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# Access to Agricultural Extension Services and Adoption of Improved Agricultural Practices among Smallholder Sunflower Farmers: Evidence from Dodoma and Singida Regions, Tanzania

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**Abstract**
The role of agricultural extension services (AES) in promoting the adoption of improved agricultural practices (IAPs) is widely recognised. However, existing studies often conceptualise extension access as a binary condition—whether farmers have contact with extension services or not-overlooking variation in how access occurs in practice. This study examined how differences in the frequency of interpersonal contact and extension communication modes jointly shape adoption behaviour among smallholder farmers. Drawing on the Diffusion of Innovations Theory, the study conceptualised extension access along two dimensions: frequency of interpersonal contact and modes of communication. A cross-sectional research design employing quantitative and qualitative approaches was used. Quantitative data were collected from 385 smallholder farmers through structured questionnaires and analysed using descriptive statistics and binary logistic regression in IBM SPSS version 23. Qualitative data were obtained through focus group discussions and were analysed thematically to complement quantitative findings. Findings indicate that adoption of IAPs remains relatively low, with only 41.8% of farmers classified as adopters. Binary logistic regression results revealed that the frequency of extension contact was significantly associated with IAPs adoption ($OR = 1.902, p < 0.05$). In contrast, digital and mass-media communication channels did not show statistically significant associations after controlling for interpersonal contact. Qualitative findings further revealed that farmers valued repeated interpersonal engagement because it enhances trust and continuous technical guidance. The findings suggest extension systems to strengthen interpersonal engagement while using digital and mass-media channels as complementary support mechanisms. However, the study is limited by its reliance on cross-sectional data, which constrains causal inference.

## Introduction

Agricultural productivity among smallholder farmers in developing countries remains constrained by limited adoption of improved agricultural practices (IAPs) such as improved seed varieties, fertiliser application, recommended planting spacing, and effective pest and disease management (Legesse et al., 2024; Mugula et al., 2023; Sithole & Olorunfemi, 2024). These practices are widely associated with increased productivity, improved household food security, and enhanced rural livelihoods. In Sub-Saharan Africa, including Tanzania, AES constitute the primary mechanism for disseminating agricultural innovations and promoting technology adoption among farmers. However, despite continued investment in extension systems, adoption of IAPs among smallholder farmers remains uneven and persistently low (Manono et al., 2025).

In many Sub-Saharan African contexts, access to extension services is constrained by limited staffing, weak logistical capacity and poor rural infrastructures (Mnukwa et al., 2025). In Tanzania, extension agents reportedly reach only about 10% of farming households (National Bureau of Statistics [NBS], 2021), resulting in infrequent and uneven interactions between farmers and extension agents. These constraints are further shaped by the decentralised extension systems introduced under the Decentralisation by Devolution (D by D) reforms in the 1990s, which transferred responsibility for extension delivery to Local Government Authorities. While intended to improve service responsiveness, the reform has produced substantial variations in extension provision across districts due to differences in institutional capacity and resource availability (Nzao et al., 2025). Consequently, access to AES varies not only in whether farmers receive services, but also in the frequency of interactions and the communication channels through which information is delivered.

This variation is particularly relevant in Dodoma and Singida regions, where sunflower production constitutes an important livelihood activity and extension support plays a critical role in improving productivity. Although the regions contribute approximately one-third of Tanzania's national sunflower output, yields remain low, typically ranging from 0.8 to 1.2 tonnes per acre compared to a potential of about 4 tonnes per acre (United Republic of Tanzania [URT], 2023). This productivity gap is largely linked to limited adoption of IAPs, many of which require sustained technical support and advisory services.

Despite the recognised importance of AES, existing studies (Mary et al., 2024; Masanja et al., 2023; Utonga, 2025) commonly conceptualise extension access as a binary condition–whether farmers have access or not. Such an approach overlooks important variations in interaction frequency and in the communication modes through which extension information is delivered. Drawing on the Diffusion of Innovation Theory, which distinguishes between mass communication channels that create awareness and interpersonal channels that influence adoption decisions, this study conceptualises access to AES as a multidimensional construct comprising interaction frequency and communication modes. By jointly examining these dimensions, the study moves beyond binary measures of extension access to analyse how variations in interaction intensity and communication modes are associated with IAP adoption behaviour among smallholder farmers.

### Theoretical Review

The study is guided by the Diffusion of Innovations Theory (DOI), which explains how innovations spread within a social system over time (Rogers, 2003). In agricultural contexts, the theory is widely used to understand how farmers acquire information and decide whether to adopt new practices. A central proposition of the theory is that communication channels influence adoption differently. Mass communication channels primarily create awareness, whereas interpersonal channels are more effective in shaping adoption decisions through persuasion, clarification, and trust-building.

The theory further emphasises that repeated exposure to information reduces uncertainty and strengthens the likelihood of adoption. Frequent interaction between farmers and extension providers, therefore, facilitates knowledge reinforcement, context-specific guidance, and conscious feedback, all of which support adoption behaviour. Guided by these propositions, the study conceptualises access to AES as a multidimensional construct comprising the frequency of farmer-extension interactions and the modes of information delivery. These dimensions are examined in relation to the adoption of IAPs among smallholder farmers.

**Empirical Literature Review**

Empirical studies show that adoption of IAPs among smallholder farmers is uneven, partial and context-specific (Araya et al., 2024; Mhango & Jeckoniah, 2024; Mwatawala & Burian, 2024). Rather than adopting complete technology packages, farmers often adopt selected practices depending on resource availability, institutional support and farm conditions (Mutengwa et al., 2023). These patterns suggest that adoption outcomes are shaped not only by technology characteristics but also by farmers'access to support services, particularly AES.

Previous studies (Justine et al., 2025; Kitole et al., 2023; Mary et al., 2024; Masanja et al., 2023; Mugizi, 2025) consistently identify AES as important for promoting technology uptake through information dissemination, training and advisory support. However, most studies conceptualise extension access as a binary condition-whether farmers have access or not (Masanja et al., 2023; Midamba & Ouko, 2024; Utonga, 2025). This approach overlooks important variations in interaction intensity and communication channels that may be associated with adoption behaviour.

Evidence regarding the role of interaction frequency remains mixed. Some studies (Kaba & Emana, 2024; Kirimi et al., 2024; Sisay et al., 2023) report that frequent interaction with extension providers enhances adoption by reinforcing knowledge and reducing uncertainty, while others (Nnahiwe et al., 2023; Miine et al., 2023; Olawuyi et al., 2024) find weak or insignificant associations. These inconsistencies may partly reflect differences in how interaction frequency is measured across studies.

In addition to interaction frequency, extension information is delivered through multiple communication channels, including farm visits, demonstrations, radio, television, and mobile-phone platforms (Hammas et al., 2024). Existing evidence generally suggests that interpersonal channels are more effective in influencing adoption decisions, whereas mass communication channels are more effective in creating awareness (Abdulai et al., 2023; Goeb et al., 2025; Tambo et al., 2023). However, the independent contribution of different communication modes to adoption outcomes remains unclear and context-dependent.

Therefore, the literature highlights the importance of AES in promoting the adoption of IAPs but offers only a limited understanding of extension access as a multidimensional construct. In particular, few studies jointly examine how both interaction frequency and communication modes shape adoption behaviour, particularly within decentralised extension systems characterised by uneven service delivery. This study addresses this gap by examining how these dimensions of extension access are associated with the adoption of IAPs among smallholder farmers. Towards operationalising the study objectives, the study advances the following hypotheses;

> **$H_1$:** *More frequent interaction between farmers and extension providers is positively associated with the adoption of improved agricultural practices.*

**$H_2$:** *Modes of extension communication are significantly associated with the adoption of IAPs.*

## Method

### *Study Area and Research Design*

The study was conducted among smallholder sunflower farmers in four districts: Chemba and Kondoa in Dodoma region, and Ikungi and Manyoni in Singida region. These areas were selected for their significance in sunflower production, which contributes approximately one-third of national output and hosts about 55% of smallholder oilseed farmers (URT, 2023). Despite their significance and inclusion in national development strategies such as the Tanzania Sunflower Sector Development Strategy, productivity remained low, suggesting variations in access to and effectiveness of AES (Isinika & Jeckoniah, 2021). The study specifically examined five IAPS: improved seeds, recommended planting spacing, fertiliser application, pest and disease management, and post-harvest handling. A cross-sectional research design employing quantitative and qualitative approaches was used to analyse the association between access to AES and adoption of IAPs at a single point in time (Mugari et al., 2025). The design allowed data collection from a relatively large sample within a limited time frame, although it does not permit causal inference (Pérez-Guerrero et al., 2024).

### *Sampling Procedure and Sample Size*

A multistage sampling procedure was used. Four districts were purposively selected, followed by random selection of eight wards and 16 villages based on sunflower production intensity. Farmer lists obtained from village authorities and extension offices served as sampling frames and were used to randomly select respondents using proportional stratified sampling to ensure representation across locations (Table 1). The final sample comprised 385 farmers, determined using Krejcie and Morgan's (1970) finite population formula at a 95% confidence level, based on an estimated population (N) of 263,313 farmers. The formula used to determine the sample size was:

$$n = \frac{X^2 * N * P(1-P)}{d^2 * (N-1) + X^2 * P(1-P)}$$

Where: n is the sample size required, $X^2$ is the table value of chi-square (3.841) for 1 degree of freedom at the desired confidence level of 95%, N is the total population size, P is the population proportion (assumed to be 0.5 for maximum sample size, and d is the degree of accuracy expressed as a proportion (0.05). Substituting N =263,313 yielded a sample size of 384.54, which was rounded to 385 respondents.

*Table 1: Distribution of Sampled Farmers by District, Ward and Village*

| Districts | No. farmers | Sample size per district | Wards | No. Farmers per ward | Sample size per ward | Villages | No. farmers per village | Sample size per village |
|---|---|---|---|---|---|---|---|---|
| Chemba | 75 050 | 110 | Gwandi | 3490 | 35 | Gwandi | 1060 | 16 |
| | | | | | | Rofati | 1245 | 19 |
| | | | Kidoka | 7413 | 75 | Pangalua | 2193 | 42 |
| | | | | | | Kidoka | 1720 | 33 |
| Ikungi | 74 527 | 109 | Puma | 8792 | 63 | Puma | 2086 | 31 |
| | | | | | | Wibiya | 2106 | 32 |
| | | | Dung'unyi | 6428 | 46 | Samaku | 2163 | 29 |
| | | | | | | Kipumbuiko | 1278 | 17 |
| Manyoni | 61 059 | 89 | Chikola | 5677 | 51 | Chidamsulu | 1094 | 23 |
| | | | | | | Chikola | 1332 | 28 |
| | | | Heka | 4171 | 38 | Heka 1 | 1071 | 16 |
| | | | | | | Azimio | 1492 | 22 |
| Kondoa | 52 677 | 77 | Pahi | 6764 | 39 | Ikova | 1382 | 15 |
| | | | | | | Pahi 1 | 2100 | 24 |
| | | | Mnenia | 6438 | 38 | Mnenia | 1608 | 20 |
| | | | | | | Itundwi | 1413 | 18 |
| **Total** | **263 313** | **385** | | | **385** | | | **385** |

### *Data Collection*

Quantitative data were collected using structured questionnaires administered via face-to-face interviews. The instrument captured socio-economic characteristics, farm attributes, access to AES and adoption of IAPs. Content validity was ensured through expert review, and pretesting was conducted with 30 farmers who were not part of the study sample. Qualitative data were obtained from four focus group discussions (FDGs), each comprising 8-12 farmers selected to reflect variation in gender, farming experience, and access to extension services. Discussions were conducted in Swahili, transcribed and translated into English.

### *Variable Measurement*

The dependent variable, adoption of IAPs, was defined as a binary outcome based on the uptake of five practices. Farmers adopting at least three practices were classified as adopters (1), while others were classified as non-adopters (0), consistent with the joint-adoption approach used in Oladele et al. (2025). This cut-off was used to capture meaningful integration of IAPs rather than the isolated adoption of individual technologies, recognising that adopting multiple complementary practices better reflects sustained technology uptake among smallholder farmers. The independent variable, access to AES, was conceptualised as a multidimensional construct capturing the frequency of interaction and communication modes. Control variables included age, sex, education, farm size and distance to extension service. District fixed effects were included to account for spatial heterogeneity. Detailed variable definitions and measurements are presented in Table 2.

*Table 2: Definition and Measurement of Study Variables*

| Variable Type | Variable | Description | Measurement |
|---|---|---|---|
| Dependent Variable | Adoption of IAPs | Adoption of improved agricultural practices | Binary: 1 = adopted ≥3 practices; 0 = otherwise |
| Independent Variables | Frequency of access | Number of times farmer interacted with extension agents | Number of visits, trainings, demonstrations, and group meetings (past 12 months) |
| | Modes of access | Channels of extension communication | Farm visits; mobile phone; radio/TV; printed materials; demonstration plots; workshops/seminars |
| Control Variables | Age | Age of farmer | Years |
| | Sex | Sex of farmer | 0= Male, 1 = Female |
| | Education | Education level | Years of schooling |
| | Farm size | Size of cultivated land | Acres |
| | Distance to AES | Distance to extension services | Kilometres |
| Fixed Effects | Districts dummies | Location-specific effects | Dummy variables (Chemba, Kondoa, Ikungi; Manyoni as reference) |

***Data Analysis***

Qualitative data were analysed using thematic and content analysis. All discussions were transcribed verbatim to ensure accuracy and completeness of the data. Transcripts were coded, categorised, and grouped into themes related to extension access and adoption behaviour. These qualitative findings were used to complement and enrich the quantitative results by explaining observed trends and relationships in access to AES and the adoption of IAPs among smallholder farmers.

Quantitative data were analysed using IBM SPSS Statistics 23, applying descriptive and inferential techniques. Descriptive statistics summarised sample characteristics and patterns of extension access and technology adoption. An adoption index ranging from 0 to 5 based on the number of practices adopted was constructed and subsequently converted into a binary variable. Farmers who adopted at least three practices were classified as adopters (1), while those who adopted fewer than three were classified as non-adopters (0). Prior to regression analysis, multicollinearity among explanatory variables was assessed using the Variance Inflation Factor (VIF) and tolerance values. A binary logistic regression model was then used to estimate the probability of adoption as a function of extension access and control variables. The model is specified as:

$$\ln\left(\frac{Pi}{1-Pi}\right) = \beta 0 + \beta 1Fi + \beta 2Mi + \beta 3Xi + \varepsilon i$$

Where: $P_i$ is the probability of adoption, Fi denotes frequency of access variables, $M_i$ represents modes of access variables, and $X_i$ includes control variables.

Following the model specification, a hierarchical modelling approach was applied to examine the contribution of different dimensions of access to AES in explaining adoption behaviour. Model 1 included socio-economic and farm-level control variables; Model 2 added indicators of the frequency of extension interactions; Model 3 introduced communication modes; and Model 4 incorporated district fixed effects. Model fit was assessed using the Omnibus Test of Model Coefficients, Nagelkerke $R^2$ and the Hosmer–Lemeshow goodness-of-fit test.

## Findings and Discussion

### *Access to Agricultural Extension Services*

Access to AES was examined along two dimensions: frequency of interactions and communication modes.

### *Frequency of Access to AES*

The frequency of farmers' engagement was assessed using four indicators: the number of interactions between extension officers and farmers; the number of training sessions attended by farmers; the number of farm demonstration events attended by farmers; and the number of group meetings related to extension services attended by farmers (Table 3).

*Table 3: Frequency of Access to AES (N=385)*

| Indicator | Mean | SD | Min | Max |
|---|---|---|---|---|
| Number of extension officers' interaction with farmers | 1.02 | 1.17 | 0 | 5 |
| Number of extension training sessions attended by farmers | 0.51 | 0.77 | 0 | 3 |
| Number of demonstration event attended by farmers | 0.65 | 0.85 | 0 | 3 |
| Number of farmer group meeting attended | 0.62 | 0.90 | 0 | 3 |

The findings indicate that farmers experienced limited and uneven interaction with extension services across all indicators. Average, interaction levels remained low, with many farmers reporting no contact with extension providers, while smaller proportions received repeated interactions. These findings reflect structural constraints within decentralised extension systems, including limited staffing and logistical capacity, which restrict regular engagement between extension officers and farmers (Daudi, 2024). Consequently, opportunities for sustained technical support and reinforcement of recommended practices remain limited.

### *Modes of Access to Agricultural Extension Services*

Beyond frequency, the modes through which farmers accessed extension information were examined to identify the most commonly used communication pathways for disseminating advisory information (Table 4).

*Table 4: Modes of agricultural extension services accessed by farmers*

| Mode of access | Accessed (n) | % | Not accessed (n) | % |
|---|---|---|---|---|
| Farm visits | 173 | 44.9 | 212 | 55.1 |
| Mobile-phone advisory services | 132 | 34.3 | 253 | 65.7 |
| Agricultural workshops and seminar | 140 | 36.4 | 245 | 63.6 |
| Radio and television programme | 159 | 41.3 | 226 | 58.7 |
| Printed extension material | 178 | 46.2 | 207 | 53.8 |
| Participation in demonstration farms | 167 | 43.4 | 218 | 56.6 |

The findings indicate that extension information was delivered through multiple channels; however, no single model reached a majority of farmers. Access remains fragmented across all channels, with more than half of farmers reporting no access to most communication channels.

Printed materials and farm visits emerge as the most common sources of information, while mobile-based advisory services recorded the lowest access levels. The reliance on printed materials may reflect their accessibility and durability for repeated use, particularly in contexts where direct contact with extension services is limited (Abate, 2025; Ejem et al., 2023). This was also reflected in focus group discussions, where one farmer noted that, "… *we keep the leaflets and can read them again when needed,* *even after the extension officer has left…"*. In contrast, lower use of digital platforms was associated with constraints related to digital access, literacy, and familiarity, consistent with previous studies in Sub-Saharan Africa (Abdulai et al., 2023). Generally, the findings suggest that the availability of multiple communication channels does not necessarily guarantee effective access to extension services.

***Adoption of Improved Agricultural Practices***

*Distribution of Adoption*

The level of adoption of IAPs was first examined in terms of the number of practices implemented by farmers, to provide an overview of the extent to which farmers adopt recommended technologies as a package rather than in isolation (Table 5).

*Table 5: Distribution of Adoption of Improved Agricultural Practices (N=385)*

| Adoption Measure | Category | Frequency | Percent (%) |
|---|---|---|---|
| Adoption status (binary) | Adopted | 161 | 41.8 |
| | Not adopted | 224 | 58.2 |
| Number of practices adopted | 0 | 41 | 10.6 |
| | 1 | 83 | 21.6 |
| | 2 | 100 | 26.0 |
| | 3 | 92 | 23.9 |
| | 4 | 42 | 10.9 |
| | 5 | 27 | 7.0 |
| | **Total** | 385 | 100.0 |

Findings indicate that adoption of IAPs is generally low and occurs incrementally rather than as a complete package. Most farmers implemented only two or three practices, while full adoption remains limited. A notable proportion (10.6%) of farmers had not adopted any practices, suggesting persistent constraints in access to information, inputs and extension support. These findings align with evidence that smallholder farmers often adopt technologies selectively due to resource limitations and production risks (Bilal & Jaghdani, 2024).

*Adoption of Individual Practices*

Table 6 presents adoption levels of individual practices, highlighting variations in uptake across technologies.

*Table 6: Adoption of individual improved agricultural practices*

| Agricultural practice | Not adopted (%) | Adopted (%) |
|---|---|---|
| Improved seed use | 34.5 | 65.5 |
| Recommended plating spacing | 44.4 | 55.6 |
| Fertiliser application (recommended) | 62.9 | 37.1 |
| Pest and disease control (recommended) | 74.3 | 25.7 |
| Proper harvesting and storage | 59.7 | 40.3 |

Findings indicate that adoption varies markedly across practices. Improved seed use and recommended planting spacing show relatively higher adoption, likely due to lower costs and ease of integration into existing farming systems. Insights from focus group discussions further indicated that subsidised seed programmes improved affordability and accessibility. In contrast, fertiliser application and pest and disease management recorded lower adoption levels. Participants associated this with high input costs, limited technical knowledge, and uncertainty regarding returns, particularly under unreliable rainfall conditions. These findings support broader evidence that input-intensive practices are less likely to be adopted in resource-constrained settings (Araya et al., 2024).

***Diagnostic Test Results***

Multicollinearity diagnostics indicated no serious multicollinearity among explanatory variables. All VIF values were below the recommended threshold of 10, and tolerance values exceeded 0.1, suggesting acceptable independence among predictors (Table 7).

*Table 7: Variance Inflation Factors for Explanatory Variables*

| Variable | Tolerance | VIF |
|---|---|---|
| Age of respondent | 0.880 | 1.136 |
| Gender of respondents | 0.935 | 1.070 |
| Number of years for schooling | 0.571 | 1.752 |
| Farm size | 0.957 | 1.045 |
| Distance to extension centre | 0.650 | 1.539 |
| Number of extension visits | 0.492 | 2.031 |
| Number of trainings sessions attended | 0.205 | 4.870 |
| Number of days engaged in demonstration farm | 0.233 | 4.298 |
| Number of group meetings attended | 0.960 | 1.042 |
| Farm visits | 0.943 | 1.061 |
| Mobile phones-advisory services | 0.945 | 1.058 |
| Workshops and seminar | 0.199 | 5.016 |
| Radio and Television programme | 0.588 | 1.702 |
| Printed extension materials | 0.567 | 1.763 |
| Demonstration plots | 0.225 | 4.454 |

***Summary of Focus Group Discussion Findings***

Focus group discussions complemented the quantitative findings by highlighting contextual factors influencing extension access and adoption behaviour. Participants reported that extension contact was often infrequent, limiting opportunities for clarification and follow-up support. Repeated interpersonal interaction was valued because it strengthened trust and provided continuous technical guidance. Printed extension materials were considered useful for their retention and reuse, whereas digital advisory services were constrained by limited accessibility and digital literacy. Farmers also identified high input costs and uncertainty regarding returns as major barriers to adopting recommended practices.

***Association Between Access to AES and Adoption of IAPs***

*Model 1: Socio-economic Characteristics on Adoption of IAPs*

Model 1 estimated the effects of socio-economic characteristics on adoption behaviour to establish a baseline model that captures individual-level heterogeneity independent of extension exposure. Table 8 presents the findings.

*Table 8: Logistic regression results - Model 1 (Socio-economic characteristics)*

| Variable | B | S.E. | Wald | Df | OR (Exp(B)) | 95% CI | Sign (p) |
|---|---|---|---|---|---|---|---|
| Age | 0.013 | 0.008 | 2.184 | 1 | 1.013 | 0.966 - 1.030 | 0.139 |
| Gender | -.208 | 0.226 | 0.848 | 1 | 0.812 | 0.522- 1.264 | 0.357 |
| Education | 0.214 | 0.054 | 16.000 | 1 | **1.239** | **1.115 - 1.376** | **0.000** |
| Farm Size | 0.010 | 0.036 | 0.074 | 1 | 1.010 | 0.941- 1.083 | 0.786 |
| Distance to extension service | 0.045 | 0.044 | 1.064 | 1 | 1.046 | 0.960 - 1.139 | 0.302 |
| Constant | -2.458 | 0.730 | 11.340 | 1 | 0.086 | | 0.001 |

Model fit: Nagelkerke $R^2$ = 0.082; Omnibus $\chi^2$ (5) = 24.151, P < 0.001, Hosmer–Lemeshow (p= 0.517)

Findings indicate that the model demonstrated acceptable fit (omnibus test $\chi^2$ (5) = 24.151, p < 0.05; Hosmer-Lemeshow p > 0.05). However, the explanatory power remained relatively low (Nagelkerke $R^2$ = 0.082), suggesting that socio-economic factors alone explain approximately 8.2% of the variation in adoption behaviour. Among variables considered, education showed a significant positive association with adoption (OR = 1.239, p < 0.05), suggesting that educated farmers are better able to process information and implement recommended practices (Gao et al., 2024). Other variables, including age, gender, farm size and distance to extension service, were not statistically significant.

*Model 2: Frequency of Extension Interaction*

Model 2 introduced variables measuring the frequency of interactions between farmers and extension systems (Table 9). The model tests the hypothesis (**$H_1$**) that more frequent farmers' interaction with extension systems explains variation in adoption behaviour beyond farmers' inherent attributes.

*Table 9: Logistic Regression Results - Model 2 (Frequency of Extension Contacts)*

| Variable | B | S.E. | Wald | Df | OR (Exp(B)) | 95% CI for EXP(B) | Sig. |
|---|---|---|---|---|---|---|---|
| Age | 0.007 | 0.009 | 0.599 | 1 | 1.007 | 0.990 - 1.025 | 0.439 |
| Gender | -0.277 | 0.236 | 1.382 | 1 | 0.758 | 0.478 - 1.203 | 0.240 |
| Education | 0.163 | 0.060 | 7.279 | 1 | **1.177** | **1.046 - 1.325** | **0.007** |
| Farm size | 0.000 | 0.038 | 0.000 | 1 | 1.000 | 0.928 - 1.076 | 0.992 |
| Distance to extension – service | 0.122 | 0.050 | 5.988 | 1 | **1.130** | **1.025 - 1.245** | **0.014** |
| Number of extension contacts | 0.633 | 0.137 | 21.195 | 1 | **1.883** | **1.438 - 2.464** | **0.000** |
| Number of trainings | -0.074 | 0.183 | 0.164 | 1 | 0.928 | 0.648 - 1.330 | 0.685 |
| Number of days in demo-farm | -0.278 | 0.156 | 3.169 | 1 | 0.757 | 0.557- 1.028 | 0.075 |
| Number of group meetings | -0.171 | 0.127 | 1.816 | 1 | 0.843 | 0.657- 1.081 | 0.178 |
| Constant | -2.407 | 0.753 | 10.219 | 1 | 0.090 | | 0.001 |

Model fit: Nagelkerke $R^2$ =0.171, Omnibus $\chi^2$ (9) = 52.297, p < 0.001, Hosmer-Lemeshow (p = 0.948)

Findings indicate that the inclusion of frequency variables improved the model explanatory power (Nagelkerke $R^2$) to 0.171, implying that interaction frequency contributes meaningfully to explaining adoption behaviour. The findings provide partial support for hypothesis one. Among the frequency variables, only the number of extension contacts shows a significant association with adoption (OR = 1.883, p < 0.05). This suggests that repeated interaction with extension agents enhances opportunities for reinforcement, clarification and continuous technical guidance. Focus group participants similarly reported that repeated visits increased confidence in applying recommended practices. One participant noted that "*repeated visits help us ask questions and understand how to apply recommendations correctly*."

These findings are consistent with studies by Miine et al. (2023) and Mburu et al. (2024), which reported that frequent interpersonal interaction strengthens technology adoption through repeated reinforcement of knowledge and reduced uncertainty. However, they differ from Arthin et al. (2024) and Mugari et al. (2025), who reported insignificant associations. Such differences may reflect contextual variations in extension systems and differences in measurement approaches across studies. Consistent with the Diffusion of Innovations Theory, repeated interpersonal interaction may reduce uncertainty and strengthen persuasion processes that facilitate adoption decisions. Other interaction variables, including training sessions, demonstration activities and group meetings, did not show significant associations with adoption. Distance to extension services was positively associated with adoption (OR = 1.130, $p < 0.05$). Although this relationship weakened after introducing district fixed effects in the final model, suggesting possible contextual influences across districts.

*Model 3: Modes of Access to Extension Services on the Adoption of IAP*

Model 3 incorporated communication models, socio-economic characteristics, and interaction frequency. The model tests whether specific communication channels independently influence adoption behaviour, controlling for socio-economic characteristics and interaction intensity (**$H_2$**). Findings are presented in Table 10.

*Table 10: Logistic regression results – Model 3 (modes of access to AES)*

| Variable | B | S.E. | Wald | Df | OR (Exp(B)) | 95% CI | Sig. |
|---|---|---|---|---|---|---|---|
| Age | 0.003 | 0.009 | 0.124 | 1 | 1.003 | 0.985 - 1.022 | 0.725 |
| Gender | 0.341 | 0.241 | 2.006 | 1 | 1.407 | 0.443 - 1.140 | 0.157 |
| Education | 0.173 | 0.063 | 7.568 | 1 | **1.189** | **1.051 - 1.345** | **0.006** |
| Farm size | 0.004 | 0.039 | 0.010 | 1 | 1.004 | 0.930 - 1.084 | 0.920 |
| Distance to extension service | 0.135 | 0.052 | 6.727 | 1 | **1.144** | **1.033 - 1.267** | **0.009** |
| Number of extension contacts | 0.657 | 0.143 | 21.166 | 1 | **1.928** | **1.458 - 2.551** | **0.000** |
| Number of trainings | -0.543 | 0.318 | 2.928 | 1 | 0.581 | 0.312 - 1.082 | 0.087 |
| Number of days in demo-farm | 0.135 | 0.272 | 0.247 | 1 | 1.144 | 0.672 - 1.949 | 0.620 |
| Number of group meetings | -0.183 | 0.131 | 1.964 | 1 | 0.832 | 0.644 - 1.076 | 0.161 |
| Farm visits | 0.257 | 0.234 | 1.204 | 1 | 1.293 | 0.817- 2.044 | 0.273 |
| Mobile phone advisory service | 0.194 | 0.245 | 0.628 | 1 | 1.215 | 0.751- 1.965 | 0.428 |
| Workshops and seminar | 0.904 | 0.517 | 3.059 | 1 | 2.470 | 0.897- 6.806 | 0.080 |
| Radio and Television | -0.522 | 0.297 | 3.091 | 1 | 0.593 | 0.332 - 1.062 | 0.079 |
| Printed extension materials | -0.122 | 0.298 | 0.167 | 1 | 0.885 | 0.493 - 1.589 | 0.683 |
| Demonstration plots | -0.904 | 0.490 | 3.408 | 1 | 0.405 | 0.155 - 1.057 | 0.065 |
| Constant | -2.884 | 0.745 | 15.000 | 1 | 0.056 | | 0.000 |

**Model fit:** Nagelkerke $R^2 = 0.211$, Omnibus $\chi^2$ (15) = 65.787, $p < 0.001$, Hosmer–Lemeshow ($p = 0.211$)

The findings indicate that the inclusion of communication modes further improves the model's explanatory power (Nagelkerke $R^2 = 0.211$). The omnibus test remained statistically significant ($\chi2(15) =65.787$, $p<0.001$), suggesting that communication variables improved model performance. The Hosmer–Lemeshow remained insignificant ($p > 0.05$), indicating adequate model fit.

However, the findings did not support Hypothesis 2, as none of the communication channels showed statistically significant independent associations with adoption after controlling for socio-economic characteristics and interaction intensity. In contrast, the number of extension contacts remained a strong predictor of adoption (OR = 1.928, $p < 0.05$). These findings suggest that extension communication channels alone may not sufficiently explain adoption outcomes unless they are reinforced by sustained interpersonal interaction. Focus group participants similarly reported that information obtained through radio programmes and printed materials often required clarification from extension officers before practical implementation. One participant explained that "*we hear information on the radio, but often we need someone to explain how it applies to our farms.*" These findings support propositions of the Diffusion of Innovations Theory, which distinguishes between mass communication channels that create awareness and interpersonal channels that strengthen persuasion and adoption decisions. The findings are consistent with Tufa et al. (2023) and Tambo et al. (2023), who found that mass communication channels are effective for awareness creation but less effective at promoting behavioural change independently. However, they differ from Abdulai et al. (2023), who reported stronger effects of digital advisory platforms. Such differences may reflect contextual variations in digital access, literacy and extension infrastructure across study settings.

*Model 4: Full Model with District Fixed Effect*

Model 4 introduced district fixed effects to account for potential spatial heterogeneity in adoption behaviours across study areas (Table 11). The inclusion of district effects controlled for unobserved contextual factors that remained constant within districts but varied across locations, thereby providing a robustness check for relationships identified in earlier models.

*Table 11: Logistic Regression Results – Full Model with District-Fixed Effects*

| Variables | B | S.E. | Wald | df | Exp(B) | 95% CI | Sig. |
|---|---|---|---|---|---|---|---|
| Age | -0.003 | 0.010 | 0.121 | 1 | 0.997 | 0.978 - 1.016 | 0.727 |
| Gender | 0.179 | 0.249 | 0.516 | 1 | 1.196 | 0.734 - 1.950 | 0.473 |
| Education | 0.167 | 0.065 | 6.687 | 1 | 1.182 | **1.041 - 1.342** | **0.010** |
| Farm size | 0.030 | 0.042 | 0.521 | 1 | 1.031 | 0.950 - 1.118 | 0.471 |
| Distance to extension service | 0.096 | 0.054 | 3.096 | 1 | **1.101** | **0.989 - 1.224** | **0.078** |
| Number of extension contacts | 0.643 | 0.148 | 18.744 | 1 | 1.902 | **1.422 - 2.544** | **0.000** |
| Number of trainings | -0.408 | 0.324 | 1.583 | 1 | 0.665 | 0.352 - 1.256 | 0.208 |
| Number of days in demo-farm | 0.135 | 0.281 | 0.232 | 1 | 1.145 | 0.660 - 1.985 | 0.630 |
| Number of group meetings | -0.122 | 0.135 | 0.820 | 1 | 0.885 | 0.680 - 1.153 | 0.365 |
| Farm visits | 0.323 | 0.242 | 1.778 | 1 | 1.381 | 0.859 - 2.221 | 0.182 |
| Mobile phone extension service | 0.250 | 0.255 | 0.964 | 1 | 1.285 | 0.779 - 2.117 | 0.326 |
| Workshops and seminar | 0.857 | 0.526 | 2.655 | 1 | 2.357 | 0.840 - 6.610 | 0.103 |
| Radio and Television | -0.457 | 0.311 | 2.166 | 1 | 0.633 | 0.344 - 1.164 | 0.141 |
| Printed extension materials | -0.137 | 0.310 | 0.196 | 1 | 0.872 | 0.475 - 1.601 | 0.658 |
| Demonstration plots | -0.941 | 0.498 | 3.571 | 1 | 0.390 | 0.147 - 1.036 | 0.059 |
| District fixed effects | | | 16.416 | 3 | | | 0.001 |
| Chemba district | -0.778 | 0.352 | 4.871 | 1 | 0.459 | 0.230 - 0.917 | 0.027 |
| Kondoa district | 0.369 | 0.368 | 1.009 | 1 | 1.447 | 0.70 4- 2.973 | 0.315 |
| Ikungi district | 0.566 | 0.346 | 2.671 | 1 | 1.761 | 0.893 - 3.470 | 0.102 |
| Constant | -2.533 | 0.771 | 10.798 | 1 | 0.079 | | 0.001 |

**Notes: Reference district:** Manyoni, OR= Odds ratios reported as Exp(B); **Model fit**: Nagelkerke $R^2$ = 0.262, Omnibus $\chi^2$ (18) = 83.353, $p < 0.001$, Hosmer–Lemeshow $\chi^2$ (8) = 10.128, $p = 0.256$

Controlling for district-level variation further improved explanatory power to 26.2%, suggesting that contextual factors contributed additional explanatory value in explaining adoption behaviour. Despite the inclusion of district effects, the main findings remained stable. Frequency of extension contact (OR = 1.902, $p < 0.05$) and education (OR = 1.182, $p < 0.05$) continued to show significant positive associations with adoption. This suggests that repeated interaction and farmers' educational attainment remained important determinants of adoption across locations. District variation was also statistically significant, indicating that institutional and contextual conditions may shape opportunities for adoption differently across study areas. Specifically, farmers in Chemba district had significantly lower odds of adoption than in Manyoni (OR=0.459, $p<0.05$), whereas Kondoa and Ikungi did not show statistically significant differences. These findings suggest that local differences in programme implementation, institutional arrangements and service environments may influence adoption beyond individual-level characteristics.

## Conclusion

The study examined the association between access to agricultural extension services (AES) and adoption of improved agricultural practices (IAPs) among smallholder sunflower farmers. Findings indicate that adoption was more strongly associated with the frequency of direct interaction between farmers and extension providers than with socio-economic characteristics or communication channels alone. Consistent with the Diffusion of Innovations Theory, the findings suggest that while communication channels may facilitate awareness, repeated interpersonal interaction plays a more important role in supporting adoption decisions by providing clarification, building trust, and offering continuous technical guidance. The findings further suggest that effective access to extension services depends not only on the availability of communication platforms but also on sustained engagement between farmers and extension providers. Although multiple extension channels were available, their independent influence on adoption was limited once interaction frequency was taken into account. This highlights the continued importance of interpersonal extension systems within smallholder agricultural contexts.

However, while these findings provide useful evidence on the relationship between access to AES and adoption behaviour, they should be interpreted in light of several limitations. First, the use of a cross-sectional design limits the ability to establish causal relationships between extension access and adoption behaviour. Second, the model's relatively low explanatory power (Nagelkerke $R^2 = 0.262$) suggests that additional factors—such as service quality, input availability, and social networks—may influence adoption outcomes. Third, the non-significant results for the communication modes should be interpreted with caution, as they may reflect measurement limitations rather than the absence of a meaningful association with adoption behaviour. In particular, the study did not capture the quality, timing, or practical relevance of information delivered through different extension channels.

These limitations point to important directions for future research using longitudinal or panel data to enable a more robust examination of the causal relationship between access to extension services and adoption. Future studies should also refine the measurement of extension access by incorporating dimensions such as service quality, content relevance, and farmers' trust in different communication channels to gain deeper insight into how extension systems can support sustained adoption of IAPs among smallholder farmers.

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