HUNGARIAN UNIVERSITY OF AGRICULTURE AND LIFE SCIENCES, GÖDÖLLŐ

The Thesis of the Doctoral (PhD) Dissertation

Daniel Ayisi Nyarko

Gödöllő, Hungary

2023

HUNGARIAN UNIVERSITY OF AGRICULTURE AND LIFE SCIENCES

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

Doctoral (PhD) Dissertation

Daniel Ayisi Nyarko

Gödöllő, Hungary

2023

Hungarian University of Agriculture and Life Sciences

Name of Doctoral School: DOCTORAL SCHOOL OF ECONOMICS AND REGIONAL SCIENCES

Discipline: Regional Sciences, Rural Extension

Head: **Prof. Dr. Zoltán BUJDOSÓ**

Head of Doctoral School of Economics and Regional Sciences

Hungarian University of Agriculture and Life Sciences

Supervisor: **Dr. József Kozári**

Habil. PhD

Regional Institute of Economics and Rural Development

Hungarian University of Agriculture and Life Sciences

Co- supervisor: **Dr. Tóth Krisztina**

Associate professor

Institute of Rural Development and Sustainable Economy

Hungarian University of Agriculture and Life Sciences

.....	.....	..…..….....
Approval of the Head of Doctoral School	Approval of Major Supervisor.	Approval of Co-supervisor

BACKGROUND OF THE WORK AND ITS AIMS

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

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

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

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

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

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

A review of literature on topics such as the importance of digital technologies in agriculture, Barriers to digital agricultural adoption, traditional media, and modern media, the difference between traditional media and new media, mobile phones and agriculture information access,

the importance of mobile phones in agriculture, existing digital agricultural services facilitating agricultural information access in developing countries, farmer information needs, the role of agricultural extension in innovation transfer, and role of digital extension service were conducted to support the research problem and the objectives.

MATERIALS AND METHODS

Dwelling on the diffusion of innovation theory and the technology adoption model. The study adopted an exploratory sequential research approach where qualitative data was collected first, followed by quantitative data. The study used multistage sampling techniques to select the sample for the quantitative data collection. The towns in each Municipality were grouped into three zones based on the operational areas zoning used by the agricultural extension department. Altogether, six zones were created in the study areas. Simple random and purposive sampling techniques were used to select the respondents in each zone. A total of 414 smallholder farmers formed the main sample size for the study. The qualitative data were collected through focus group discussions and one-on-one interviews, while the quantitative data was collected through a survey. The qualitative data were analyzed by coding the interview responses to generate major themes. The quantitative data were also analyzed using descriptive statistics and the logistic regression model was used to establish the relationships among the dependents and the independent variables. Also, the study adopted the Hurt et al. (1977) innovativeness determination scales to classify the respondents into the five main innovative categories proposed by Rogers.

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

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

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

Econometric Model

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

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

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

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

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

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

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

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

RESULTS AND DISCUSSION

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

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

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

ownership systems in Ghana. Lands in Ghana are largely owned by families (customary lands). Families usually do not sell the lands; they rather share among family members. This practice could account for the increase in inheritance as the main source of land ownership in the study areas.

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

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

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

The possibility of accessing digital agricultural information by smallholder farmers depends on existing policies and the ownership and access to digital devices. The result of the main digital devices used by respondents in the study areas showed that mobile phone without internet access was the highest (77.7%) digital device owned and used by smallholder farmers in the study areas. This result suggests that mobile phones have become the most preferred digital tool used by smallholder farmers in Ghana. Hence, a mobile phone can be the best medium to reach a large number of smallholder farmers with agricultural innovations.
The current findings corroborate with the study of Krell et al. (2021), who observed that more than 90% of respondents in their study own mobile phones compared to other ICT devices. Contrary to the current findings, Fawole and Olajide (2012) observed in their research that

among the rural farmers in Nigeria, radio and televisions were the most widely used ICT devices compared to mobile phones. It should be noted, however, that Fawole and Olajide's study was carried out in 2012, whereas the current study was conducted in 2022. This suggests that time and geographical location play important roles in digital technology adoption and usage.

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

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

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

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

New scientific results

The following new scientific results were obtained from the study;

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

Conclusions and recommendations

Based on the results obtained from the data analysis in this research, Conclusions are made that gender, age, levels of education, marital status, family sizes, income, landownership, sources of income, land size, farming types, extension visits, membership of farmer association language barriers and cost of accessing digital information were the main demographic, economic and institutional factors influencing smallholder farmers digital agricultural technologies adoption in the Ketu Municipalities. Also, language barriers and high service costs were the most challenges that smallholder farmers face with the existing digital agricultural services available to farmers in the study area.

Furthermore, smallholder farmers in the Municipalities are literate. Contrary to past research findings, smallholder farmers in the Ketu Municipalities can read, write, and perform basic

arithmetic that is necessary for running successful agricultural enterprises. This finding is novel in the study of smallholder farmers in Ghana because past studies have consistently classified smallholder farmers in Ghana as illiterate who cannot read or write in their native languages. Additionally, majority of smallholder farmers in the Municipalities annual income from farming is above the national annual minimum wage. That is, more than half of the farmers annual income was above GHS10,000 (1,200 Euro).

Innovativeness among smallholder farmers in the Ketu Municipalities has increased. The number of farmers in the laggards cohorts has decreased while the innovators cohorts increased. This is an improvement in the Rogers innovativeness classification.

Mobile phone is the most used ICT device in the Municipalities. The municipalities also have good telecommunication networks and electricity; These position farmers in these areas to use mobile phones to access agricultural information. Smallholder farmers in the municipalities have different information needs. These information needs are classified into weather information, agricultural input, subsidies, farm credit, feed and feeding information, market for produce, postharvest practices, pests and diseases. Farmers information needs depend largely on the type of agricultural enterprises they undertake.

Smallholder farmers in the Ketu Municipalities have the capacity to access and are willing to use digital agricultural information services because majority of them are literate, their innovativeness has increased, they have good telecommunication networks, electricity, and use more mobile phones than any other ICT devices. We, therefore, propose the implementation of a digital agricultural information model called Decentralized Digital Agricultural Information Services (DDAIS) in the Ketu Municipalities to enhance smallholder farmers and extension communication. Taking advantage of these available resources to implement the DDAIS will reduce the asymmetry in extension service access in the municipalities.

We recommend that the DAES should partner with mobile telecommunication companies that offer good services in the area to roll out this programme. The current study results give insight to policymakers to implement decentralised agriculture policy that meets farmers needs in the geographical areas they find themselves. Livestock farmers, crop producers, fish farmers/fishermen information needs are different. Therefore, policymakers need to be guided. The study also helps the extension services to know the current trend of digital technology use in Ghana and the need to develop programmes and training that meet the current trends of farmers information access in the country.

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

Proposed Decentralized Digital Agricultural Information Services (DDAIS)

The Decentralized Digital Agricultural Information Services (DDAIS**)** will provide two services. An Information Desk (ID) and Voice Audio text Messages (VAM). The information desk will function as a customer support service. The DDAIS will be operated in the Ewe language, the dominant language in the study areas. The service can be accessed using a simple mobile phone. DDAIS will help serve the different farmer groups in the Municipalities. It will also help increase extension coverage in the areas. Farmers will get up-to-date agricultural information to speed up their decision-making on production. The logistic regression model results showed that farmers willingness to use the Decentralized Digital Agricultural Information Services (DDAIS) was 85%. This shows that the system would not face accessibility challenges.

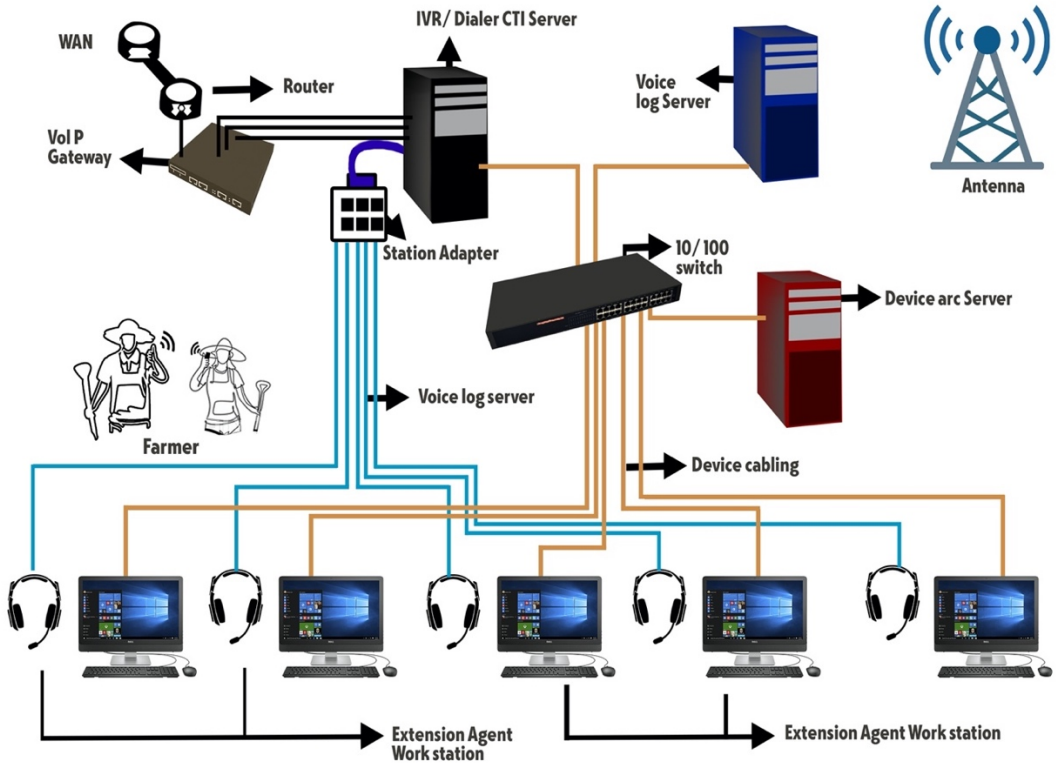

Figure 1. The proposed Decentralized Digital Agricultural Information Services (DDAIS) model.

LIST OF PUBLICATIONS

Reviewed Journal articles

1. Ayisi, D. N., Kozári, J., & Krisztina, T. (2022). Do smallholder farmers belong to the same adopter category? An assessment of smallholder farmers innovation adopter categories in Ghana. Heliyon, 8(8), e10421.
2. Ayisi, D. N., & Krisztina, T. (2022). Gender Roles and Gender Differences Dilemma: An Overview of Social and Biological Theories. Journal of Gender, Culture and Society, 2(1), 51-56.
3. Nyarko, D. A., & Kozári, J. (2021). Information and communication technologies (ICTs) usage among agricultural extension officers and its impact on extension delivery in Ghana. Journal of the Saudi Society of Agricultural Sciences, 20(3), 164-172.
4. Yeboah, F. K., Adingo, S., Coffie, C. P. K., & Nyarko, D. A. (2021). Commercializing Agriculture in Deprived Regions of Ghana: A Case of the Ekumfi District, Central Region. International Journal of Food and Agricultural Economics (IJFAEC), 9(1128-2021-392), 59-71.
5. Nyarko, D. A., & Kozári, J. (2020). Influence of socioeconomic characteristics of cocoa farmers on the use of E-agriculture in Ghana. Asian J. Agric. Extension, Econ. Soc, 82-91.
6. Nyarko, A. D., & Kassai, Z. (2017). High rice import as a threat to food security and a hindrance to sustainable rice production in Ghana. Archives of current Research international, 7(2), 1-13

Conference Proceedings

7. Nyarko, D. A. (2022). Penetration and usage of Information Communication Technologies in Africa: an evaluation of the prospects of Electronic Agricultural Advisory Services in selected Sub-Saharan African countries. The Association of Hungarian PhD and DLA Candidates (DOSZ) 1st Ghana Students Scientific Conference, Budapest. 2022, Conference Proceedings. ISBN: 978-615-6457-05-9.
8. Ayisi, D. N., Nuhu, Y. B. (2022). Analysis of Socio-Demographic Trends in Subsaharan Africa: Impact on Food Security And Rural Economic Development. DOSZ XXV. Tavaszi Szél Konferencia. Budapest. 2022. ISBN 978-615-6457-13-4.
9. Nyarko, D. A., & Kozári, J. (2020). Determinants of E-Extension Adoption Among Cocoa Farmers in The Akim Akyease Cocoa District, Ghana. 17th International Scientific Days Online Conference. Gyöngyös Hungary June, 2020. ISBN 978-615-5969-02-7 (online).