly household-level phenomenon and not an exclusively individual technological decision.

Farmer-Based Organisation (FBO) membership has a positive and statistically significant effect at the 5% level. The odds ratio indicates that members of farmer-based organisations have approximately 3.1 times the odds of accessing mobile-enabled extension compared with non-members. This finding is consistent with Miine et al. (2023), who found that membership in farmer-based organisations increased the probability and number of digital agricultural solutions adopted by Ghanaian farmers. The studies show a striking similarity, which gives strong evidence that farmer organisations are a suitable institutional entry point for digital agricultural extension.

The average marginal effect of small ruminant rearing experience is positive and significant at 0.054. This means that an increase in livestock-rearing experience is related to about a 5.4-percentage-point increase in the probability of mobile-enabled extension access.

The importance of this result is that it is specific to the livestock context, where more experienced small-ruminant farmers may have greater exposure to livestock diseases and strong relationships with extension officers. This gives them a better chance of knowing the value of mobile-enabled extension on their production. Thus, the positive relationship is aided by providing them with an information-demand mechanism.

Duration of mobile-phone use has a positive and weakly significant relationship with mobile-enabled extension. The marginal effect of 0.026 indicates that a unit increase in mobile-phone-use duration is associated with approximately a 2.6-percentage-point increase in the probability of mobile-enabled extension access. The positive direction suggests a learning or familiarity effect. Farmers who have used mobile phones for longer periods may be more familiar with making calls, seeking information and communicating with colleague farmers. This result is broadly consistent with Nyaplue-Daywhea et al.(2021), who found that mobile-phone competency and usage characteristics were associated with agricultural extension use.

Kendall's Coefficient of Concordance (W) and Constraints Ranking

To measure agreement among respondents regarding constraint severity, Kendall's Coefficient of Concordance (W) was computed across 9 specific challenges rated on Likert scales. The outcome estimation is statistically significant at the 5% level, indicating a low level of agreement (near non-concordance) among respondents. The results also show mean ranks of how each respondent rated each constraint relative to the others. Ruminant farmers display heterogeneous priorities and distinct, highly localised constraint profiles across communities. The results in Table 4 show several critical constraints affecting smallholder farmers' use of mobile technology for agricultural extension, highlighting evolving challenges in digital adoption within rural Ghana.

Table 4: Constraints Ranking on Mobile-Enabled Extension Access

Rank	Constraint	Mean	Mean Rank
1	Inadequate Electricity Coverage in the Community	3.69	7.75
2	High Cost of Mobile Device	2.21	5.54
3	High Cost of Device Management	1.98	5.09
4	Unable to read Text SMS from Extension Agents	2.25	5.02
5	Limited Knowledge in Using Mobile Phone Technology	2.19	4.97
6	Unable To Subscribe to Credit Recharge	2.2	4.93
7	Limited Mobile Network Coverage	1.79	4.59
8	Unstable Reception / Calls Breaking Unexpectedly	1.54	3.68
9	Higher Call Tariffs	1.44	3.44

Source: Authors' Analyses, 2026

Inadequate electricity coverage was the highest-ranked constraint affecting mobile-enabled extension services, with a mean score of 3.69. Access to electricity is still a big challenge in most communities of Northern Ghana. Among these, the high cost of device management was the third most significant barrier, with a mean score of 1.98 and a mean rank of 5.09. This includes the cost of charging, maintenance, repairs and buying accessories that are needed to keep mobile devices running. This highlights the need to account for the whole range of costs of digital adoption and spending to support inclusive access.

Another important constraint is the capacity of farmers to understand SMS messages from extension agents, which was rated fourth with a mean score of 2.25 and mean rank of 5.02. The score reflects moderate concern overall, but the high relative ranking reveals that literacy and language competencies are foundational to the usage of SMS-based extension programs. A farmer can have a mobile device, network coverage and enough credit, but the usefulness of SMS decreases greatly if the message content is in a language or format they do not understand. This finding supports earlier research by Ayisi-Nyarko et al. (2024), who stressed that the lack of sufficient digital information in local languages is a key obstacle. In practice, this means that the inclusion of voice-based services, interactive voice response (IVR) and local-language audio messages to SMS could help to overcome literacy challenges, thereby making digital extension more inclusive and accessible.

Limited knowledge or skills in using mobile phone technology is the fifth, with a mean score of 2.19 and a mean rank of 4.97. This points to a large digital divide not only in the infrastructure, but also in the skills of the users. Abdulai et al. (2023) showed that this point is supported by digital skills, such as making calls or navigating basic functions, which are strong predictors of participation in digital agricultural services. The results indicate that digital adoption should not be confused with digital competence; farmers can own mobile phones and use simple voice functions but may not have the skills to use SMS, apps or multimedia platforms.

The ability to subscribe to credit recharge is ranked sixth with a mean score of 2.20 and a mean rank of 4.93, indicating that continued access to active communication services depends on farmers' capability to retain credit. This is in line with previous studies by Nyaplue-Daywhea et al. (2021), which found challenges including renewing recharge credit and high pricing. The

current survey, however, showed less concern about high call costs, suggesting that the major challenge has shifted from the nominal cost of calls to liquidity and the sustained ability to subscribe to recharge credits. Farmers' limited income or cash flow constraints often prevent their engagement in extension activities, as they are unable to consistently purchase airtime. Mobile network coverage remains relevant (mean score = 1.79; mean rank = 4.59) and ranked 7th. Although network quality remains a challenge, its lower rating compared to other constraints may reflect improvements in infrastructure that now allow basic voice and SMS services to operate more reliably. The relatively low ranking of network quality may indicate that the network infrastructure within the research area may have influenced access to mobile phone use information in deprived communities. Poor network reception and limited access to communications are perennial barriers to scaling up digital agricultural extension in Ghana, highlighted by Nyaplue-Daywhea et al. (2021). Unstable call reception was seen as a minor constraint, being the eighth ranked with a mean score of 1.54 and mean rank of 3.68. This contrasts with Folitse et al. (2019), in which network failure was the major concern. The difference points out the importance of geography in the current study area, which has adjusted to occasional network disruptions or has access to multiple networks, reducing the perceived impact of unreliable calls. Unreliable calls, however, can still have major operational effects despite their lower rating, especially for two-way communication required in extension operations such as disease diagnosis or market information sharing. Finally, increased call tariffs were ranked ninth with the lowest mean score of 1.44 and mean rank of 3.44. This shows that overall, farmers do not perceive call charges as a substantial barrier. This finding differs from previous research conducted by Nyaplue-Daywhea et al. (2021), which found that high tariff rates are perceived as a significant impediment to mobile phone use among farmers. The results also imply that airtime pricing is not the main obstacle for farmers, but it is more about concerns of infrastructure and digital literacy in general.

Conclusions and Implications for Research and Practice

The findings demonstrate that access to mobile-enabled extension is not evenly distributed among small-ruminant farmers. The results identified household size, FBO membership and small-ruminant-rearing experience as significant determinants of mobile-enabled extension access. In addition, years of mobile-phone use also influence mobile-enabled extension access in ruminant production. Again, male farmers had substantially higher odds of accessing mobile-enabled extension than female farmers. These findings indicate that access to digital agricultural extension is influenced not only by the availability of mobile technology but also by farmers' socioeconomic and institutional circumstances. The constraint analysis provides further insight into the barriers affecting effective utilisation. Inadequate electricity coverage emerged as the most important constraint, followed by the high cost of mobile devices, the high cost of device management, inability to read or understand text SMS from extension agents and limited knowledge of mobile-phone technology, among others.

The findings therefore demonstrate that the effectiveness of mobile-enabled extension depends on more than mobile-phone ownership. Farmers require reliable electricity, affordable devices, appropriate digital skills, and accessible communication services, among others. Mobile-enabled extension should consequently be viewed as a complementary mechanism rather than a complete substitute for conventional extension. The findings support an integrated approach in which digital communication expands the reach and frequency of extension while face-to-face services remain available for more complex livestock-production and animal-health needs.

Based on these findings, several policy recommendations are proposed. First, rural electricity and alternative device infrastructure should be prioritised in agricultural communities. Investments in rural electrification should be complemented by solar-powered charging stations in areas where grid electricity is unavailable or unreliable. Second, gender-responsive digital extension programmes should be developed. The very large gender differential in access indicates that women should not be assumed to benefit equally from digital agricultural services. Digital literacy and mobile-phone training should become part of agricultural extension programmes.

Furthermore, extension agents should reduce dependence on text-based SMS communication. Since inability to read or understand SMS ranked among the major constraints, agricultural information should increasingly be delivered through voice calls, recorded voice messages and local-language audio content. This approach would make mobile-enabled extension more accessible to farmers with limited literacy.

Livestock-specific digital extension content should also be developed to provide timely information on small-ruminant diseases, vaccination, and other husbandry practices through veterinary agents in the various districts. Government and telecommunications companies should strengthen collaboration to improve the sustainability of mobile-enabled extension. Finally, the study concludes that mobile phone-enabled agricultural extension has substantial potential to improve access to livestock information among small-ruminant farmers in Northern Ghana. However, its benefits will remain uneven unless the socioeconomic, infrastructural and digital-capability barriers identified by farmers are addressed.

Declaration

Author Contributions

Conceptualization, IA, AI, HA; Data acquisition, IA; Analysis and interpretation, AI, HA, IA; Supervision, HA, AI; Writing – original draft, IA; Manuscript review and editing, AAM, HA, AI . The paper is based on IA's MPhil thesis, supervised by HA and AI. All authors read and agreed to the final version of the manuscript.

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Ethical Approval

Not applicable

Informed Consent

All conditions were written and read to the respondents. This particularly applied to farmers who were not literate, while those who were literate were provided with a copy of the consent form or it was read to their understanding before the interviews. All participants therefore consented to participate.

Data Availability

The authors confirm that the data supporting the findings of this study are available and will be shared upon request.

Competing Interest

There is no competing interest whatsoever associated with this manuscript.

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APPENDIX

Distribution of Sampled Farmers by Districts and Communities

Sampled Districts	Small ruminant household population	Fisher's sample size determination formula	Community	Sample farmers
Gushegu Municipality	6389	n^G= 1/(1/138 + 1/6389) n^G= 135	Gushegu	49
			Kpatinga	29
			Galwei	32
			Nawuhugu	25
Savelegu Municipality	9001	n^S= 1/(1/138 + 1/9001) n^S= 136	Savelugu	47
			Pong-Tamale	36
			Moglaa	20
			Diare	33
Tolon District	5556	n^T= 1/(1/138 + 1/5556) n^T= 135	Tolon	41
			Nyankpala	35
			Kasuliyili	29
			Tali	30
Total	**20946**		**12**	**406**

Source: Author's Design, 2026