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# Digital advice for agroecological intensification - A randomised controlled trial to assess effectiveness of interactive voice recordings in Mali

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**Abstract**

Agroecological intensification is a key strategy for the development of sustainable food systems. The scaling of agroecological approaches and practices requires effective knowledge sharing mechanisms. Digital extension can complement traditional advisory services, especially in contexts where resources and reach are lacking or where security risks restrict access, as is the case in the Sahel. Interactive voice recordings (IVR) can work with standard phones and without the need for an internet connection or literacy. Based on a randomised controlled trial in Sikasso, Mali, this study tests the hypothesis that IVR messages increase awareness, knowledge sharing, learning and confidence around agroecological farming practices, such as intercropping, mulching or composting. While previous impact studies have focused rather on more conventional agricultural approaches, it is the first rigorous impact evaluation of digital training oriented explicitly towards agroecology. When aggregating across practices, significant positive effects were obtained for all outcome variables (awareness, intention to use, sharing of practice, interest to learn more, confidence in applying the practice). Effects range from 12% to 48%. When it comes to individual practices, not all outcomes are significant anymore, apart from mulching use, where effects lie between 24% and 195%. The evaluation results demonstrate that IVR-based advice has a relevant role in promoting agroecological intensification.

**JEL Codes:** Q010 Sustainable Development; Q120 Micro Analysis of Farm Firms, Farm Households, and Farm Input Markets; Q100 Agriculture: General

IAAE

**Keywords:** Sahel, extension, sustainable agriculture, agroecological practices, learning outcomes

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## 1. Introduction

The Sustainable Development Goals (SDGs) have set ambitious targets for achieving the transformation of societies across the globe by 2030. In the realm of agriculture and food systems, these targets include zero hunger with global food and nutrition security, increased rural income opportunities and more sustainable consumption. Many smallholder farmers in low- and middle-income countries are struggling with low agricultural productivity and precarious livelihoods. In the Sahel especially, there is a need to intensify production in a manner that can also enhance degraded ecosystems and raise living standards. In the context of the SDGs and the specific challenges in the Sahel region, ample opportunities exist for agroecological intensification strategies in order to develop productive, environmentally safe and resilient farming systems, which provide food sovereignty and stable livelihoods (HLPE, 2019; Wezel et al., 2020; Leroux et al., 2022; Grovermann et al. 2023). On the basis of agroecological concepts and principles, an increasing number of local solutions have been developed that the aim at preserving long-term productivity and food security, providing ecological benefits, and reducing negative externalities, including issues related to injustice and inequality of the currently predominant conventional agricultural systems (Ewert et al. 2023).

Agroecological approaches are often more knowledge-intensive and context-specific than solutions for conventional intensification. Traditionally, this has been regarded as a disadvantage and a barrier to scaling agroecology (Stassart et al., 2012; Dumont et al., 2021). However, with digital technologies more readily available, the promotion of agroecological approaches becomes easier. Ewert et al. (2023) point out the huge potential of digitalisation for the transition of production systems towards agroecology. Affordable mobile data and smartphones, platforms (e.g. FAO's Hand in Hand) or applications (e.g. Farmbetter) hold promise to deliver tailored advice on appropriate agricultural practices based on the socio-ecological conditions of diverse farms (GSMA, 2023). While extension services, both public and private, will continue to play a key role in disseminating knowledge and new practices, they are however often chronically underfunded and understaffed. (Jane and Sanchez, 2021). This can be especially acute in low-income countries, such as Mali. Against this background, digital extension can help to address important knowledge gaps.

Fabregas et al. (2019) point out in their article on digital advisory services in agriculture that benefits likely exceed the cost of information transmission by an order of magnitude. Yet digital extension approaches have not been fully put into practice in many parts of the world. They are still relatively new and untested. Evidence is gradually increasing, with previous studies showing mixed results when it comes to adoption of new practices, but suggesting productivity and efficiency gains from finetuning agricultural production (Abate et al., 2023; J-PAL, 2023; Ding et al., 2022). Fabregas et al. (2019) report a 4% yield rise and a 22% increase in applying recommended input amounts across studies in their meta-analysis. In addition, recent research suggests that combining digital approaches with in-person training can considerably improve their impact (J-PAL, 2023, Mwambi et al., 2023). Existing studies have however focused on assessing the promotion of more conventional agricultural innovations. Little is known about the effectiveness of digital advice for the dissemination of agroecological solutions.

Interactive Voice Recordings (IVR) are an innovative system of using recorded voice messages via phone calls to disseminate information and raise awareness. In comparison with text messages, IVR does not need a recipient to be literate. Compared with WhatsApp or other app-based learning, IVR does not necessitate a smartphone or an internet connection. IVR has been shown to constitute a cost-effective approach to provide basic training and awareness-raising on sustainable agricultural approaches (Walter et al., 2020; Dione et al., 2021). This is especially pertinent for populations with limited mobile internet access and limited literacy among farmers as well as for conflict-affected contexts, such as certain rural areas in the Sahel. Therefore, this research aims at generating novel and relevant insights into the outcomes of developing agroecology capacities through IVR in Mali.

To the knowledge of the authors, this study is the first rigorous impact evaluation of the impact of digital agroecology training. Based on a randomised experiment, it established a causal link between the intervention and key learning outcomes. We test the hypothesis that IVR messages increase awareness, knowledge sharing, learning and confidence around practices which are considered key for shifting production systems in the Sahel towards more productivity in a sustainable manner. The results highlight the positive impact of digital advisory services in terms of key learning outcomes, which is especially relevant for capacity development in fragile contexts prone to insecurity from conflicts. The next section describes the data and methodology. Balance checks and attrition assessment are presented in section 3, while the results of the evaluation are shown in section 4. This is followed by a discussion and conclusions.

## 2. Material and Methods

### *2.1 Intervention and monitoring*

The study assesses the effectiveness of IVR messages in enhancing learning outcomes, specifically in terms of confidence and knowledge sharing related to agroecological intensification practices. The IVR training focused on training farmers about agroecological principles and practices. The content, structured into seven lessons, was derived from the Organic African Training Manual and adapted to the agricultural and cultural context in the Sahel zone. The initial two lessons provided a general overview, outlining the training format and fundamental agroecological principles. Subsequent lessons delved into more specific topics related to soil fertility, pest management and post-harvest and storage. For a detailed breakdown of the lesson content, refer to Table 1. At the conclusion of each lesson, a brief quiz was administered to assess participants' comprehension. The training spanned over six weeks during October and November 2022, with one lesson delivered per week. Employing a storytelling approach reflecting the local context (e.g. cropping system, specific pest and diseases occurring in the case study region), the lessons were delivered through audio messages in Bambara, the local language spoken by the communities involved in this study.

*Table 1. IVR lessons on agroecological intensification.*

| **Lesson number** | **Lesson name** | **Content description** |
|---|---|---|
| 1 | Introduction to the Training | Participants are introduced to the project and the training format. |
| 2 | Introduction to Agroecology | The key principles of agroecology including the potential market opportunities for agro-ecological products are outlined. |
| 3 | Steps to Engage in Agroecology | This lesson delves into multiple practices designed to improve soil quality, encompassing the application of compost, the utilization of mulching, and the adoption of intercropping and crop rotation. |
| 4 | Agroecological practices: Soil Fertility | This lesson concentrates on soil quality and associated practices, including the avoidance of burning, and the utilization of organic matter derived from trees and shrubs. |
| 5 | Agroecological practices: Pest Management | This lesson delves into alternative pest control methods and highlights the importance of regular scouting to prevent severe outbreaks. |
| 6 | Agroecological practices: Disease Management | This lesson focuses around the management of fungal diseases, emphasizing disease recognition aspects and the use of biopesticides. |
| 7 | Harvest and Post-harvest Practices | This lesson concentrates on strategies to prevent insects or other rodents from compromising the harvest. |

### *2.2 Study area and baseline data*

The IVR intervention focused on Sikasso in Mali, which is at the southern edge of the Sahel zone. More concretely, our study area corresponds to Sikasso and Kadiolo districts in the administrative region of Sikasso. This study area is situated in a region, where heightened security concerns currently render physical extension visits, training sessions or farmer field schools more difficult. At the same time, information on agroecological intensification through circular and regenerative farming practices is particularly relevant for farmers in the Sahel and adjacent territories, who often have limited access to or cannot afford external inputs and who often face degraded soils. Therefore, it is sensible to test the effectiveness of digital extension tools for agroecological intensification of farming systems in such contexts.

This study relies on baseline data from a survey conducted by IITA in southern Mali in 2019 for the Climate Smart Agriculture Technologies (CSAT) project. To select farm households for data collection, a two-stage cluster sampling procedure was applied. In the first stage, 80 villages were randomly selected from a sampling list of villages in Sikasso and Kadiolo districts in the Sikasso region. The inclusion of a village in the sampling list was contingent on the farmers in the village having agriculture as the main source of livelihood (including cereal and legume production). Once the villages had been chosen, between six and nine households per village were randomly selected to participate in the survey, depending on the overall farm household population at each site. This resulted in a sample size of 483 farm households across 80 villages. For the data collection, a structured questionnaire was designed, consisting of approximately 250 questions covering plot, household, and village-level characteristics. The questionnaire was administered in the local languages to the head of the household. All enumerators and supervisors were trained for approximately two days to ensure that they were sufficiently familiar with the questionnaire and process before the field survey. A pre-test of the survey instrument was conducted before the actual data collection process, whereby two villages were selected for checking the relevance and intelligibility of questions. The pre-test experience was used to modify the questionnaire to ensure that the questionnaire was well-structured, easily understood by the enumerators and farmers, and devoid of ambiguity regarding the definition of the questions. The pre-test was also useful in determining the average time it takes to complete one questionnaire, which was approximately two hours.

### *2.3 Sampling and evaluation design*

The goal of the evaluation was to test whether IVR messages improve farmers awareness, knowledge sharing, confidence and intention to adopt agroecological intensification practices. The evaluation is a two-arm randomized controlled trial, where the treatment was randomly allocated at the village level. More specifically, the eighty villages included in the baseline survey were randomly assigned either into treatment or control groups. In total, the evaluation consisted of 40 treatment villages with eligible farmers receiving seven automated phone calls with lessons covering all components of the IVR agroecology training. 40 control villages that served as a counterfactual, as shown in Figure 1. The sample size for our evaluation is powered to detect at least a 10% increase for our key primary outcomes of interest (see Section 2.4) using the baseline data described in Section 2.2. We also computed the intra-cluster correlation (ICC) using the baseline data. Using parameters drawn from the baseline data, we find that with a sample size of 451 households from 80 villages, we are able to detect at least a 10% effect size (assuming 80% power at 5% significance level) for all our primary outcomes of interest. In total 244 farms were assigned to the control group and 239 farms were assigned to the intervention group. Balance between groups at baseline was checked to confirm similarity between the two groups, with results shown in Section 3.1.

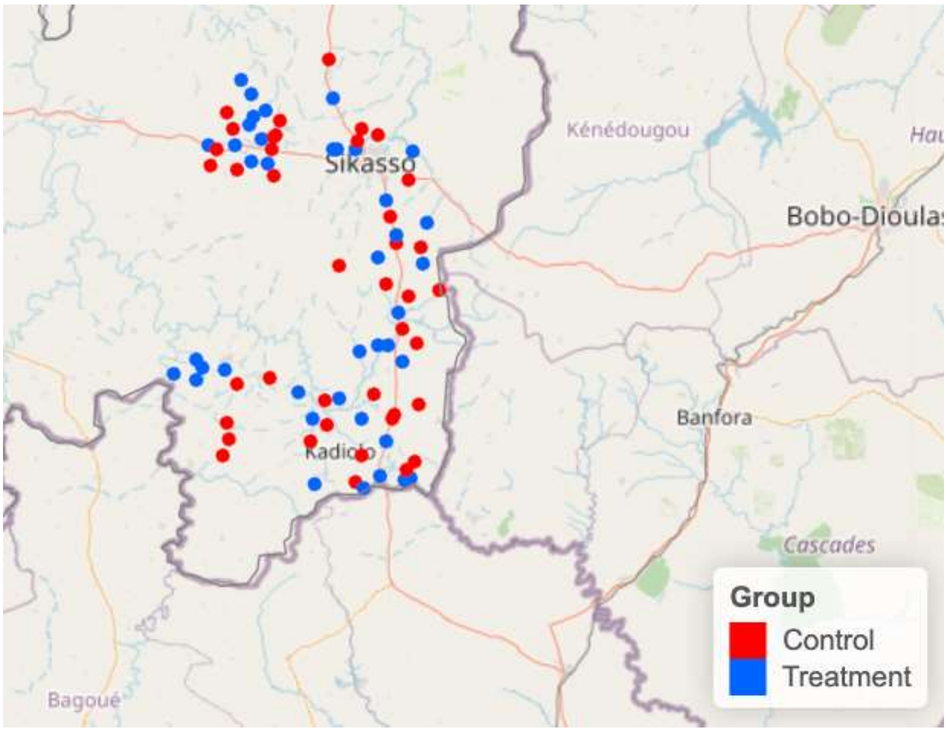

*Figure 1. Villages in control and treatment groups in the study area (Sikasso region, southern Mali)*

As mentioned above, the IVR training spanned over six weeks during October and November 2022. In April 2023 endline data collection was carried out through phone interviews with farmers in the control and intervention groups. To ensure cost-effectiveness of the RCT, a simplified questionnaire focused on the outcome variables was administered via phone interviews rather than in-person interviews. The final endline sample consisted of 157 farmers in the intervention group (out of 239 farmers in the baseline sample) and 144 in the control group (out of 244 farmers in the baseline sample). Attrition was assessed to better understand the implications of the reduced final sample on the validity of the RCT (see section 3.3).

### *2.4 Outcome variables*

Our impact evaluation provides evidence on various aspects of the uptake of agroecological intensification practices. For the evaluation, six practices and related outcome variables were defined, as shown in Tables 2 and 3. The choice of outcomes is determined by the content of the IVR messages and related to the Organic African Organic Farming Training Manual (FiBL, 2020) as well as the 13 principles of agroecology (Wezel et al., 2020).

*Table 2. Agroecolgical intensification practices selected for the endline survey*

| Variable name | Description |
|---|---|
| P1. Rotation with legumes | *Rotation of sorghum or millet with cowpea or groundnut* |
| P2. Intercropping with legumes | *Intercropping of sorghum or millet with cowpea or groundnut* |
| P3. Mulching | *Systematic direct application of shrub and tree residues* |
| P4. Composting | *Systematic use of shrub and tree residues to produce compost for later application to crops* |
| P5. Multi-purpose shrubs | *Systematic integration of piliostigma and guiera senegalensis shrubs with annual crops* |
| P6. Bio-pesticide application | *Application of herbal concoctions, bacillus thuringiensis or bacillus subtilis* |

The outcome variables follow an impact pathway logic leading from cognizance of practices to adoption intention, sharing of knowledge, eagerness to learn more and confidence to apply practices. Outcomes are reported as aggregated indicators across all six practices and as indicators for each individual practice (P1 – P6). For *awareness*, *intention*, *sharing* and *learning*, aggregation is carried out through a count of practices, while for *confidence* an average score is computed and standardised from zero to unity (0-1). Table 3 provides an overview of the variables name and the related questions from the endline survey.

*Table 3. Overview of outcome variables used in the analysis*

| Variable name | Question | Measurement |
|---|---|---|
| **Awareness** | *Have you ever heard of the practice?* | *Individual practices P1 – P6 (YES/NO) & Aggregated practices (#)* |
| **Intention** | *Do you plan to use this practice in the coming planting season?* | *Individual practices P1 – P6 (YES/NO) & Aggregated practices (#)* |
| **Sharing** | *Have you told anyone else about this practice?* | *Individual practices P1 – P6 (YES/NO) & Aggregated practices (#)* |
| **Learning** | *Are you actively trying to learn more about this practice?* | *Individual practices P1 – P6 (YES/NO) & Aggregated practices (#)* |
| **Confidence** | *How confident do you feel in applying this practice?* | *Individual practices P1 – P6 (YES/NO) & Average confidence score (0-1)* |

### *2.5 Empirical estimation strategy*

Randomisation allows for a straightforward estimation of average treatment effects. The effectiveness of the IVR campaign is evaluated through comparison of the intervention and control groups. To account for the different distributions of outcome variables, three simple regression models were specified with the outcomes as dependent variable and the treatment as the only explanatory variable. For the count variables *awareness, intention, sharing and learning*, Poisson regression models were applied. A fractional regression model was used for the outcome variable *confidence*, which is bounded between zero and unity. For the estimation of average treatment effect for the individual practices, probit regression models were required.

*Table 4. Randomization balance checks*

| **Variable** | **Full sample Mean (SE)** | **Control Mean (SE)** | **Treatment Mean (SE)** | **Difference Mean** |
|---|---|---|---|---|
| Age | 52.56 | 51.99 | 53.10 | -1.11 |
| | (0.64) | (0.88) | (0.93) | |
| household size | 7.96 | 8.23 | 7.70 | 0.53 |
| | (0.29) | (0.46) | (0.36) | |
| Number of years of experience in farming | 34.92 | 34.39 | 35.42 | -1.03 |
| | (0.73) | (1.02) | (1.05) | |
| How many years has the family lived in this village? | 52.61 | 52.44 | 52.77 | -0.33 |
| | (0.87) | (1.25) | (1.23) | |
| Head is educated (1=yes) | 0.32 | 0.25 | 0.39 | -0.14*** |
| | (0.02) | (0.03) | (0.03) | |
| Do you irrigate your farmland (1=yes) | 0.10 | 0.09 | 0.10 | -0.01 |
| | (0.01) | (0.02) | (0.02) | |
| Access to extension agents (1=yes) | 0.75 | 0.73 | 0.76 | -0.03 |
| | (0.02) | (0.03) | (0.03) | |
| Attended any training before (1=yes) | 0.37 | 0.34 | 0.39 | -0.05 |
| | (0.02) | (0.03) | (0.03) | |
| Distance to nearest town (km) | 18.88 | 19.73 | 18.09 | 1.64 |
| | (0.88) | (1.40) | (1.08) | |
| Distance to nearest market (km) | 9.82 | 9.77 | 9.86 | -0.09 |
| | (0.65) | (0.84) | (0.99) | |
| Travel time to market (minutes) | 21.38 | 17.91 | 24.66 | -6.75 |
| | (2.04) | (1.83) | (3.56) | |
| Travel time to all-weather road (minutes) | 55.24 | 43.04 | 66.75 | -23.72 |
| | (20.26) | (18.26) | (35.45) | |
| Total land size (ha) | 10.43 | 10.22 | 10.63 | -0.40 |
| | (0.38) | (0.55) | (0.52) | |
| Member of cooperatives (1=yes) | 0.58 | 0.58 | 0.59 | -0.02 |
| | (0.02) | (0.03) | (0.03) | |
| Member of saving and credit associations (1=yes) | 0.10 | 0.09 | 0.11 | -0.02 |
| | (0.01) | (0.02) | (0.02) | |
| Do you own radio(1=yes) | 0.84 | 0.84 | 0.85 | -0.02 |
| | (0.02) | (0.03) | (0.02) | |
| Do you own television(1=yes) | 0.61 | 0.59 | 0.63 | -0.04 |
| | (0.02) | (0.03) | (0.03) | |
| Estimated asset value (mil CFA) | 5.77 | 5.12 | 6.39 | -1.27 |
| | (0.43) | (0.61) | (0.61) | |
| Joint balance test (F-stat) | | | | 1.06 |
| Joint balance test (p-value) | | | | 0.39 |
| Number of observations | | | | 451 |

## 3. Descriptive statistics

### *3.1 Baseline Randomisation Balance Check*

To test whether the randomisation successfully balanced observable household characteristics between the treatment and control groups, we report the randomization balance test in Table 4**.** It presents summary statistics for pre-treatment characteristics of survey participants at baseline. Reassuringly, the balancing test shows that the randomization worked as intended, with only 14 percent difference in respondent age being statistically significant ($p < 0.05$). Table 4 demonstrates that at baseline, treatment and control groups were similar in almost all key characteristics that may likely determine our outcomes of interest.

### *3.2 Participation*

We reached out to a total of 195 farmers through the IVR training program. As depicted in Figure 2, we obtained a strong and sustained response rate throughout the lessons, with an impressive average completion rate across the lessons of 84% among participating farmers. This underscores the suitability of the technology and emphasizes the farmers' keen interest in acquiring knowledge pertaining to agroecology.


*Figure 2. Share of participants having completed the different lessons (in %)*

### *3.3 Attrition*

As mentioned in section 2.3, the endline sample consisted of 301 households across 80 villages. Attrition was substantial in both treatment and control groups due to invalid phone numbers, intervention drop-outs and unwillingness to participate in the endline phone survey. As the relatively large attrition rate was similar across treatment and control groups (p=.884), the sample remains well balanced despite the attrition. We also checked whether attrition is random to rule-out selective attrition. To do so, we ran a probit model where treatment status and baseline characteristics are included as predictors of attrition (i.e., attrition takes a value of zero if the household is interviewed in both baseline and endline surveys and one otherwise). The correlates of attrition reported in Table 5 shows the absence of selective attrition bias in our sample.

*Table 5. Correlates of attrition*

| | (1) | (2) |
|---|---|---|
| **Treatment** | **0.04** | **0.06** |
| | **(0.04)** | **(0.05)** |
| Age | | -0.00 |
| | | (0.00) |
| Household size | | -0.00 |
| | | (0.00) |
| Education | | -0.07 |
| | | (0.05) |
| Access to extension | | 0.02 |
| | | (0.06) |
| Distance to market | | 0.00 |
| | | (0.00) |
| Farm size | | 0.00 |
| | | (0.00) |
| Membership to cooperatives | | -0.01 |
| | | (0.05) |
| Membership to credit & saving associations | | -0.03 |
| | | (0.08) |
| Own radio | | 0.04 |
| | | (0.06) |
| Own TV | | -0.03 |
| | | (0.05) |
| Asset value | | -0.00 |
| | | (0.00) |
| Prob > F | 0.3344 | 0.8424 |
| N | 451 | 451 |

## 4. Results

In this section we present impacts of the IVR intervention at aggregate level as well as for each of the six practices. Average treatment effects are shown in absolute and relative terms

*Table 6. Estimation of aggregated treatment effects*

| | Awareness | Intention | Sharing | Learning | Confidence |
|---|---|---|---|---|---|
| | *# practices* | *# practices* | *# practices* | *# practices* | *score (0-1)* |
| ATE | 0.678 | 0.402 | 0.892 | 0.694 | 0.178 |
| SE | 0.249 | 0.218 | 0.185 | 0.248 | 0.057 |
| Sign | *** | * | *** | *** | *** |
| POM | 4.347 | 3.375 | 2.146 | 4.306 | 0.374 |
| ***ATE (%)*** | ***16%*** | ***12%*** | ***42%*** | ***16%*** | ***48%*** |
| n | 301 | 301 | 301 | 301 | 301 |

Notes: See Table 2 for explanation of outcome variables; ATE = Average Treatment Effect; SE=Standard error; Sign. = Significance; POM = Potential Outcome Mean; ATE (%) is calculated as ATE/POM; Significance levels: ***=0.01, **=0.05, *=0.1.

Across all six practices, significant positive results were obtained for all outcome variables, with effects ranging from 12% to 48% (Table 6). This demonstrates that IVR-based advice has a relevant role in promoting agroecological intensification. Especially outcomes related to sharing of knowledge and confidence building have been affected by the phone messages. When it comes to individual practices a more nuanced picture of results emerges (Table 7).

*Table 7. Estimated treatment effects for individual practices*

| | | **Agroecological Practices** | | | | | |
|---|---|---|---|---|---|---|---|
| **OUTCOMES** | | ***P1. Rotation Legumes*** | ***P2. Intercrop Legumes*** | ***P3. Mulching*** | ***P4. Composting*** | ***P5. Multi-purpose shrubs*** | ***P6. Bio-pesticides*** |
| **Awareness** | ATE | 0.023 | 0.212 | 0.177 | 0.001 | 0.026 | 0.239 |
| | SE | 0.022 | 0.052 | 0.054 | 0.009 | 0.041 | 0.056 |
| | Sign | ns | *** | *** | ns | ns | *** |
| | POM | 0.951 | 0.590 | 0.556 | 0.991 | 0.840 | 0.417 |
| | ***ATE (%)*** | ***2%*** | ***36%*** | ***32%*** | ***0%*** | ***3%*** | ***57%*** |
| **Intention** | ATE | 0.032 | 0.076 | 0.200 | 0.019 | 0.073 | 0.039 |
| | SE | 0.040 | 0.057 | 0.056 | 0.014 | 0.053 | 0.042 |
| | Sign | ns | ns | *** | ns | ns | ns |
| | POM | 0.84 | 0.389 | 0.354 | 0.99 | 0.659 | 0.139 |
| | ***ATE (%)*** | ***4%*** | ***20%*** | ***56%*** | ***2%*** | ***11%*** | ***28%*** |
| **Sharing** | ATE | 0.176 | 0.184 | 0.205 | 0.055 | 0.181 | 0.092 |
| | SE | 0.056 | 0.053 | 0.053 | 0.044 | 0.056 | 0.033 |
| | Sign | *** | *** | *** | ns | *** | *** |
| | POM | 0.486 | 0.243 | 0.222 | 0.792 | 0.354 | 0.049 |
| | ***ATE (%)*** | ***36%*** | ***76%*** | ***92%*** | ***7%*** | ***51%*** | ***188%*** |
| **Learning** | ATE | 0.038 | 0.200 | 0.187 | 0.001 | 0.033 | 0.246 |
| | SE | 0.025 | 0.053 | 0.052 | 0.004 | 0.041 | 0.055 |
| | Sign | ns | *** | *** | ns | ns | *** |
| | POM | 0.93 | 0.583 | 0.556 | 0.982 | 0.866 | 0.656 |
| | ***ATE (%)*** | ***4%*** | ***34%*** | ***32%*** | ***0%*** | ***4%*** | ***38%*** |
| **Confidence** | ATE | 0.281 | 0.096 | 0.257 | 0.293 | 0.248 | 0.065 |
| | SE | 0.055 | 0.051 | 0.048 | 0.055 | 0.055 | 0.033 |
| | Sign | *** | * | *** | *** | *** | * |
| | POM | 0.299 | 0.229 | 0.132 | 0.313 | 0.236 | 0.063 |
| | ***ATE (%)*** | ***94%*** | ***42%*** | ***195%*** | ***94%*** | ***105%*** | ***103%*** |
| | n | 301 | 301 | 301 | 301 | 301 | 301 |

Notes: See Table 2 for explanation of outcome variables; ATE = Average Treatment Effect; SE=Standard error; Sign. = Significance; POM = Potential Outcome Mean; ATE (%) is calculated as ATE/POM; Significance levels: ***=0.01, **=0.05, *=0.1.

The IVR intervention has a large impact on the confidence of farmers in applying all six agroecological practices, with the effect size ranging from 42% to 195%. Awareness, intention to use the practice, knowledge sharing and eagerness to learn more were also affected by the intervention, but we see more mixed outcomes. When comparing across practices, mulching use stands out with significant effects for all five outcome variables, with impacts between 20% and 195%.

## 5. Discussion and conclusions

The evidence on the impact of digital tools for agricultural advice has been growing (Fabregas et al., 2019; Ding et al., 2022; Abate et al., 2023; J-PAL, 2023; Mwambi et al., 2023), including an RCT to assess IVR interventions on animal health (Dione et al., 2021). This study expands on the existing literature by evaluating a digital training that explicitly promotes agroecological approaches and practices. Findings suggest substantial positive effects resulting from farmers' exposure to IVR messages, which disseminate knowledge on principles of agroecology together with concrete advice on rotation and intercropping with legumes, mulching, composting, integration of multi-purpose shrubs and bio-pesticides. Such knowledge gains from IVR and similar digital trainings have also been shown by other studies that focused on more conventional intensification practices (Dione et al., 2021; Abate et al., 2023).

While this study assesses key immediate outcomes, e.g. intention or confidence as regards application of practices, it does not capture more intermediate outcomes, which are covered by other studies, such as actual adoption (Mwambi et al., 2023) or productivity change (Fabregas et al., 2019). Future studies should also pay attention to other sustainability dimensions, which are often neglected in impact evaluations (Blockeel et al., 2023). To do so, an additional data collection round will be required two to three years after the IVR campaign. It will be essential to also develop understanding on the long-term implication for production and livelihoods that originate from digital interventions focused on promoting agroecological intensification.

Attrition in our RCT has been substantial in both treatment and control groups due to invalid phone numbers, intervention drop-outs and unwillingness to participate in the endline phone survey. Therefore, for any future data collection on more long-term impacts, it will be important to consider in-person interviews, which are morecostly than the phone-based interviews that we had reverted to for the endline survey in this study. The relatively large attrition rate from baseline to endline is a threat to the internal validity of the RCT. We ascertained that attrition was similar across treatment and control groups and that the sample remains well balanced despite the attrition. We could also rule out selective attrition.

In Sub-Saharan Africa agroecological intensification has great potential to support farmers in their transition to more productive, resilient and profitable production systems (Manyanga et al., 2023). Food security of farmers in the Sahel for instance has been shown to benefit from greater diversity of crops and trees (Leroux et al., 2022). Digital tools for agroecology dissemination are particularly needed in contexts like the Sahel. Rural areas are often very remote and difficult to access, with security risks prevailing in many parts of Mali and neighbouring countries. IVR is an instrument to reach farmers living in such areas who might not possess a smartphone with internet access, as the tool also works with standard phones. While our study is a site-specific pilot, IVR can also be used at national level to provide a large number of farmers with advice on crop production (Walter et al., 2020). It can however not provide the level of information, customisation and interactivity of a smartphone-based application or, even more so, a direct interaction between extension providers and farmers. Therefore, interest in blended approaches has been growing, with recent evaluations examining the importance of combining in-person and digital knowledge sharing approaches (Ding et al., 2022; Mwambi et al., 2023). Besides blended learning, also blended sustainability is a research topic, which deserves to be examined in future impact studies. Mockshell and Kamanda (2018) have for instance illustrated ways in which agroecological intensification can be combined with genetic intensification and institutional or social innovations. In a first step, the knowledge gap on digital tools for agroecology promotion needs to be addressed. In a next step, promising practices from different strategies for agricultural intensification may be individually and jointly piloted, with each treatment being systematically evaluated for economic, social and environmental outcomes to provide a holistic picture of impact that can demonstrate potential trade-offs and synergies between sustainability dimensions. Research on blended learning and blended sustainability can help to answer urgent questions on how to better design service provision at scale beyond specific project-funded approaches.

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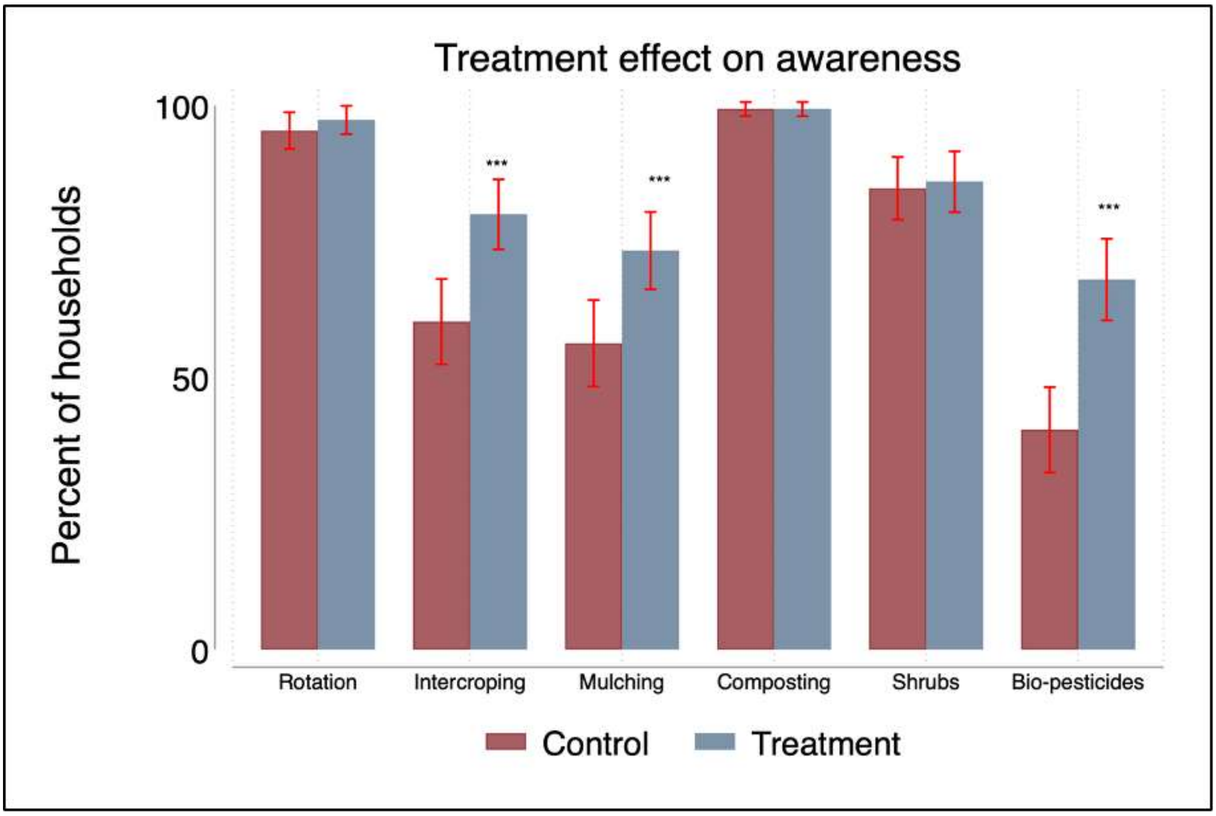
**Appendix**



Treatment effect on awareness
Percent of households
100
50
0
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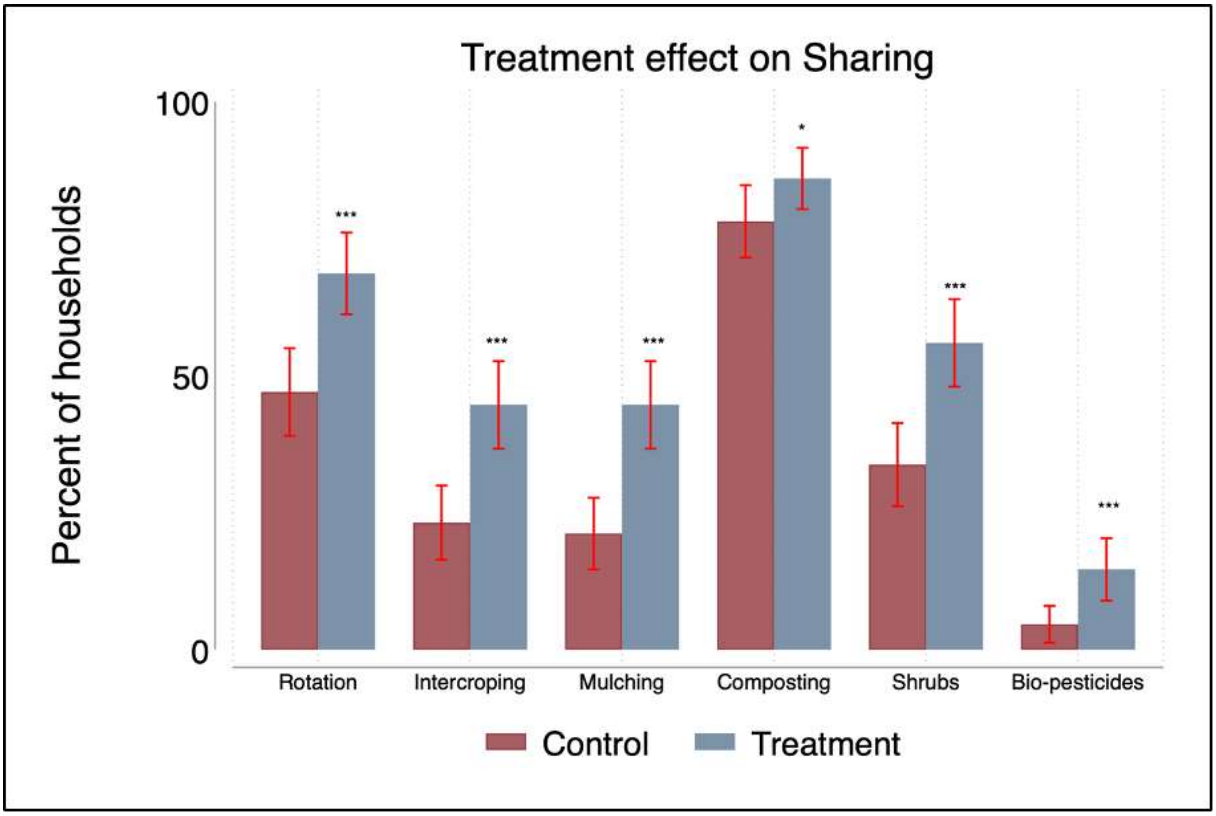
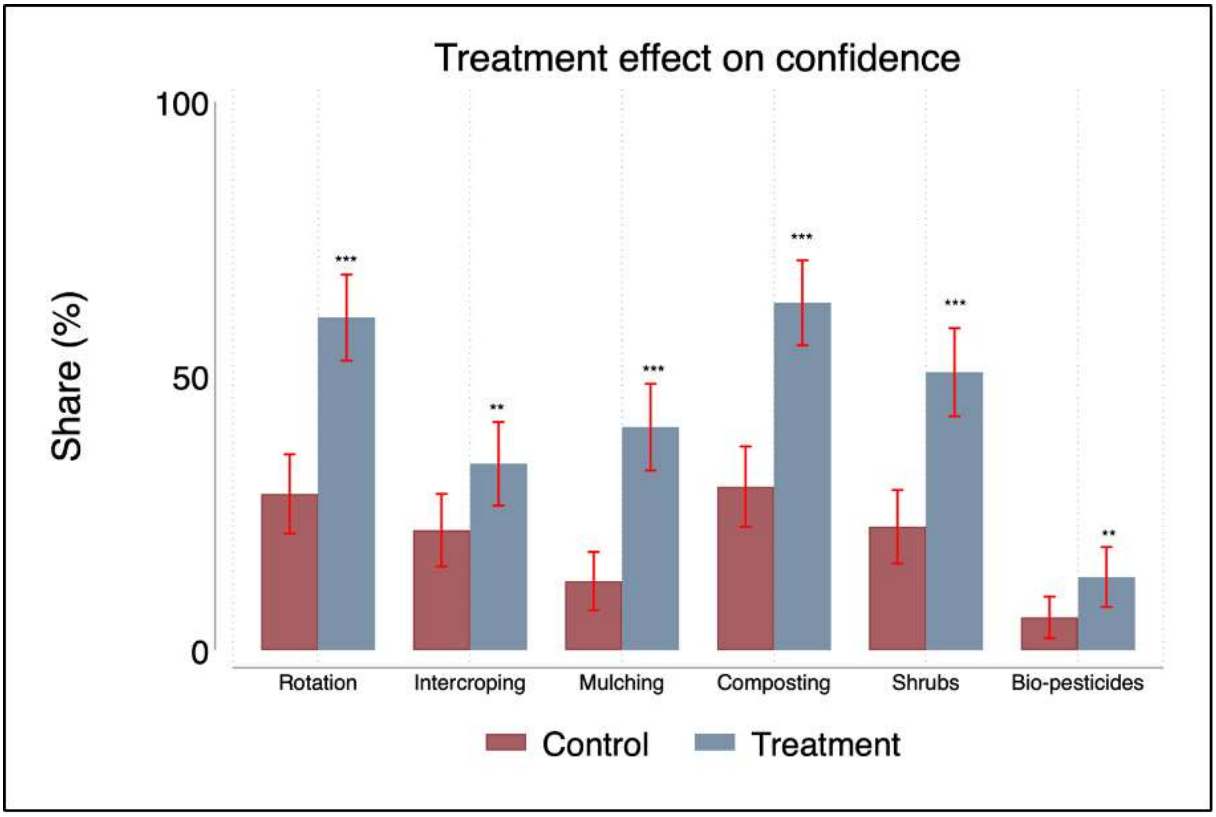
***
Rotation
Intercroping
Mulching
Composting
Shrubs
Bio-pesticides
Control
Treatment

Treatment effect on Sharing
Percent of households
100
50
0
***
***
***
*
***
***
Rotation
Intercroping
Mulching
Composting
Shrubs
Bio-pesticides
Control
Treatment



Treatment effect on confidence
Share (%)
100
50
0
***
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***
***
***
**
Rotation
Intercroping
Mulching
Composting
Shrubs
Bio-pesticides
Control
Treatment