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Drivers of Small-Scale Farmers' Adoption of Mobile Phone Technology for Rice Production and Marketing in Dodoma Region

Steven L. Mwaseba*, Provident J. Dimoso, and Shauri K.Timothy

Department of Rural Development and Regional Planning, Institute of Rural Development Planning, Donbosco Road, 41213 Mbwanga, P.O. Box 138, Dodoma, Tanzania.

Abstract

Despite the benefits of Mobile Phone Technology (MPT) in enhancing agricultural communication in Tanzania, a significant gap exists between the rise in mobile phone subscriptions and the actual adoption of MPT by farmers for agricultural production and marketing. This study utilised multinomial logistic regression to analyse factors influencing MPT adoption among 454 small-scale farmers in Bahi District, Dodoma Region. The findings indicated that 62 percent of the farmers adopted MPT, while 38 percent did not. Key factors influencing MPT adoption for rice production communication only included; having household members under 15 years, mobile phone ownership, time spent on using mobile phones, land size, use of hired labour, market distance and distance to all-weather roads. This study revealed that significant determinants for the adoption for rice marketing communication only were farmer's sex, time spent on mobile phones and market distance. Further, the study showed that significant factors for the adoption for combined rice production and marketing communication were the farmer's education level, mobile phone ownership, land size, use of family and hired labour, and market distance. Understanding these factors provides a foundation for developing interventions to increase MPT adoption among key stakeholders. Increased adoption of MPT will improve access to market information and agricultural practices in rural areas, thereby enhancing rice production and marketing and improving farmers' livelihoods.

Keywords: Adoption, mobile phone technology, small-scale farmers, rice production and rice marketing

1. Introduction

Agriculture remains crucial for the economies of many developing nations, including Tanzania, as it provides substantial employment and contributes significantly to livelihood and national income (Lyatuu et al., 2015; The United Republic of Tanzania, 2013, 2015). For instance, in Tanzania, it constitutes approximately one-third of the Gross Domestic Product (GDP) and employs two-thirds of Tanzanians (USAID, 2023). Despite their crucial role, agricultural productivity and effective agricultural marketing remain notably low in most developing countries (Rehman et al., 2019). Enhancing agricultural productivity and marketing is therefore crucial for these economies (Afolami et al., 2015; Challa and Tilahun, 2014).

In Tanzania, agricultural production and marketing face challenges with low productivity and inefficient marketing systems (Afolami et al., 2015; Challa and Tilahun, 2014; Fu and Akter, 2016). Improved technologies and management systems offer a key strategy to boost productivity and marketing efficiency (Kitole et al., 2024; Mgendi et al., 2022; Rodríguez-Entrena and Arriaza, 2013).

Among these interventions is employing communication technologies to access improved inputs and markets for agricultural produce (Chan, 2015; Hoang, 2020; Jensen, 2010; Kinyashi et al., 2022; Kitole et al., 2024; Mgendi et al., 2022; Quandt et al., 2020; Thar et al., 2021). Studies by Mushi et al. (2022) and Kitole et al. (2024) highlight the importance of digital technologies in agriculture for reducing poverty and improving food security. Digital transformation in the agricultural sector, driven by the widespread use of mobile and communication technologies in Tanzania, has been significant (Kitole et al., 2024), with Mobile Phone Technology (MPT) playing a crucial role in enhancing agricultural information for smallholder farmers (Chan, 2015; Hoang, 2020; Jensen, 2010; Kinyashi et al., 2022; Quandt et al., 2020; Thar et al., 2021). However, a gap exists between rising mobile subscriptions and the actual adoption of these technologies in rice farming and marketing practices, suggesting unknown factors influencing their effective use among small-scale rice farmers (Kinyashi et al., 2022).

This study uniquely focuses on the factors influencing the adoption of MPT in both rice production and marketing among small-scale farmers in Bahi District, Dodoma Region, Tanzania. Unlike previous studies in Tanzania that often generalise across various crops or different aspects of agricultural technologies such as those by Kisena and Kwesigabo (2023), Quandt et al. (2020), Ndimbo et al. (2023) and Nyagango et al. (2023), this study disaggregates its analysis to separately examine production, marketing and combined use. Using multinomial logistic regression, the study provides a strong understanding of how different factors uniquely affect each aspect of MPT adoption. By including both adopters and non-adopters in the analysis, the study offers comprehensive insights into barriers and facilitators specific to the local context (Hosmer Jr. et al., 2013; Long and Freese, 2006). This targeted approach not only fills the gaps in the literature but also provides practical insights for developing tailored interventions to enhance rice productivity and marketing efficiency, thereby improving the livelihoods of small-scale farmers in Tanzania.

Given the importance of information in facilitating rice production and marketing, understanding the factors that influence the adoption of MPT among small-scale rice farmers is crucial. This study aims to identify these factors and bridge the gap between mobile phone ownership and its practical application in rice farming and marketing. By investigating the factors of MPT adoption, this study aims to provide insights that can help enhance rice productivity and marketing through better communication and information dissemination.

The study contributes to the existing body of knowledge by exploring the specific factors that influence the adoption of MPT among small-scale rice farmers in the Bahi District, Dodoma Region. The findings are expected to inform policymakers, agricultural extension services and technology developers on how to tailor interventions that promote the effective use of MPT in rice production and marketing. By addressing the identified factors facilitating the adoption process, the study aims to enhance rice productivity and marketing efficiency, ultimately improving the livelihood of small-scale rice farmers in Tanzania.

2. Materials and Methods

2.1. Data and sample

The study was conducted in Bahi District, Dodoma Region, specifically in the

villages of Bahi-Makulu, Nagulobahi, and Bahi-Sokoni. A cross-sectional survey design was used, and data were collected electronically using smartphones equipped with survey questions through a survey solution program. The use of smartphones for data collection enabled real-time data entry and validation, minimising errors and ensuring high data quality[1].

The Bahi district agricultural officer facilitated the selection of rice-producing villages, ensuring that the study focused on areas with significant rice-production activity. Due to the unknown number of small-scale rice producers in these areas, the sample size recommendation by Eichenberger et al. (2011) and Luanglath (2014) was followed. According to these guidelines, any sample above 100 for an unknown population is statistically acceptable, providing a reliable basis for analysis.

A total of 454 respondents were randomly identified and interviewed with the assistance of village leaders and extension officers. Initially, households with small scale rice producers were identified, followed by random selection of theses households, where the head of household was selected for interview. This sample included both mobile phone users and non-users, offering a comprehensive perspective on the factors influencing the adoption of MPT in rice production and marketing[2]. Also including both mobile phone users and non-users was important to know the adopters and non. The involvement of local leaders and extension officers was crucial in gaining the trust of respondents and ensuring the smooth execution of the survey process.

2.2. Empirical analysis

The study aimed to identify the factors influencing the adoption of MPT in rice production, marketing, and both production and marketing separately, using multinomial logistic regression. This approach was chosen as the adoption categories were not ordered Meena et al. (2016) also used it in the technology adoption study. Multinomial logistic regression, an extension of logistic regression, facilitated the analysis of these three groups, with non-MPT adopters serving as the reference group. The multinomial logistic regression allows for the comparison of multiple groups simultaneously, using one group as a reference group (Hosmer Jr. et al., 2013; Long and Freese, 2006).

MPT adoption was defined as its use for communicating either rice production or marketing or both, based on the Diffusion of Innovation Theory (DIT) developed by Rogers (1962), which suggests that an individual adopts a technology when deciding to use it. The study assumed that MPT had already been adopted by farmers. Therefore, MPT use was treated as the outcome variable with unordered categories: 0 for not using MPT, 1 for using MPT in communicating rice production, 2 for using MPT in communicating rice marketing, and 3 for using MPT in communicating both rice production and marketing.

The intuition behind adoption is that if the utility associated with that adoption choice (V_{1i}) is greater than the utility associated with the decision not to adopt (V_{0i}), an individual will decide to adopt MPT. As a result, there is a latent or unobservable variable in this model that takes all values in (-∞, +∞). These two distinct alternatives and their corresponding utilities can be quantified as $M^* = V_{1i} - V_{0i}$ (Koop, 2003; Wooldridge, 2010) and thus the model's

[1] Data were collected in the year 2020

[2] Mobile phone non-users were included for comparison purposes.

econometric specification is given in its latent form as:

$$Y_i = \begin{cases} 1, Y_i^* \geq 0 \\ 1, Y_i^* \leq 0 \end{cases} \quad \text{(i)}$$

Where M_i takes the value of one (1) for adopters and Zero (0) for non-adopters. Then, to estimate Y, equation (1), becomes:

$$Y^* = x\beta_i + \mu_i \quad \text{(ii)}$$

Where Y^* is a latent variable representing the propensity of a rice farmer to adopt MPT, x is the vector of independent variables (rice farming households' socio-demographic attributes, MPT characteristics, as well as rice production and marketing variables) that influence the adoption decision, β is representing parameters to be estimated, μ_i is a normally distributed error term.

Thus, according to this latent model specification, the utility function depends on farmer-specific attributes X and a disturbance term (u) having a zero mean:

$$U_{ij} = \sigma + \beta_J X_i + \mu_{i0}\, for\ MPT\ Adopters \quad \text{(iii)}$$

Since utility is assumed to be random (Wooldridge, 2010), the i^{th} household will adopt MPT if and only if $U_{i1} > U_{i0}$. Thus, for the household i, the probability of adoption is given by:

$$P(1) = P(U_{ij} > U_{i0}) \quad \text{(iv)}$$

The probability of MPT j (j=0 non-adopters; j=1 adopted for communicating rice production; j=2 adopted for communicating rice marketing and; j=3 adopted for communicating both rice production and marketing) is given by the following multinomial logistic regression model in equation (v) below. Given that Y is the dependent variable X is the vector of independent variables.

$$P(Y_i = j) = \frac{\exp(x_{ij}\prime\beta_j)}{\sum_k \exp(x_{ik}\prime\beta_k)} \quad \text{for j and k = 0,1,2,3} \quad \text{(v)}$$

The covariates used in this study are based on previous studies. In Tanzania, studies by Nyagango et al. (2023), Quandt et al. (2020) and Ndimbo et al. (2023) examined variables such as age, marital status, education, household size, farm size, economic factors and farming experience in relation to mobile technology adoption for marketing and productivity. Autio et al. (2021) investigated practices and technology access in Kenya, while Abebe (2023) explored factors like education status, distance, and mobile ownership in Ethiopia. In South Africa, Sikundla et al. (2018) focused on socioeconomic factors. Meena et al. (2016) researched agricultural technology adoption in India, emphasising household factors, access to technology facilities and agricultural practices. Therefore, this study analysed factors, influencing MPT adoption by categorising them into three groups: socio-demographic factors (age, sex, education level, marital status, and household size), mobile phone usage (ownership, network strength and time spent on using a mobile phone) and rice production and marketing factors (land size, family labour, hired labour, distance to the market and distance on all-weather roads). Table 1 provides a description of the variables.

Table 1: Description of the variables

Variable	Description
Dependent variable	
UseMPTproMktBoth	*Adopt MPT for communicating rice production, marketing, both or didn't adopt* *0 if respondent didn't adopt MPT* *1 if respondent adopted MPT to communicate rice production* *2 if respondent adopted MPT to communicate rice marketing* *3 if respondent adopted MPT to communicate both rice production and marketing*
Independent Variables	
Age	Age of household head (in years)
Sex	Sex of the respondent
Edu	Education level of household head (1=Formal education, 0=No formal education)
HHMart	Marital status of household head (1=Couple, 0=Single)
Hhsize	Household size, involved number of family members
Agebelow15[3]	Household members with age below 15 years
Ageabove64[4]	Household members with age above 64 years
OwnPhone	Ownership of mobile phone (1=Mine, 0=Borrowed)
NetStrength	Mobile phone network strength (1=Satisfactory, 0=Weak)
TimePh	Period one has been using mobile phone (1 for 3 years and above, 0 for less than 3 years)
Landsize	Size of land cultivated rice (in Acres)
FamLabour	Number of family labour in rice production and marketing activities
HireLabour	Number of hired labour in rice production and marketing activities
MrktDis	Distance to the market (in Km)
RoadDis	Distance to all-weather road (in Km)

3. Results

3.1. General Characteristics of Adopters and Non-Adopters of MPT

According to the findings, 282 (62 percent) of small-scale farmers used MPT for communicating rice production and marketing, while the remaining 172 (38 percent) did not, specifically, 14 percent of the total sample used for rice production communication, 19 percent used for rice marketing communication and 29 percent for both purposes. Because of the heterogeneity of the farmers, adoption is not uniform (Heiman et al., 2020).

The variables used to assess adoption were well represented by both MPT adopters and non-adopters. Only six variables used to measure adoption had statistically significant differences between adopters and non-adopters, as shown in Table 2. This implies that the two groups (adopters and non-adopters) are statistically comparable.

[3] Indicates dependent population
[4] Indicates dependent population

Table 2: Respondents' characteristics

Variables	Pooled (454)	Adopters (282)	Non-Adopters (172)	t-test/ χ^2Values of Mean Difference
Socio-Demographic Attributes				
Age	40.20	39.90	40.70	0.6057§
Sex	68.06	69.50	65.70	0.7119†
Edu	80.84	86.52	71.51	15.5451†***
HHMart	76.43	78.72	72.67	2.1701†
HHsize	5.17	5.24	5.07	-0.6250§
Agebelow15	2.08	2.19	1.91	-1.7091§
Ageabove64	0.23	0.22	0.24	0.3134§
Mobile phone Characteristics				
OwnPhone	86.56	97.16	69.19	71.898†***
NetStrength	74.01	74.11	73.84	0.0042†
TimePh	63.66	67.73	56.98	5.3404†***
Rice Production and Marketing Variables				
Landsize	4.70	5.01	4.2	-1.7334§
FamLabour	2.58	2.42	2.85	3.0707§***
HireLabour	3.74	4.61	2.30	-5.5905§***
MrktDis	6.41	7.70	4.28	-4.7195§***
RoadDis	3.79	3.99	3.47	-1.8510§*

*Asterisk ***, **, and * is significant at 1, 5%, and 10% levels; t-test values denoted by §; χ^2 values denoted by †*

3.2. Factors Affecting Small-Scale Farmers to Adopt MPT

Table 3 indicates general statistically significant results at the 1 percent level (prob>chi2=0.0000), suggesting that the explanatory variables reliably predict MPT adoption. The multinomial logistic regression uses the non-adopters of MPT as a reference group.

The analysis of the factors influencing MPT adoption focused on three categories: communication for rice production, rice marketing, and both rice production and marketing. Significant factors for adopting MPT for rice production communication include having household members under 15 years, mobile phone ownership, time spent on mobile phones, land size, use of hired labour, market distance and distance to all-weather roads. For rice marketing communication, significant factors include the farmer's sex, time spent on mobile phones and market distance. For both rice production and marketing communication, significant factors are the farmer's education level, mobile phone ownership, land size, use of family and hired labour, and market distance (see Table 3 for details).

Factors that increase the likelihood of adopting MPT for rice production communication include longer market distance, mobile phone ownership, hiring labour, and living in households with members under 15 years old. For rice marketing communication, only a longer market distance significantly increases MPT adoption. For both rice production and marketing communication, significant factors are longer market distance, mobile phone ownership, hiring labour and living in households with members under 15 years old (see Table 3).

Factors that reduce the likelihood of adopting MPT for rice production communication include longer mobile phone use, longer distance to all-weather roads and larger land size. For rice marketing communication, only a larger land size significantly reduces MPT

adoption. For both rice production and marketing communication, larger land size significantly reduces MPT adoption (see Table 3).

Table 3: Regression results factors affecting small-scale farmers to adopt MPT in communicating production and marketing information

	Multinomial Logistic Regression Results (y= *UseMPTproMktBoth)* (Didn't adopt MPT was the base outcome)		
Item	Production	Marketing	Both production and Marketing
	Odds ratio	Odds ratio	Odds ratio
Age	1.017	0.994	1.017
Sex	0.741	1.838*	1.193
Edu	1.067	1.540	3.895***
HHMart	1.414	1.826	0.956
Hhsize	0.843	0.932	0.973
Agebelow15	1.494**	1.254	1.202
Ageabove64	0.853	0.823	1.013
OwnPhone	22.53***	2.66e+07	12.56***
NetStrength	2.056*	0.985	1.267
TimePh	0.338***	0.424**	0.834
Landsize	0.798***	0.943	0.923**
FamLabour	0.774*	0.887	0.831*
HireLabour	1.221***	1.033	1.247***
MrktDis	1.100***	1.098***	1.096***
RoadDis	0.857**	0.908	1.009
Constant	0.035***	2.39e-08	0.005***
Number of obs	454		
Prob > chi2	0.0000		
Pseudo R2	0.1946		
Log likelihood	-482.21122		

*Asterisk ***, **and * means significant at 1% (p<0.01), 5% levels (p<0.05) and 10% (p<0.1) respectively.*

4. Discussion

Mobile phones have become essential tools for agricultural production and marketing (Jensen, 2010; Katengeza et al., 2011; Kisena and Kwesigabo, 2023; Kitole et al., 2024; Krell et al., 2021; Ndimbo et al., 2023; Nyagango et al., 2023; Sikundla et al., 2018). Owning a phone provides convenient communication, enabling farmers to stay connected and share information on both rice production and marketing. The findings indicate that phone ownership plays a significant role in MPT adoption, as it is the prerequisite for adoption. A study in Tanzania found that having a mobile phone increases agricultural yields and profitability (Quandt et al., 2020).

Literature shows that people with higher education levels are more likely to adopt new technology due to cognitive functioning (Hoang, 2020; Khan et al., 2020; Mittal and Mehar, 2016; Thar et al., 2021; Ugochukwu and Phillips, 2018). Individuals with higher education levels are exposed to the new technologies. This study found that a higher education level correlates with a higher MPT adoption rate, as educated farmers are more likely to understand the benefits of MPT in accessing information regarding rice production and marketing. However, another study from Tanzania reported opposite results, indicating educational level negatively relates to MPT adoption in grape marketing (Nyagango et al., 2023).

The length of time an individual is exposed to a particular technology or innovation can influence adoption. According to the technology diffusion theory, not all individuals adopt innovations simultaneously (Anand et al., 2018). There are a few early adopters (innovators) and a few late adopters (laggards), with many others (early adopters, early majority, and late majority) in between. This study observed that those who have used a mobile phone for more than three years have lower odds of adopting MPT, indicating that they are early adopters, early majority, or late majority. Farmers who have owned phones for a long time may be limited by their familiarity with current technologies, restricting them from adopting new technologies.

In developing countries, including Tanzania, agricultural activities are labour-intensive (The United Republic of Tanzania, 2015). Having more family members who cannot work on the farm necessitates hiring labour (Dorward, 2013; Osabuohien et al., 2019). Engaging in hired labour increases communication, which increases the likelihood of adopting communication innovations compared to the use of family labour. The results indicated that hiring labour was a significant factor in increasing the odds of MPT adoption and using family labour had odds of decreasing the adoption though was significant at a 10 percent level.

This study found that households with dependents younger than 15 years old are more likely to adopt MPT, particularly for rice production information than those with members 65 and older. In rural communities, younger household members are normally exposed to technology (Thar et al., 2021) and they assist other household members in using new technology, thus increasing the odds of MPT adoption.

Moreover, with most of the small-scale farmers using labour-intensive techniques (The United Republic of Tanzania, 2015), adopting new technologies is challenging for those with large land sizes. These farmers do not see immediate benefits from new technologies and prioritise buying inputs that are significant for production processes. Most of these farmers are well connected to the local networks for producing and marketing their products, so the notion of adopting new technology is modest. This study found that owning a large land s reduces the odds of MPT technology. However, other literature suggests that having a large farm size is a sign of economic status that motivates technological adoption (Mittal and Mehar, 2016).

Communication is critical for market access, especially when the market is located far from the farm (Baumüller, 2015). This study found that the market distance has a positive and significant impact the likelihood of adopting MPT. Small-scale farmers living far from markets adopt the MPT to improve communication with customers and stay informed about market prices. However, the study found that the longer the distance from all-weather roads decreases the odds of adopting MPT, as staying away from these roads reduces network connectivity among remote rural communities.

5. Conclusion

The study explored the adoption of MPT among small-holder farmers in Bahi district, Dodoma region, Tanzania, focusing on its implications for agricultural practices and market access. It emphasised the crucial role of mobile phones in facilitating communication and information sharing for agricultural

production and marketing. The study found a link between higher levels of education and adoption of new technologies. The study further found that longer exposure to mobile phones as a communication tool reduces the odds of adopting MPT. The hiring of labour, rather than relying on family labour increases communication and thereby the likelihood of adopting MPT. Additionally, households with younger members are more likely to adopt MPT, facilitated by their familiarity with technology and support in its usage. However, the large land size and distance from all-weather roads pose challenges to technology adoption among farmers. These insights into factors influencing the adoption of MPT among small-holder farmers in Tanzania highlight the role of education, labour practices, household demographics and geographical factors in technology adoption. This understanding is crucial for policymakers and organisations aiming to promote agricultural productivity and market access through mobile technology interventions, thereby improving the livelihoods of small-holder farmers.

6. Limitations of the study and areas for further research

The study limitation is based on the relatively small size of Bahi District in Dodoma Region, which may not represent all small-scale rice farmers in Tanzania. Further studies may utilise large and more diverse samples to enhance generalizability. Moreover, the use of self-reported data from the farmers may introduce bias, like over-reporting of the positive outcomes and underreporting of the challenges. The study did not differentiate between the phases of technology adoption, which could provide a deeper understanding of the adoption process. Lastly, there is a potential for further research to explore gender-specific barriers and facilitators in MPT adoption, taking into account cultural and socioeconomic factors.

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