



Research article

From advice to action: Experimental evidence on agroecology messaging in Mali

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ABSTRACT

Agroecological intensification is essential for building sustainable food systems and addressing environmental challenges such as land degradation and climate change, particularly in resource-constrained regions like the Sahel. Scaling agroecological practices requires effective, accessible knowledge-sharing mechanisms. This study evaluates the impact of an interactive voice recording (IVR) training programme on agroecological knowledge and adoption among farmers in Mali's Sikasso region through a randomised controlled trial (RCT). The IVR intervention provided training on intercropping, mulching, composting, and integrated pest management (IPM) using mobile phone technology accessible to farmers without internet access or literacy. Results demonstrated significant improvements in farmers' awareness, information sharing, confidence, and adoption of agroecological practices, with intention-to-treat effects ranging from 12% to 97%. Adoption was notably high for mulching and IPM, highlighting the intervention's potential to induce behavioural change, all the way from phone-based advice to increased confidence and implementation in the field. Using a rigorous RCT approach, this study thus demonstrates how simple digital tools can support agroecological transitions, which ultimately promotes sustainable land management and food security in vulnerable regions.

1. Introduction

Smallholder farmers in low- and middle-income countries face persistent challenges of low agricultural productivity, insecure livelihoods and environmental risks. These issues are particularly severe in the Sahel, where agroecological intensification is an essential strategy for restoring degraded ecosystems, raising productivity and improving living standards (Bayala et al., 2012). The Sahel is among the dry sub-humid regions that are most severely impacted by land degradation and climate change, with over 80% of its agricultural land suffering from soil erosion, nutrient depletion, and declining productivity (Yan et al., 2024). This environmental crisis directly threatens the livelihoods of millions of smallholder farmers, who depend on fragile ecosystems for food security and income. Climate change and land-use pressures on these degraded lands are further exacerbated by competition for scarce resources among herders and farmers (Brottem, 2016). This makes the development and dissemination of sustainable agricultural practices a

critical priority for policymakers and development practitioners.

Agroecological intensification is increasingly seen as a transformative strategy to develop productive, environmentally sound and resilient farming systems. This ultimately contributes to food security, stable livelihoods and the preservation of natural resources (FAO, 2018; HLPE, 2019; Wezel et al., 2020; Kerr et al., 2021; Leroux et al., 2022; Manyanga et al., 2023; Romero Antonio et al., 2024). On the basis of agroecological concepts and principles, an increasing number of local solutions have been developed that aim at preserving long-term productivity and food security, at providing ecological benefits, and at reducing negative externalities (HLPE, 2019; Boeraeve et al., 2020; Bharucha et al., 2020; Ewert et al., 2023; Romero Antonio et al., 2024). In the Sahel for instance, the synergistic effects of shrubs and trees have been shown to enhance soil health and increase the productivity and resilience of crop production (Bayala et al., 2015; Leroux et al., 2022). However, the adoption of these and other complex agroecological practices often remains limited among smallholder farmers, as is also the

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case for the countries in the Sahel (Grovermann et al., 2023; Carroll II et al., 2025).

Extension services, training, and information provision have been identified in the literature as key drivers in the diffusion of agroecological practices among smallholder farmers (Ewert et al., 2023; Mockshell et al., 2023; Ogotu et al., 2025; Piñeiro et al., 2020). Agroecological approaches are often more knowledge-intensive and context-specific than solutions for conventional agricultural 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 the increased availability of digital technologies, tailored and locally appropriate digital advice on agroecological practices has become more feasible. Ewert et al. (2023) point out the huge potential of digitalisation for the transition of production systems towards agroecology. While extension services, both public and private, play a key role in disseminating knowledge and new practices, they are often chronically underfunded and understaffed, particularly in low-income countries, such as Mali (Jayne and Sanchez, 2021). Against this background, digital advice on agroecological crop management approaches can help to address important knowledge needs among farmers. For instance, an app in Tanzania supports farmers to identify best-fit agroecological practices in their areas (Kihoma et al., 2023).

Many tools for digital advice are also still relatively new and untested in terms of their effectiveness. Limited connectivity and low digital literacy have been found to limit broader uptake of digital advisory tools among farmers (Choruma et al., 2024). With usage rates remaining at low or moderate levels in Sub-Saharan Africa, there is a need for solutions that bridge the digital divide and for research that improves the understanding of possible implications for smallholder farmers (Cariolle, 2021). A recent systematic review on digital agricultural services revealed that most existing studies focused on agronomic advice for farmers as well as economic and social impacts, while considerable evidence gaps exist on interventions and outcomes that relate to environmental goals and climate resilience (Porciello et al., 2022). Existing studies also show mixed results when it comes to adoption of new practices and suggest small productivity and efficiency gains from finetuning agricultural production (Abate et al., 2023; Ding et al., 2022; J-PAL, 2023; Silvestri et al., 2021). Fabregas et al. (2019) report a 4% yield rise and a 22% increase in applying recommended input amounts across studies in their meta-analysis. Current digital tools tend towards promotion of external input adoption and efficiency gains in conventional agriculture settings (Hilbeck et al., 2022). Farmer-centred agroecological content and interfaces are gaining ground, but only few systematic assessments of the related tools exist to date (e.g. Mwambi et al., 2023).

Interactive Voice Recordings (IVR) are an innovative low-cost digital extension tool to disseminate information and raise awareness. It relies on recorded voice messages, which are accessed via phone calls, and includes some response options. In comparison with text messages, IVR does not need a recipient to be literate. Compared to chat apps or purpose-built learning apps, IVR does not necessitate a smartphone or an internet connection. IVR has been shown to constitute a cost-effective approach to provide basic advice on improved agricultural production (Walter et al., 2020; Dione et al., 2021). Phone calls and chat apps have the potential to be used more than externally driven tools, such as specialised smartphone apps (Coggins et al., 2022). This is especially pertinent for communities with limited mobile internet access and limited literacy among farmers as well as for conflict-prone contexts, such as certain rural areas in the Sahel, which are afflicted by banditry, herder-farmer disputes and other insecurity. Therefore, from a practical and policy perspective, this research aims at generating novel and relevant insights into the outcomes of developing agroecological crop management capacities through IVR-based advice in the Sahel region and similar contexts, where digital advice with low technical thresholds for users is appropriate and which are affected by conflict. It's also a region that has received comparatively little attention when it comes to

research on digital services in agriculture (Porciello et al., 2022). We focus on immediate and behavioural outcomes. Since productivity and income changes take longer to materialise, such long-term outcomes are beyond the scope of this study, but form part of the intervention's overall theory of change. From a methodological perspective, the present study is, to the knowledge of the authors, the first experimental impact evaluation that provides insights from a real-world farm setting on the effectiveness of a digital training explicitly oriented towards agroecology. This contributes towards developing a more systematic body of causal evidence on agroecology interventions. Effects of an in-person training for organic farming have for instance recently been assessed through a randomised experiment in Indonesia (Grimm and Luck, 2023).

Drivers of adoption of sustainable practices have received considerable attention in the literature, but mostly based on the analysis of observational farm data (Piñeiro et al., 2020; Grovermann et al., 2023; Carroll II et al., 2025). Evidence from experimental evaluations in real world farm settings related to the effect of capacity development interventions on the adoption of agroecology-based crop management is scarce (Dumont et al., 2021; Köthke et al., 2023; Ewert et al., 2023). This is even more the case when it comes to digital advisory tools that focus on environmental and economic sustainability of farming (Porciello et al., 2022). The present study seeks to go beyond analysis of observational data by contributing towards filling this knowledge gap. It applies a randomised experiment to analyse the link between agroecology advice through phone messages and key learning outcomes as well as practice uptake. This methodology is highly suitable for causal inference, which in turn supports the generation of credible evidence on the effectiveness of organic and similar agroecological approaches. Findings can be used to inform decisions by advisory services and policymakers.

We test the hypothesis that IVR training increases awareness, information sharing, learning, confidence and adoption around six practices, which are considered key for intensifying production systems in the Sahel through agroecology. Randomisation is used to address potential confounding effects resulting from observed or unobserved farm, farmer or environmental characteristics. The findings of the study highlight the positive impact of digital advice on farmers' capacities and practice uptake. This advances the understanding of how digital advisory approaches can overcome adoption barriers in resource-constrained environments, offering policymakers and development practitioners evidence-based guidance on cost-effective scaling of regenerative agroecology-based crop intensification.

The rest of the paper is organised as follows. Section 2 describes the IVR intervention, data and methodology, while the results of the evaluation are reported in Section 3. This is followed by a discussion and conclusions.

2. Material and methods

2.1. Description of the IVR intervention

The IVR intervention focused on training farmers in general agroecological principles and six practices relevant to the agroclimatic conditions of the study area. The content, structured into seven lessons, was derived from the African Organic Farming Training Manual (FiBL, 2020), with careful consideration and tailoring for the agricultural and cultural context in the Sahel zone, and optimised for mobile delivery. The Malian producer organisation AOPP supported the selection of relevant content and its contextualisation. Table 1 provides a detailed breakdown of the lesson content. Each lesson (as IVR messaging) focused on one of six selected agroecological practices designed to enhance soil health, climate resilience, and overall farm productivity. The first two lessons delivered a general overview, outlining the training format and fundamental agroecological principles. Subsequent lessons covered more specific agroecological practices related to soil fertility

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 agroecological 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 utilisation 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 utilisation 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.

and pest management (such as legume-based rotations and intercropping, mulching, composting, integration of multi-purpose shrubs, and bio-pesticide application) as well as post-harvest handling and storage. These practices were chosen for their potential to enhance food security and soil quality while reducing dependency on external inputs, aligning well with the Sahel's unique environmental challenges.

The training spanned six weeks, during October and November 2022, with one lesson delivered per week. Employing a storytelling approach that reflected the local context (e.g., cropping system, specific pests and diseases in the study region), the lessons were delivered through audio messages in Bambara, the language spoken by farmers in the communities involved in this study. Beyond passive learning (i.e., merely receiving information through a phone call), farmers were encouraged to engage with the material by reflecting on its applicability to their own farms, enhancing both knowledge retention and practical application. More specifically, an interactive component was included in the form of a brief quiz to assess participants' comprehension at the end of each lesson. Farmers could use the keypad of their phone to answer the quiz.

2.2. Sampling and evaluation design

2.2.1. Study area and baseline data

The IVR pilot was conducted in southern Mali at the edge of the Sahel zone. More specifically, our study area includes Sikasso and Kadiolo districts in the administrative region of Sikasso, where maize, sorghum, peanut and millet are the main crops. This area has faced security concerns for several years, which can render physical extension visits, in-person 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 similar territories, who often have limited access to or cannot afford external inputs, while often growing their crops on degraded soils. Therefore, it makes sense to test the effectiveness of digital extension tools for a more widespread uptake of agroecological practices in such a context.

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. 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 five and seven households per village were randomly selected to participate in the survey, depending on the overall farm household numbers in each village. This resulted in a sample size of 451 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 Bambara 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 prior to the actual data collection process, whereby two villages were selected for checking the relevance and clarity of questions. The pre-test experience was used to modify the questionnaire to ensure it was well-structured, easily understood by both enumerators and farmers, and free of ambiguity. The pre-test also helped determine the average time needed to complete one questionnaire, which was approximately 2 hours.

2.2.2. RCT setup

The goal of the evaluation was to test whether IVR training improve farmers awareness, information sharing, confidence and adoption of agroecological intensification practices. The evaluation has been designed as a two-arm cluster randomised controlled trial (RCT), where treatment was randomised at the village level. Contrary to the analysis of observational or time-series data, this impact evaluation design requires fewer assumptions for causal identification. When correctly set up and carried out, the RCT eliminates confounding from both observable and unobservable factors. We were thus able to establish a direct causal link between the phone message delivery and the learning and adoption outcomes. Randomisation in our study drastically reduced the risk of selection bias that would occur if project implementers had purposively selected message recipients or if farmers had self-selected into the treatment group. More specifically, the eighty villages included in the baseline survey were randomly assigned to either the treatment group or the control groups. In total, the evaluation consisted of 40 treatment villages with eligible farmers in these villages receiving seven automated phone calls with lessons covering all components of the IVR agroecology training. 40 control villages served as a counterfactual. As the interest was to assess the effectiveness of the IVR campaign and resources were limited, no additional treatment arms were included. Randomisation at village level rather than farm level was included to reduce the risk of information spill-overs during the RCT. The location of the villages in the RCT in Southern Mali is shown in Fig. 1.

The sample size for our evaluation is powered to detect at least a 10% increase in key primary outcomes (see Section 2.4) based on the baseline data described in Section 2.2. We also estimated the intra-cluster correlation (ICC) using the baseline data. With a sample size of 451 households from 80 villages, we were confident to detect a minimum 10% effect size for all our primary outcomes of interest, including awareness, intention to adopt, information sharing, interest in learning more, confidence in applying the practice and adoption (assuming 80% power at 5% significance level). Of the 451 farm households, 244 from 40 villages were part of the control group, while 239 from 40 villages were in the treatment group. Baseline balance between the groups was checked to confirm their similarity and ANCOVA was used to test for any possible effect of pre-existing knowledge and adoption levels, with the exact methods explained in section 2.4 and results reported in the appendix.

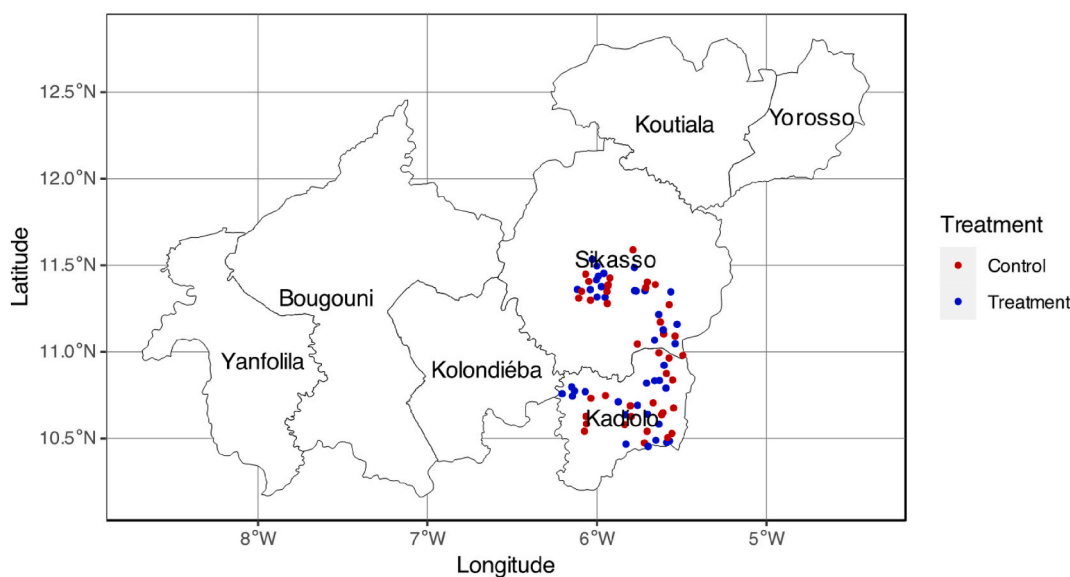


Fig. 1. Districts in the Sikasso region of Mali with location of villages from the control and treatment groups.

2.2.3. Participation in IVR training

The evaluation aimed to capture changes across a defined set of agroecological practices central to the IVR training content. The focus on specific practices—such as legume rotation, intercropping, mulching, composting, integration of multi-purpose shrubs, and bio-pesticides—enabled a targeted assessment of the intervention's effectiveness. Within this framework, the treatment group farmers received a sequence of seven IVR lessons (as mentioned in Table 1) delivered through phone calls. Each lesson covered essential elements of agroecological techniques and concluded with a quiz. Control group farmers did not receive any intervention, serving as a counterfactual to assess outcomes in the absence of IVR training. Monitoring of the six-week IVR intervention revealed high engagement and sustained interest across the lesson series, underscoring the potential of IVR as an effective tool for delivering agricultural training to dispersed and resource-constrained communities. The campaign ultimately reached a total of 195 farmers, since not all 239 selected farmers from the treatment group picked up the IVR phone calls. We obtained a strong and sustained participation rate throughout the roll-out of the lessons, with an average completion rate across lessons of 84% among the 195 farmers. From the participating farmers 91% reported that the audio training content provided useful advice for them, while 98% indicated that they are keen to take part in future IVR-based trainings. This underscores the suitability of the technology and farmers' interest in acquiring knowledge related to agroecological practices.

2.2.4. Evaluation timeline

The evaluation consisted of five steps: (1) baseline data collection, (2) random assignment to the IVR intervention using the baseline data, (3) IVR intervention in October and November 2022, (4) an initial follow-up phone survey after the IVR training in April 2023 and (5) an in-person endline data collection in June 2024 from the same households that were interviewed during the baseline survey.

After the end of the IVR training in the end of November 2022 an initial follow-up data collection was carried out in April 2023 through phone interviews. As IVR-based trainings were an untested extension approach in the Malian context, a quick feedback loop was important. For this purpose, a streamlined questionnaire focusing on key immediate outcome indicators (awareness, information sharing, learning, and confidence, adoption intention) was administered via phone rather than in-person, for cost-effectiveness. The phone survey included 157 farmers from the treatment group and 144 farmers from the control group,

totalling 301 respondents. From the 157 interviewed farmers in the treatment group 13 did not pick up the calls, thus receiving no advice. The sample size reduction from 239 treated farmers in the baseline is primarily due to non-participation and logistical issues with the phone calls, e.g. invalid phone numbers. Attrition analysis indicated that the reduction in sample size did not significantly impact the comparability of treatment and control groups, preserving the RCT's internal validity (see section 2.3.2).

To further assess the intermediate outcome of adoption, thus measuring behavioural change, an in-person endline survey approximately two years after the intervention included the entire baseline sample of 451 farmers. This round of data collection provided a robust measure of actual adoption, complementing the earlier data on adoption intentions and allowing for a deeper examination of the intervention's impact on sustainable farming practices in the longer term. Outcomes related to awareness were also reassessed using the complete sample. By combining phone-based and in-person follow-ups, the study provides a comprehensive view of both immediate intentions and long-term adoption outcomes, capturing the IVR intervention's effect across different stages of the adoption pathway.

2.2.5. Outcome indicators

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 Table 2. The choice of practices and outcomes was guided by the content of the IVR training and draws on the African Organic Farming Training Manual (FiBL, 2020), the agroecology report of the High Level Panel of Experts on Food Security and Nutrition (HLPE, 2019) as well as the 13

Table 2
Agroecological intensification practices selected for the evaluation.

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 <i>piliostigma</i> and <i>guiera senegalensis</i> shrubs with annual crops
P6. IPM (Integrated pest management)	Scouting for pests and application of herbal concoctions, <i>bacillus thuringiensis</i> or <i>bacillus subtilis</i>

principles of agroecology (Wezel et al., 2020), which stress diversification, reduced reliance on external inputs and holistic systems approaches. Indicator choices are also aligned with previous studies that analysed the adoption of agroecological practices, as described in the review of Mockshell et al. (2023). Focusing on combinations of practices rather than individual techniques accounts for the multifunctional nature of agroecology approaches (Amekawa et al., 2010; Ewert et al., 2023).

The intervention's impact was evaluated through outcome indicators measuring stages of engagement with agrological practices, structured along an impact pathway that begins with awareness of practices and moves sequentially through information sharing by farmers, eagerness to learn more, confidence in applying practices, adoption intention and actual adoption.

Each outcome indicator corresponded to one of the six focal practices in the training. Awareness measured farmers' familiarity with each practice, capturing the IVR's initial impact on knowledge exposure. Intention to adopt recorded farmers' stated plans to implement each practice, while information sharing documented whether farmers shared the practices with others, reflecting community-level knowledge diffusion. Learning indicated farmers' proactive interest in expanding their agroecological knowledge, and confidence captured self-assurance in applying each practice, with higher scores reflecting a greater likelihood of sustained use.

Outcomes are reported both as aggregated indicators across all six practices and as indicators for each individual practice (P1 – P6). For awareness, sharing and learning, intention and adoption, aggregation is done by counting the number of practices, while confidence is measured by an average score, standardised on a scale from zero to one (0-1). Table 3 provides an overview of the outcome indicators and the corresponding questions used to measure them from the initial follow-up phone survey (O1 – O5) as well as the in-person endline survey (O6).

2.3. Empirical estimation strategy

To rigorously assess the impact of the IVR intervention on key outcomes, we employed both Intention-to-Treat (ITT) and Local Average Treatment Effect (LATE) estimation approaches (Imbens and Wooldridge, 2009). The ITT estimates represent the average effect of being assigned to the treatment, regardless of actual participation, while the LATE estimates provide insights into the effect of the intervention on those who actively participated in the IVR training. Both estimates consider the clustered nature of the data, with standard errors clustered at the village level to account for intra-cluster correlation. In all our empirical estimations, standard errors were clustered at the village level to adjust for intra-cluster correlation. Moreover, we employ three sets of regression models tailored to the nature of the outcome variables: (A) For count variables such as the number of practices for which respondents are aware, intend to adopt, share knowledge, or seek more information, we use Poisson regression; (B) For the confidence outcome, which is bounded between 0 and 1, we apply a fractional logit regression. (C) For binary outcomes related to individual agroecological practices (P1–P6), such as awareness, intention, sharing, learning, and

Table 3
Overview of outcome variables used in the analysis.

Variable name	Question	Measurement
O1. Awareness	Are you familiar with this practice?	Individual practices P1 – P6 (YES/NO) & Aggregated practices (#)
O2. Sharing	Have you told anyone else about this practice?	Individual practices P1 – P6 (YES/NO) & Aggregated practices (#)
O3. Learning	Are you actively trying to learn more about this practice?	Individual practices P1 – P6 (YES/NO) & Aggregated practices (#)
O4. Confidence	How confident do you feel in applying this practice?	Individual practices P1 – P6 (YES/NO ¹) & Average confidence score (0-1)
O5. Intention	Do you plan to use this practice in the coming planting season?	Individual practices P1 – P6 (YES/NO) & Aggregated practices (#)
O6. Adoption	Have you used this practice in the last planting season?	Individual practices P1 – P6 (YES/NO) & Aggregated practices (#)

Note: ¹To estimate the effect of the training on confidence for the individual practices, the ordinal variable (not confident, slightly confident, confident) was transformed to a binary variable (not + slightly confident vs confident).

confidence, we use logit regression models.

2.3.1. Intention-to-treat (ITT) estimation

The ITT analysis estimates the causal effect of treatment assignment on primary outcomes, providing a conservative measure of the intervention's impact. We implemented ITT estimation using each of the aforementioned outcome variable-specific regressions (A, B & C) as follows:

$$Y_{ij} = \alpha + \beta T_{ij} + \zeta X_{ij0} + \epsilon_{ij} \tag{1}$$

where Y_{ij} is the outcome of interest (i.e., awareness, sharing, interest in learning more, or confidence in applying agroecological practices, intention to adopt, actual adoption) for household i in village j . T_{ij} is an indicator for assignment to the group with IVR intervention, X_{ij0} represents baseline covariates to improve estimation precision and ϵ_{ij} is the error term. Our parameter of interest, β , is the ITT estimate and provides the effect of treatment assignment, regardless of actual participation rates, thus maintaining the validity of random assignment despite non-compliance.

2.3.2. Local Average Treatment Effect (LATE) estimation

Given that only 195 out of 239 farmers assigned to the treatment group engaged with the IVR training, we employed an instrumental variable (IV) approach to estimate the Local Average Treatment Effect (LATE), focusing on the effect of actual participation in the IVR campaign. For this, we used treatment assignment as an instrument for participation, leveraging random assignment as an exogenous source of variation in IVR exposure.

The first stage of the IV estimation models actual participation in the IVR training as a function of treatment assignment:

$$IVR_{ij} = \pi_0 + \pi_1 T_{ij} + \theta X_{ij0} + \nu_{ij} \tag{2}$$

where IVR_{ij} is an indicator for whether household i in village j engaged with the IVR training. The second stage then estimates the causal effect of participation on our outcomes of interest using the outcome variable-specific regressions (A, B & C):

$$Y_{ij} = \alpha + \gamma \widehat{IVR}_{ij} + \varphi X_{ij0} + \epsilon_{ij} \tag{3}$$

In this framework, γ represents the LATE, or the causal effect of IVR participation among those who complied with the treatment assignment, where compliance is defined as receiving the IVR call and completing the training lessons. This approach provides an estimate of the intervention's effect on engaged participants, offering a more precise view of the impact among compliers. By instrumenting participation with assignment, the IV estimation corrects for potential biases introduced by non-compliance, isolating the treatment effect for those who received the intervention.

2.4. Robustness checks

2.4.1. Baseline balance check

To determine whether the randomisation successfully balanced

observable household characteristics between the treatment and control groups, we report the randomisation balance test in Table A1 in the appendix. The table provides summary statistics for pre-treatment characteristics of survey participants at baseline. Reassuringly, it confirms that the randomisation worked as intended, with only a 14% difference in respondents' education being statistically significant ($p < 0.05$). At baseline, the treatment and control groups were similar across key characteristics likely to influence our outcomes of interest. Therefore, we can rule out that variables, such as age of the farmer, distance to markets or farm size, confound the determined effectiveness of the IVR training.

2.4.2. Attrition check in the phone survey

As we were able to interview only 301 households in the phone survey across treatment and control villages out of the 451 farm households interviewed at baseline, attrition was substantial. This was due to a variety of reasons: invalid phone numbers, intervention drop-outs (i.e., as mentioned before, only 195 out of the 239 farmers assigned to the IVR treatment participated in the training) and unwillingness to participate in the endline phone survey.

To assess whether attrition was random and rule out selective attrition, we specified a probit model, where treatment status and baseline characteristics were included as predictors of attrition (i.e., with attrition coded as zero if the household participated in both baseline and endline surveys, and one otherwise). The correlates of attrition reported in Table A2 in the appendix indicate no evidence of selective attrition bias in our sample. Given that the relatively high attrition rate was similar across both treatment and control groups (Prob > F = 0.849), we conclude that the groups remained balanced despite the attrition. However, it reduced statistical power, meaning we moved from being able to detect at least a 10% effect size for outcome variables to detecting effect sizes between 15% and 20%.

The endline in-person follow-up, conducted with the complete baseline sample, allowed us to further mitigate the impact of attrition by collecting data on actual adoption from all 451 farmers who initially participated. By using the full sample for the final assessment, we increased the robustness of the adoption findings and ensured that the final analysis captures a more comprehensive view of the intervention's behavioural impacts. This dual-method approach—combining phone-based follow-ups with a complete sample endline survey—thus helps counterbalance the challenges posed by attrition, providing a more reliable estimate of the IVR intervention's effectiveness.

2.4.3. ANCOVA check

We also conducted a further robustness check using an ANCOVA specification. This approach adjusts for individual baseline outcomes in the estimation of treatment effects, thus controlling for any pre-existing difference in awareness and adoption at baseline. Specifically, our regression extends the standard model to the following ANCOVA form:

$$Y_{ij} = \alpha + \beta T_{ij} + \zeta X_{ij0} + \gamma Y_{ij0} + \epsilon_{ij} \tag{4}$$

Where Y_{ij} is the endline outcome, and Y_{ij0} is the corresponding baseline outcome value (awareness or adoption). This ensures that treatment effects are estimated net of any pre-treatment differences for those outcomes. As shown in Table A4 in the appendix, the estimates remain robust.

3. Results

This section examines the aggregate and practice-specific effects of the IVR intervention on farmers' adoption intentions and practices in agroecological methods. Table 4 provides the aggregated effects, while Fig. 2 offers a detailed breakdown of outcomes across specific practices.

3.1. Aggregate treatment effects

Table 4 presents both Intention-to-Treat (ITT) estimates, reflecting the effect on all farmers assigned to the intervention, and Local Average Treatment Effect (LATE) estimates, which capture the impact on farmers who fully engaged with the IVR training. The differences between ITT and LATE offer insights into the added value of full participation.

Both the ITT and LATE estimates reported in Table 4 show that the IVR intervention had a substantial positive impact on all key metrics. Specifically, the ITT results reveal that the training increased awareness by an average of 0.678 additional practices (i.e., the treatment group experienced a 16% increase in awareness of agroecological practices compared to the control group), indicating a notable improvement in farmers' knowledge about agroecological practices. Information-sharing activities also surged, with participants reporting an increase of 0.892 practices (i.e., a 42% increase in practices shared), highlighting the intervention's success in fostering community-level information exchange.

Learning engagement improved by 16%, reflecting the IVR campaign's success in motivating farmers to deepen their understanding of agroecological methods. Additionally, confidence in applying these practices nearly doubled, showing a 97% increase over the baseline, which suggests that the campaign significantly boosted farmers' belief in their ability to implement sustainable farming practices. Additionally, the IVR intervention increased farmers' intentions to adopt agroecological practices by about 12%. This strong effect on both confidence and intention suggests that IVR messaging was effective in motivating farmers' readiness and self-efficacy for sustainable practice adoption.

The LATE estimates, focusing on farmers who fully engaged with the IVR training, show even greater improvements. Awareness among these participants increased by 17%, while information sharing rose by 45%. Confidence, a critical factor for sustainable practice adoption, grew by 107% among fully engaged participants, highlighting the heightened impact of full participation. Intentions to adopt agroecological practices rose by 13% in the ITT estimates and by 16% in LATE estimates, indicating that the training successfully motivated farmers' readiness to adopt. Finally, actual adoption was assessed post-harvest through in-person interviews with the full endline sample (N = 451). ITT

Table 4
Estimation of aggregated treatment effects.

	Awareness	Sharing	Learning	Confidence	Intention	Adoption
	# practices	# practices	# practices	score (0-1)	# practices	# practices
POM	4.352	2.158	4.322	0.213	3.384	2.311
ITT	0.678*** (0.20)	0.892*** (0.25)	0.694*** (0.20)	0.206*** (0.06)	0.402*** (0.15)	0.531*** (0.15)
ITT (%)	16%	42%	16%	97%	12%	23%
LATE	0.739*** (0.21)	0.973*** (0.26)	0.757*** (0.21)	0.225*** (0.06)	0.438*** (0.16)	0.651*** (0.18)
LATE (%)	17%	45%	18%	107%	13%	28%
N	301	301	301	301	301	451

Notes: See Table 2 for explanations of the outcome variables; POM = Potential Outcome Mean (Control mean); ITT = Intention to Treat Effect; ITT(%) is calculated as ITT/POM; LATE = Local Average Treatment Effect; LATE(%) is calculated as LATE/POM; Significance levels: *** = 0.01, ** = 0.05, * = 0.1.

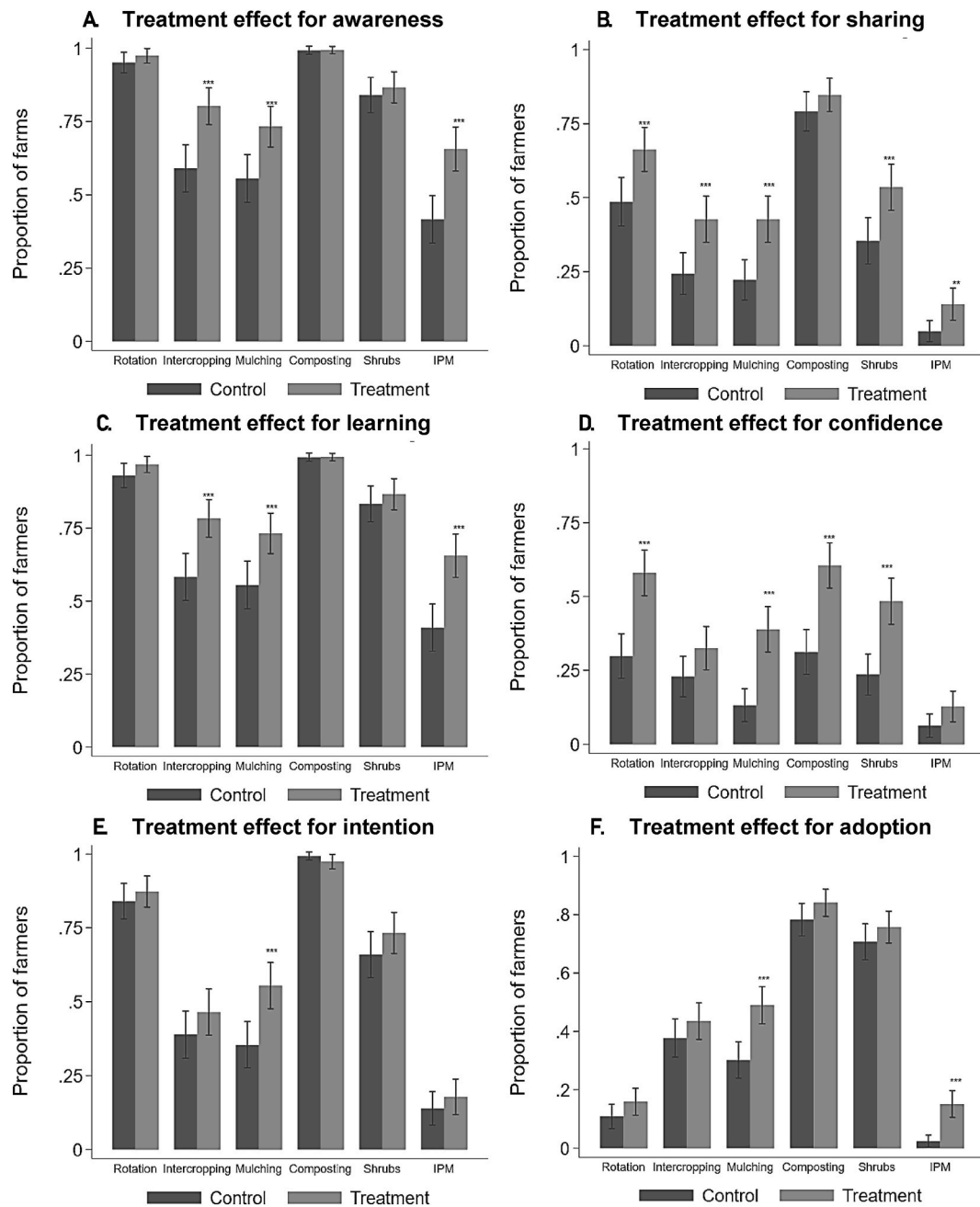


Fig. 2. Differences in outcomes between control and treatment groups for each practice.

estimates showed that adoption increased by 0.53 practices (i.e., by 23% compared to the control mean on 2.3 practices) across the general sample, while for those who fully engaged in IVR training (LATE), adoption rose by 0.65 practices (i.e., by 28%). This result underscores the long-term impact of the IVR intervention, showing that while all assigned participants benefited, full engagement with the training led to the most substantial behavioural changes and sustainable practice adoption.

Overall, we observed that awareness, learning and intention effects were less pronounced than sharing, confidence and adoption effects. This can largely be explained by relatively high baseline levels of existing knowledge for several practices as well as an existing willingness to learn and adopt among the farmers in the study area, including those in the control group. Confidence and adoption levels were comparatively lower at baseline for farmers in the control and treatment groups. These baseline trends shape the Potential Outcome Means

(POM) in Table 4, which show the differences in reference values for the six outcome variables. The effect sizes are thus a reflection of the POM as well as the intervention itself. Once additional knowledge through the IVR training was made available to farmers in the treatment group, impacts became more evident for those outcomes with lower POMs. Moreover, the magnitude of confidence effects widely exceeded that of adoption impact. This largely due to the fact that actual field implementation of agroecological practices requires more than knowledge and confidence to occur. For example, sufficient labour or secure access to land need to be in place too. The aggregate effects described here are further unpacked in sub-section 3.2, where the same behavioural mechanism are underlying the observed differences in effect sizes.

3.2. Practice-specific treatment effects

Examining the effects on specific practices provides a nuanced view

of how the IVR intervention influenced different agroecological techniques, particularly in terms of awareness, information sharing, learning, confidence, and adoption. Differences between control and treatment groups across all outcomes and for each practice are showcased in Fig. 2, based on the ITT estimates. Exact effects for both estimation options (ITT and LATE) are explained in the following text, with coefficients shown in Table A3 in the appendix.

Awareness: The IVR intervention led to substantial increases in awareness across multiple agroecological practices. Awareness of intercropping with legumes increased by 21% (ITT) and 23% (LATE), illustrating the intervention's efficacy in conveying the benefits of this sustainable practice. Mulching saw similarly strong effects, with awareness increasing by 18% (ITT) and 19% (LATE). A similar effect was observed for bio-pesticides, with awareness increasing by 24% (ITT) and 26% (LATE). These results demonstrate that the IVR campaign effectively broadened farmers' understanding of sustainable practices, especially for techniques that address critical issues like pest and soil management.

Information Sharing: The intervention significantly promoted peer-to-peer knowledge exchange, indicating that farmers felt confident in their understanding of these practices and valued sharing them within their communities. Farmers in treatment villages were 18-20% more likely to share information about crop rotation, 19-21% more likely to share knowledge about intercropping, and 21-25% more likely to share knowledge about mulching compared to those in control villages. The likelihood of sharing information about bio-pesticides also increased significantly by 10% (ITT) and 11% (LATE). These substantial increases suggest that the intervention not only enhanced knowledge acquisition but also fostered a collaborative environment where farmers felt confident sharing valuable practices with peers.

Learning: Learning was substantial, particularly for techniques that deliver tangible, practical benefits. Interest in intercropping increased by 20% (ITT) and 22% (LATE), while learning about mulching rose by 18% (ITT) and 20% (LATE). Farmers were also highly engaged in learning about bio-pesticides, with learning engagement increasing by 25% (ITT) and 27% (LATE). The higher LATE estimates suggest that farmers who fully engaged with the IVR programme were more likely to seek deeper knowledge, motivated by a genuine interest in mastering effective agroecological techniques. These findings highlight the IVR intervention's ability to generate curiosity and drive educational engagement, particularly for practices with visible on-farm benefits.

Confidence: Confidence in applying agroecological practices showed substantial improvements across all practices, reflecting the IVR intervention's effectiveness in boosting farmers' self-assurance. Confidence in applying rotation increased by 28% (ITT) and 30% (LATE) while confidence in applying mulching increased by 26% (ITT) and 28% (LATE), suggesting that the training had a profound impact on farmers' belief in their capacity to adopt composting. Confidence in applying multi-purpose shrubs and composting also increased significantly. These gains highlight the intervention's success in building farmers' belief in their ability to implement these practices, essential for sustained behaviour change.

Intentions and Actual Adoption: The IVR intervention successfully translated intentions into actual adoption, particularly for mulching. In the phone survey sample, intentions to adopt mulching were 20% (ITT) and 22% (LATE) more likely among farmers in treatment villages compared to those in control villages. Actual adoption, assessed post-harvest in the endline survey (N = 451), indicated that the IVR intervention drove sustained behaviour change in actual adoption for several practices. Specifically, adoption increased by 19% for mulching, and 13% for bio-pesticides. These findings suggest that the IVR intervention effectively converted intentions into actual adoption. These adoption rates suggest that the IVR intervention not only inspired intentions but also resulted in tangible, sustained behaviour changes in the field. Moreover, the higher confidence gains among fully engaged farmers (i. e., LATE estimates) suggest that in-depth participation in the IVR

intervention was instrumental in reinforcing farmers' belief in their own skills, a key factor for long-term adoption. For successful and sustained adoption at scale a number of factors need to come together. Therefore, we also asked farmers to report perceived constraints to the adoption of the promoted practices. Gaps in technical knowledge are most prominently mentioned. Lack of labour during peak times as well as limited access to material for planting and protecting shrubs and trees were also reported by farmers.

4. Discussion and conclusions

4.1. Findings in context

The evidence on the impact of digital tools for agricultural advice has been growing in recent years. Knowledge gains and adoption impacts from IVR-based and similar digital trainings have been identified by other studies, with a different focus albeit (Fabregas et al., 2019; Ding et al., 2022; Abate et al., 2023; J-PAL, 2023; Mwambi et al., 2023). Prior research also includes an RCT that also assessed an IVR intervention, in that case related to animal health (Dione et al., 2021). Regarding the magnitude of effects, the adoption rates caused by the intervention analysed in our study are somewhat similar or even above the range of adoption effects in other studies on digital advisory services, such as the average 22% increase reported in the meta-analysis of Fabregas et al. (2019) for the rather simple practice of applying recommended input amounts. Mwambi et al. (2023) find a 20% IPM adoption effect only if phone messages are combined with in-person field demonstrations. Similarly, (Giulivi et al. (2023)) do not find any significant effect for voice messages as a stand-alone intervention, while in their study effects from smartphone-based advice turned out to be in the range of 8 to 13%. Highly relevant content for farmers and an emphasis on locally available on-farm inputs is likely to have contributed to the comparatively high adoption rates that we find in our analysis. However, the lasting use of these practices will need to be confirmed through an additional round of data collection.

Our research expands on the existing literature on agroecology interventions as well as digital tools in agriculture by evaluating a digital training that explicitly promotes approaches and practices for the agroecological intensification of cropping systems. We do so by using a randomised experiment that allows for causal identification, which addresses an important research gap related to the systematic attribution of observed impacts to agroecology interventions. Findings suggest clear positive effects resulting from farmers' exposure to phone 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. Effect sizes vary by practice and outcome. Besides knowledge flows, a range of other factors influence adoption of agricultural technologies and agroecological practices more specifically. These include, for instance farmer education, household size, land area, access to credit, land tenure, distance to roads and markets (Arslan et al., 2020; Grovermann et al., 2023; Ruzzante et al., 2021). Through randomisation these characteristics are similar among farmers in the control group and the treatment group. However, these factors can explain why high impacts on confidence levels do not translate into equally high levels of adoption. Insecure land tenure or lack of labour may act as constraints for more widespread uptake. Overall, the results reinforce the potential of IVR as a scalable, cost-effective tool for promoting targeted, sustainable agricultural practices in rural settings. The study thus contributes to developing the wider evidence base on the impacts of capacity development interventions for an agroecological transformation, complementing existing quasi-experimental and experimental impact research, e.g. on the effectiveness of in-person trainings (Grimm and Luck, 2023) or of related digital approaches (Mwambi et al., 2023).

4.2. Limitations

It should be noted that the possible ranges for adoption impact estimates were confined by high levels of pre-existing knowledge and adoption in the case of composting and shrub integration. As the farmers in the control group were already well-informed and applied these two practices to a certain extent, detecting significant effects was restricted. This highlights the importance of taking into account the knowledge levels prior to the design phase of IVR interventions. It also shows the need to more specifically ask about the depth of knowledge and application, which is to some extent reflected by the confidence outcome in our analysis.

The relatively large attrition rate from baseline to initial follow-up is a threat to the internal validity of the midline RCT findings. We ascertained however that attrition was similar across treatment and control groups and that the sample remained well balanced despite the attrition. We could also rule out selective attrition. The combined results from both survey rounds (midline and endline) reveal some discrepancies between farmers' stated intentions to adopt (captured in the initial follow-up phone survey) and their reported actual adoption behaviour (captured during the endline survey). Both adoption measures are based on self-reported data rather than field-level verification or quantitative metrics such as percentage of land converted. While this may introduce some measurement error, we do not anticipate systematic bias across treatment arms, given the randomised design. While the effect size estimates are relatively similar between the two outcome variables, the potential outcome estimates are somewhat lower in the case of actual adoption. This leads to differences in the percentage-effects. We mainly ascribe this finding to farmers in the control group slightly overreporting intention to adopt the agroecological intensification practices. It shows that there is a need to interpret any survey questions on adoption intention with caution.

4.3. Research and policy implications

In Sub-Saharan Africa agroecological intensification has great potential to support farmers in improving soil health and thus transitioning to more productive, resilient and profitable production systems (Manyanga et al., 2023; Romero Antonio et al., 2024). 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). Agroecological practices have also been linked to higher provision of regulating ecosystem services (Boeraeve et al., 2020). However, adoption of agroecological practices is often limited, as shown for countries in the Sahel (Grovermann et al., 2023; Carroll II et al., 2025)). Digital tools that disseminate agroecology knowledge and promote the uptake of agroecological practices are particularly needed in contexts like the Sahel. Rural areas in this region are often remote and difficult to access, with security risks prevailing in 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 IVR works well 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, ways of combining different extension modalities should be further explored. 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).

Smart mixes of different sustainability strategies also warrant further examination in future impact studies. Mockshell and Kamanda (2018), for instance, have illustrated ways in which agroecological intensification can be combined with genetic improvements and institutional or social innovations. In a first step, the knowledge gap on digital tools for

agroecology promotion needs to be addressed (Hilbeck et al., 2022). In future impact evaluations, promising practices from different strategies for agroecological intensification may be individually and jointly piloted, with each treatment 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. While this study assesses a range of immediate outcomes, such as intention or confidence, as well as change in behaviour in terms of practice uptake, it does not capture more long-term outcomes. Such impacts would only materialise after a longer period of time following the completion of the intervention. Future studies should also go beyond productivity and pay attention to multiple sustainability dimensions (e.g. Blockeel et al., 2023; Grovermann et al., 2024). Environmental outcomes are generally touched upon in few impact evaluations on digital tools (Porciello et al., 2022). Unintended consequences from digital agroecology interventions also deserve more attention, as for instance the uptake of biopesticides may induce new vulnerabilities on a farm, e.g. in terms of additional labour requirements (Johansson et al., 2024). Any study to assess longer-term outcomes of IVR would need to consider such unintended consequences alongside intended economic or environmental gains. The involvement of end-users in the content creation for digital tools is key in this regard and needs to be fostered (Coggins et al., 2022). This can also ensure that IVR content is fine-tuned beyond general suggestions, taking into account farmers' preferences, local input availability as well as soil and climate conditions. The complexities of bundling practices together to suit the farm setting requires tailored crop-specific advice.

Research on blended learning and its sustainability impacts can help to answer urgent questions on how to better design the delivery of advisory services at scale beyond specific project-funded approaches. There is a need to further establish frameworks to evaluate the environmental, economic, and social impacts of multi-faceted agroecological interventions. For policy-making our findings imply that investments in digital extension services should be integrated into funding and capacity strengthening programmes for holistic agricultural development, supporting sustainable land management and focusing on systems complexity rather than adoption of single conventional intensification technologies. Impactful interventions do not necessarily require smartphone apps, but can also be delivered through more simple tools, such as IVR. This can be useful for the capacity development programmes implemented by NGOs, public extension services and private service providers working in remote contexts such as the Sahel. It should be noted that the digital divide can already be mitigated in the short run simply through engaging IVR campaigns, in combination for instance with improved access to affordable prepaid phone credit. For settings where extension services are under strain and conflicts restrict access to rural area, our analysis shows that stand-alone digital advice can already make a difference, even beyond knowledge gains, as demonstrated by the change in behaviour among farmers in the treatment group. While blended learning is generally recommended, there is not necessarily the need for in-person events to achieve such change. We consider the focus on farm-generated materials rather than externally purchased inputs as a key factor in the observed adoption levels, which is reinforced by the fact that combinations of agroecological practices produce synergies rather than trade-offs. This altogether will contribute to climate resilient farms, enhanced soil conservation and better food security, especially in regions that are vulnerable and difficult to access.

CRedit authorship contribution statement

Christian Grovermann: Conceptualization, Formal analysis, Investigation, Methodology, Supervision, Writing – original draft. **Tesfamichael Wossen:** Conceptualization, Data curation, Formal analysis, Methodology, Visualization, Writing – original draft. **Johan Blockeel:** Data curation, Investigation, Methodology, Resources, Software, Visualization. **Assane Beye:** Conceptualization, Methodology, Validation,

Writing – original draft. **Tahirou Abdoulaye:** Conceptualization, Funding acquisition, Methodology, Project administration, Resources, Supervision. **Benjamin Gräub:** Conceptualization, Funding acquisition, Project administration, Resources, Software, Supervision, Validation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence

the work reported in this paper.

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Appendix

Table A1
Randomisation balance checks

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

Note: Significance levels: *** = 0.01, ** = 0.05, * = 0.1.

Table A2
Correlates of attrition

Variables	Attrition (Yes = 1) Coeff. (SE)	Attrition (Yes = 1) Coeff. (SE)
Treatment	0.022 (0.045)	0.044 (0.046)
Age (years)		0.001 (0.002)
Household size (persons)		-0.002 (0.004)
Years of experience in farming (#)		-0.001 (0.002)
Years the family lived in this village (#)		-0.002 (0.002)
Household head with formal education (1 = yes)		-0.063 (0.051)

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Table A2 (continued)

Variables	Attrition (Yes = 1) Coeff. (SE)	Attrition (Yes = 1) Coeff. (SE)
Irrigated farmland (1 = yes)		-0.032 (0.079)
Access to extension agents (1 = yes)		0.016 (0.057)
Attended agricultural training before (1 = yes)		-0.048 (0.052)
Distance to nearest town (km)		0.001 (0.001)
Distance to nearest market (km)		0.001 (0.002)
Travel time to market (minutes)		-0.001 (0.001)
Travel time to all-weather road (minutes)		-0.000 (0.000)
Total land size (ha)		-0.000 (0.003)
Member of cooperatives (1 = yes)		-0.013 (0.048)
Member of saving and credit associations (1 = yes)		-0.032 (0.080)
Radio owned (1 = yes)		0.037 (0.064)
Television owned (1 = yes)		-0.036 (0.050)
Estimated asset value (mil CFA)		-0.002 (0.003)
		0.396*** (0.136)
Prob > F	0.616	0.849
N	451	451

Table A3
Estimated treatment effects of the IVR training for individual practices

OUTCOMES		P1. Rotation	P2. Intercropping	P3. Mulching	P4. Composting	P5. Multi-purpose shrubs	P6. Bio-pesticides
Awareness	ITT	0.023 (0.032)	0.212*** (0.076)	0.177*** (0.066)	0.001 (0.009)	0.026 (0.042)	0.239*** (0.064)
Phone sample (N = 301)	LATE	0.025 (0.035)	0.231*** (0.081)	0.193*** (0.071)	0.001 (0.010)	0.028 (0.046)	0.261*** (0.068)
Sharing	ITT	0.176** (0.069)	0.184*** (0.069)	0.205*** (0.054)	0.055 (0.052)	0.181*** (0.058)	0.092** (0.039)
Phone sample (N = 301)	LATE	0.192*** (0.073)	0.200*** (0.073)	0.223*** (0.055)	0.060 (0.056)	0.197*** (0.061)	0.100** (0.042)
Learning	ITT	0.038 (0.034)	0.200*** (0.075)	0.177*** (0.066)	0.001 (0.009)	0.033 (0.042)	0.246*** (0.064)
Phone sample (N = 301)	LATE	0.041 (0.037)	0.218*** (0.080)	0.193*** (0.071)	0.001 (0.010)	0.036 (0.045)	0.269*** (0.068)
Confidence	ITT	0.281*** (0.080)	0.096 (0.072)	0.257*** (0.050)	0.293*** (0.083)	0.248*** (0.065)	0.065 (0.042)
Phone sample (N = 301)	LATE	0.306*** (0.084)	0.104 (0.077)	0.280*** (0.051)	0.319*** (0.086)	0.270*** (0.068)	0.071 (0.045)
Intention	ITT	0.032 (0.049)	0.076 (0.068)	0.200*** (0.059)	-0.019 (0.013)	0.073 (0.053)	0.039 (0.045)
Phone sample (N = 301)	LATE	0.035 (0.053)	0.083 (0.074)	0.218*** (0.064)	-0.020 (0.014)	0.079 (0.057)	0.043 (0.049)
Adoption	ITT	0.051 (0.04)	0.058 (0.06)	0.188*** (0.05)	0.058 (0.05)	0.050 (0.05)	0.127*** (0.03)
Endline sample (N = 451)	LATE	0.062 (0.05)	0.071 (0.07)	0.230*** (0.06)	0.071 (0.06)	0.061 (0.07)	0.156*** (0.04)

Notes: ITT = Intention to Treat Effect; Significance levels: *** = 0.01, ** = 0.05, * = 0.1; The same results are also shown in Fig. 2 in the main body of the manuscript; Explanations of the practice-specific treatment effects are provided in section 3.2.

Table A4
Estimated treatment effects for individual practice

OUTCOMES		P1. Rotation	P2. Intercropping	P3. Mulching	P4. Composting	P5. Multi-purpose shrubs	P6. Bio-pesticides
Awareness	ITT	0.023 (0.032)	0.212*** (0.076)	0.177*** (0.066)	0.001 (0.009)	0.026 (0.042)	0.239*** (0.064)
Phone sample (N = 301)	LATE	0.025 (0.035)	0.231*** (0.081)	0.193*** (0.071)	0.001 (0.010)	0.028 (0.046)	0.261*** (0.068)
Awareness ANCOVA	ITT	0.023 (0.03)	0.181*** (0.07)	0.141** (0.06)	-0.001 (0.01)	0.025 (0.03)	0.237*** (0.06)
Phone sample (N = 301)	LATE	0.025 (0.03)	0.198*** (0.07)	0.154** (0.06)	-0.001 (0.01)	0.027 (0.04)	0.259*** (0.07)
Adoption	ITT	0.051 (0.04)	0.058 (0.06)	0.188*** (0.05)	0.058 (0.05)	0.050 (0.05)	0.127*** (0.03)
Endline sample (N = 451)							

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Table A4 (continued)

OUTCOMES		P1. Rotation	P2. Intercropping	P3. Mulching	P4. Composting	P5. Multi-purpose shrubs	P6. Bio-pesticides
	LATE	0.062 (0.05)	0.071 (0.07)	0.230*** (0.06)	0.071 (0.06)	0.061 (0.07)	0.156*** (0.04)
Adoption ANCOVA	ITT	0.040 (0.04)	0.061 (0.06)	0.181*** (0.05)	0.021 (0.05)	0.068* (0.04)	0.125*** (0.03)
Endline sample (N = 451)	LATE	0.049 (0.04)	0.075 (0.08)	0.221*** (0.06)	0.026 (0.06)	0.083* (0.05)	0.153*** (0.04)

Data availability

Data will be made available on request.

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