Received: 16 January 2025 | Accepted: 11 November 2025

DOI: 10.1111/ajae.70032

ARTICLE

# Information flow and the adoption of soil-improving and water conservation measures, and household welfare: Insights from a randomized controlled trial in Uganda

**Esther Gloria Mbabazi**[1,2] | **Awudu Abdulai**[1] | **Enoch M. Kikulwe**[3] | **Elisabetta Gotor**[4]

[1]Department of Food Economics and Consumption Studies, University of Kiel, Kiel, Germany

[2]Alliance of Bioversity International and CIAT, Kampala, Uganda

[3]Alliance of Bioversity International and CIAT, Nairobi, Kenya

[4]Alliance of Bioversity International and CIAT, Rome, Italy

**Correspondence**
Awudu Abdulai, Department of Food Economics and Consumption Studies, University of Kiel, Olshausenstrasse 40, 24098 Kiel, Germany.
Email: aabdula@food-econ.uni-kiel.de

**Funding information**
Bill and Melinda Gates Foundation, Grant/Award Number: A1272; Academy for International Agricultural Research (ACINAR)

**Abstract**

Extension services are designed to facilitate the flow of information from researchers to farmers. However, information failures continue to impede the diffusion of soil-improving and water conservation technologies in Sub-Saharan African countries. We use a randomized controlled trial (RCT) to examine the impact of an extension-based campaign on the adoption of soil and water conservation measures and welfare outcomes among farmers in Uganda. The experiment involves the use of mass media including radio programs and video shows, lecture trainings, and practical sessions involving demonstration trials and farmer field days in disseminating information pertinent to soil-improving and water conservation practices. We compare the impact of utilizing audio-visual and hands-on approaches in disseminating information relative to audio means of communication. We employ machine learning techniques to analyze the heterogeneous effects and for covariate adjustment. We find that augmenting mass media in public extension has far-reaching effects. Our results reveal that the transmission of information through multiple communication channels significantly increases the adoption of the soil-improving and water conservation measures. We also find that the intervention significantly increases welfare measures like banana yields, marketed surplus, and household incomes. These findings provide evidence that the use of mass media for increased awareness of improved technologies and utilizing audio-visual and hands-on communication channels in facilitating changes in attitudes and behavior of the end-users, can enhance the adoption of these technologies and contribute to increased household welfare.

**KEYWORDS**
information flow, randomized controlled trial, soil-improving and water conservation practices

**JEL CLASSIFICATION**
Q12, Q16, Q55, O33, C93

## 1 | INTRODUCTION

Climate change, with its impacts such as droughts and floods, presents a worldwide challenge, placing mitigation and adaptation measures at the forefront of global priorities. Sub-Saharan Africa, a region characterized by high population growth, high dependence on agriculture, and minimal use of soil-improving and natural resource conservation measures, faces the most drastic climate change effects (Kansiime et al., 2022; Kihara et al., 2022). Continuous cropping without nutrient replenishment or organic amendments has led to soil depletion and declining productivity (Kihara et al., 2022). Reliance on mineral fertilizers is unsustainable in the long run since yearly crop harvests result in a decline in soil fertility due to nutrient extraction and loss in organic matter. Given the rising population coupled with shrinking farm sizes, rapidly degrading soils and climate change, it is imperative to consider the use of sustainable agricultural intensification practices that can increase yields and address current and future threats to food security, farmers' welfare, and ecosystem services (Shiferaw et al., 2013). These practices include soil-improving and water conservation measures like mulching, manure application, and drainage channels/trenches (Abdulai et al., 2011).

The adoption of soil-improving and water conservation practices enhances agricultural productivity and promotes environmental sustainability, which is crucial to achieving the goals of food security and poverty alleviation in Sub-Saharan African countries (Pan et al., 2018). Hence, understanding the effects of interventions on sustainable farming practices and their impact on household welfare has huge implications for agricultural and environmental policy design (Rudolf et al., 2020; Vasilaky et al., 2023).

Earlier studies highlighted the role of secure property rights in encouraging investment in conservation measures (e.g., Abdulai et al., 2011; Abdulai & Goetz, 2014; Besley, 1995), while recent research emphasizes the importance of information transfer in facilitating the adoption of these practices (e.g., Pan et al., 2018; Rudolf et al., 2020). For example, Pan et al. (2018), demonstrated that information provision fosters adoption and improves productivity.

The lack of information and knowledge is one of the most frequently highlighted barriers to the adoption of agricultural innovations among smallholder farmers in developing countries (Abdulai, 2023; Aker, 2011; Baul et al., 2024; Harou et al., 2022). Furthermore, some of the adopted agricultural technologies are not implemented according to the recommended guidelines due to existing knowledge gaps (Hörner et al., 2019). In Sub-Saharan Africa, public agricultural extension systems are mandated to transfer information to end-users to enhance farmers' innovative capacity. However, as noted by the National Planning Authority (NPA) in Uganda, the public extension systems are under-resourced, leaving most farming communities underserved (NPA, 2018). Evidence from various countries indicates that the number of public extension officers is critically low.

Statistics from Tanzania show a ratio of one extension officer to 831 farmers (Mabaya et al., 2017); in Ghana, the ratio is 1:1850 (MoFA, 2019) whereas in Uganda 2000 extension officers serve over five million farmers, translating to 1:2500 (NPA, 2018; UBOS, 2020). Such low staffing levels severely limit the diffusion and adoption of technologies through public extension services (Benin et al., 2011).

To reach wider audiences, agricultural extension systems have integrated information communication technologies (ICT) like mobile phones, radios, and videos. The effective use of ICT as complementary channels in agricultural extension for disseminating information broadly in the region has been widely documented (Abate et al., 2023; Baul et al., 2024; van Campenhout et al., 2021). In Uganda, however, most documented experimental ICT agronomy extension studies focus on single-season interventions targeting annual crops like maize, rice, and beans, often using videos and electronic media like short message services (SMS) (e.g., Cai et al., 2014; Lecoutere et al., 2023; van Campenhout, 2021; van Campenhout et al., 2021). Videos engagingly blend audio and visual information, making it easy for even illiterate farmers to grasp key concepts and ensure message consistency across recipients (Baul et al., 2024). However, watching a video may be a passive exercise, increasing the likelihood that farmers would forget some of the details, particularly if there are multiple practices screened, some of which are complex, and if the lag between screening and implementation is long (van Campenhout et al., 2021). When used in isolation, these methods may not suffice in the promotion of multiple technologies in the production of perennial crops like bananas, which require continuous engagement with farmers, while also involving in-person practical sessions to enhance knowledge retention (Parsa et al., 2014). To address this need, our study implements a randomized controlled trial (RCT) that combines audio, audio-visual, and hands-on extension methods to disseminate agronomic information to 471 smallholder banana farmers in Uganda. The combined dissemination methods are not merely additive; they possess unique features that synergistically enhance effective communication. We specifically examine how targeted information flow can boost farmers' adoption of soil-improving and water conservation practices and evaluate the impact of these practices on household welfare.

The intervention was designed to compare effects across combined channels relative to a single audio channel. Agronomic audio information was broadcast through radio stations with nationwide coverage, reaching out to farmers in the control and treatment groups. Additionally, the treatment group received audio-visual content, through video drama screenings and lecture trainings, alongside hands-on approaches including demonstration trials and farmer field days. This campaign-based approach, although common in public health and nutrition sectors (Rekhy & McConchie, 2014), remains underexplored in agricultural extension systems promoting soil and water conservation practices, particularly in experimental settings.

Our study makes several contributions to the literature. First, we estimate the causal impacts of campaign-based, multi-modal information delivery on the adoption of soil-improving and water conservation practices, extending the work of Pan et al. (2018), who evaluated the causal impacts of a large-scale agricultural extension program for smallholder women farmers on technology adoption in Uganda and van Campenhout et al. (2021), who investigated the effectiveness of ICT-based agricultural information dissemination, including videos, SMS, and interactive voice response in the same country. Second, we assess the differential effects of single versus combined communication channels, highlighting that multiple modalities enhance adoption more effectively than a single channel. As Parsa et al. (2014) assert, leveraging multiple information dissemination channels can substantially enhance the adoption of natural resource conservation practices. Third, we estimate Local Average Treatment Effects (LATE) for the conservation practices to evaluate their direct influence on yield, marketed surplus, and household income. This causal analysis enables us to provide evidence-based policy recommendations for analysts and policymakers focused on implementing natural resource conservation measures.

Unlike previous studies that primarily rely on observational data (e.g., Tambo et al., 2019), which are susceptible to endogeneity concerns, our RCT design enables robust causal inference. Our results reveal that transmitting information through multiple channels significantly increases the adoption of soil-improving and water-conservation practices and has positive and significant impacts on household welfare.

The remainder of the paper is structured as follows: Section 2 describes the study context, and Section 3 highlights the experimental design. Section 4 outlines the data and empirical strategy. Section 5 presents results on the adoption of the practices and welfare impacts, and explores heterogeneous effects and the cost-effectiveness of the campaign intervention. Section 6 concludes with policy implications.

## 2 | CONTEXT AND STUDY AREA

Uganda is an agrarian country with a high population growth rate, estimated at 3.2% per annum, with about 73% of its populace living in rural areas and largely dependent on agriculture, which contributes 24% to the Gross Domestic Product (GDP) and 68% to aggregate employment (UBOS, 2021). Like in many other Sub-Saharan African countries, the provision of information to farmers is part of the state's mandate. However, the public agricultural extension system is overstretched, characterized by few extension officers assigned to cover wide areas with limited facilitation (NPA, 2018). Development partners help to bridge the gap when they implement projects that provide smallholder farmers with information and knowledge, although these are not widespread and are usually short-lived (NPA, 2020). Lack of information due to inadequate extension services is a major constraint to the adoption of soil-improving and natural resource management practices by smallholder farmers (NPA, 2018), resulting in lower yields for many key crops.

Banana is a priority perennial crop in Uganda, cultivated by one in every two households (UBOS, 2020). It is a primary source of food and income for millions of households (Mbabazi et al., 2021). Uganda is not only the leading banana producer in East and Central Africa, but also has the highest per capita consumption of the crop globally. Furthermore, banana cultivation provides significant environmental benefits within farming systems, as it mitigates soil erosion on steep slopes, preserves soil structure, and offers shade to intercrops such as beans, ground nuts, and coffee (Wairegi et al., 2010).

Despite its importance, the banana crop is affected by several biotic constraints, such as pests and diseases, and abiotic constraints like drought stress and soil nutrient deficiencies that have resulted in inherently low yields (van Asten et al., 2011; Wairegi et al., 2010). Poor soil fertility is a persistent problem because of continuous production without sufficient nutrient replenishment and nutrient loss via increased banana sales (Wairegi et al., 2010). The long dry spells leading to moisture stress compound low productivity (van Asten et al., 2011). To boost productivity, various interventions have been implemented in the banana-producing regions in Uganda, though each targeted a specific constraint, and they were isolated in time and space. For example, van Asten et al. (2011) showed that effective management of drought stress through providing adequate water substantially improves yields. Our study improves on the previous approaches by tackling various constraints concurrently, promoting environmentally friendly practices.

Over the years, various soil-improving and water conservation measures, including manure and mulch application and drainage channels known as trenches, have been recommended to mitigate declining soil fertility and water shortage (Bationo et al., 2007; Kihara et al., 2022). Manure enhances soil nutrient content and organic matter, which improves soil structure, promotes better aeration, increases water infiltration, and enhances the soil's water-holding capacity (Bationo et al., 2007). These improvements collectively increase nutrient use efficiency, which is especially critical in the low-input banana farming systems common across the country's agroecological zones (van Asten et al., 2011). Mulching suppresses weeds, offering a labor-saving benefit, and improves water infiltration and retention. Over time, mulch decomposes to release nutrients into the soil, contributing to higher yield (Ngetich et al., 2014). Trenches enhance rainwater infiltration and storage in the soil, reducing the adverse effects of drought stress, a major constraint in rain-fed banana production (van Asten et al., 2011). While trenches are more effective than mulch in capturing runoff and improving infiltration on sloping terrain, mulch is superior in minimizing soil water loss through evaporation (Kihara et al., 2022). Furthermore, mulch derived from external biomass sources, beyond the recycling of banana residues, introduces additional nutrients to the system. Combining mulch with manure enhances soil nutrient stocks more substantially than either input alone. Empirical evidence shows that while each of these soil-improving and water conservation practices contributes significantly to improving soil fertility, water use efficiency, and productivity, none of them on their own is sufficient in achieving all the requirements (Bationo et al., 2007; Kihara et al., 2022). Given their complementary effects, integrating manure, mulch, and trenches into an integrated soil fertility and water conservation (ISFWC) package will likely produce substantial productivity gains. For instance, Bationo et al. (2007) reported significantly higher yields when combining all three practices.

Although there is vast evidence suggesting positive yield returns, adoption of these practices by smallholder farmers has stagnated over the years and this has been primarily attributed to improper information dissemination (Adolwa et al., 2018) and knowledge constraints that lead to incomplete uptake of packages like ISFWC (Hörner et al., 2019). Poor communication of the performance and benefits of agricultural technologies to the end users has created wide communication gaps between the change agents and the farmers (Adolwa et al., 2018). Foster and Rosenzweig (2010) noted that such barriers to learning about correct technology usage or benefits constrain the adoption of seemingly basic practices like those considered in our study, namely, trenches, mulch, and manure application, especially when promoted as a package. Previous research shows that although farmers may simultaneously adopt several practices at the household level, they tend to employ them on different plots rather than combining them on one plot, and as such miss out on their synergistic potential (Hörner et al., 2019). Furthermore, we observed that some farmers in our study were excessively drying manure and applying it when it had lost most of its potential, while others were just scattering mulch without regard to the recommended depth/thickness. These sub-optimal practices would result in minimal yield improvements that normally discourage farmers. Moreover, extension activities typically focus on raising awareness about agricultural practices and offering guidance on how to implement them, but they often overlook the importance of explaining why these practices are advantageous (Hörner et al., 2019). To address these concerns, we provided intricate details regarding each technology emphasizing "*the how*" and "*the why*" including the necessary materials and the mode of preparation (e.g., for manure), the appropriate timing for employing each practice, the optimal amounts, and the frequency of application that would minimize costs and maximize the benefits per unit area. We also highlighted the synergistic benefits of employing the three technologies jointly (ISFWC package). Our extension-based campaign uses multiple communication channels—including radio talk shows, video screenings, "lecture" trainings, demonstration trials, and farmer field days—to disseminate uniform information on the soil-improving and water conservation practices through a randomized controlled trial (RCT). We selected these complementary channels because they have been widely documented as effective means for increasing awareness, knowledge, and the adoption of agricultural technologies (Harou et al., 2022; Kondylis et al., 2017; van Campenhout et al., 2021). Although we do not assess the effectiveness of each channel independently, previous experimental research shows that combining ICT-based extension approaches with in-person trainings has a significant impact on the uptake of farming practices (Lecoutere et al., 2023; Parsa et al., 2014).

The extension-based campaign was a component of the banana agronomy scaling project, aimed at improving smallholder farmers' welfare by boosting banana productivity. To achieve the project's objectives of reducing the yield gap and extension gap, information on several yield-enhancing agronomic practices was disseminated through the campaign, using multiple communication channels. The campaign was implemented with a team of scaling partners consisting of district local government extension officers, personnel from Non-Governmental Organizations, zonal agricultural research institutes, farmers' associations, and media houses. Promotional items such as branded

T-shirts and caps, posters, factsheets, and training manuals were developed and distributed to scaling partners.

The project started in 2017 in six major banana-growing districts of Nakaseke and Luwero in central, Kabarole and Bunyangabu in mid-western, and Rugando and Isingiro and Rwampara in south-western Uganda. These districts were selected because of their dominance in banana production in the country. One district from each region was randomly selected as the treatment (including Nakaseke, Bunyangabo, and Isingiro) and the other as the control. In each treatment district, one subcounty was randomly selected as the treatment unit, including Nakaseke subcounty in Nakaseke district, Rwimi in Bunyangabo, and Birere in Isingiro, while one subcounty from each control district was randomly selected as the counterfactual. The control group consisted of Makulubita subcounty in Luwero, Busoro in Kabarole, and Rugando in Rwampara district. Figure 1 is a map of Uganda showing the study areas.

## 3 | EXPERIMENTAL DESIGN

Figure 2 presents the timeline of the experiment. The study commenced with two baseline surveys. From March to April 2017, we conducted a socioeconomic survey among 471 randomly selected households to understand farmers' agronomic practices, their sources of agricultural information, yields, and household demographic characteristics. From April to June 2017, a team of agronomists carried out a biophysical survey among the same households to assess the agronomic practices in place and take allometric measurements in banana plantations for yield estimations. Between July and December 2017, we conducted stakeholder mapping and engagement through focus group discussions with farmers in the treatment sites to identify their sources of agricultural information, the type of information they received, how often they received it, and their preferred channels. We also contacted extension officers in the treatment sites and generated a list of stakeholders and scaling partners from these consultations. We held a stakeholders' workshop in January 2018, and another in September 2018, to develop a technology brief and communication materials respectively, that

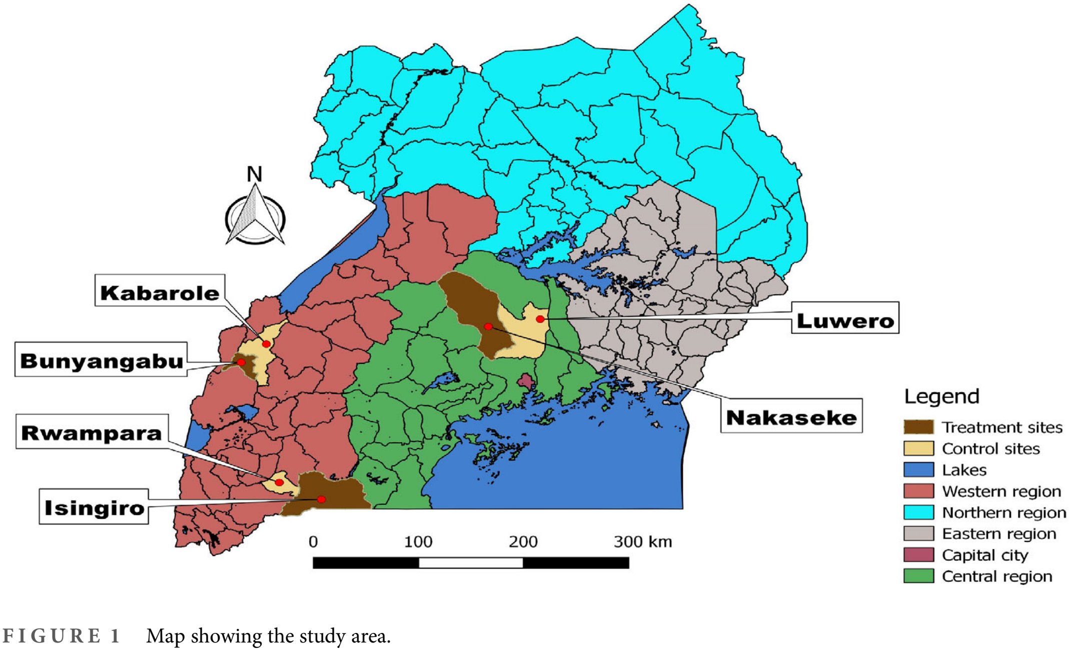


FIGURE 1 Map showing the study area.

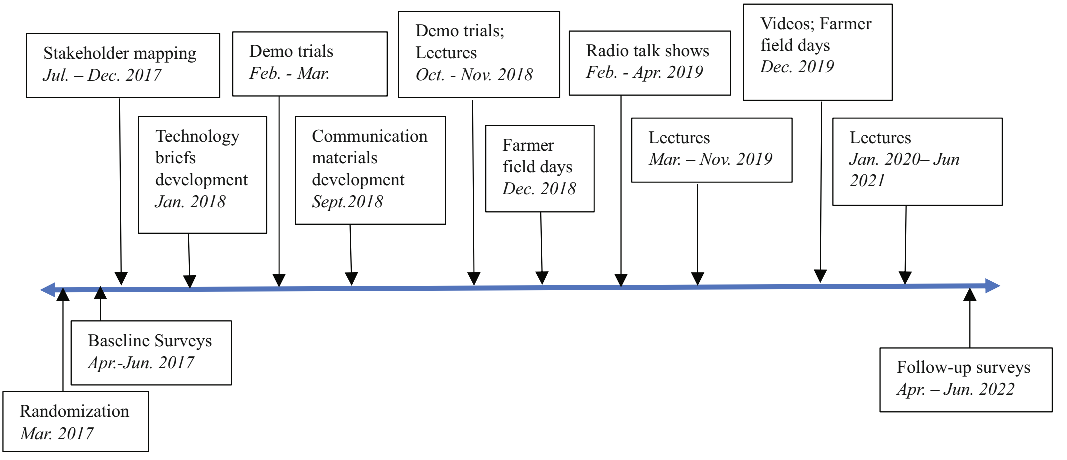


FIGURE 2 Timeline of the experiment.

guided the implementation of the practices. The communication materials, including posters, fact sheets, a training manual, a story chart, a radio script, and a video drama script, contained information on banana agronomic practices. Experts translated these materials into local dialects, after which we pretested, and refined them before dissemination.

We commenced the campaign with launches in the treatment sub-counties in February 2018. During these launches, the farmers highlighted and ranked the banana production constraints faced, and control measures employed and developed action points. Subsequently, using multiple channels, we disseminated information on the practices that farmers would use to combat the constraints. Both men and women attended the various trainings conducted.

## 3.1 | Audio dissemination channel

### Radio talk show

We broadcast a 12-week radio talk show from February to April 2019 via five radio stations, two with broad coverage in the central region, two based in the mid-western region, and one in the south-western region. The coverage of these stations and the actual audience for the talk shows spanned across the major banana-growing regions in the country. Therefore, farmers within the treatment and control sites were exposed to the radio broadcast. We selected the audio medium as the base channel because a substantial portion of the sampled households (77%) at baseline owned and mentioned radio as a source of agricultural information. In addition to being a low-cost transmission means, the radio channel is effective in creating awareness among vast audiences (Dzanku et al., 2020), and it has been documented to spur technology adoption when utilized in a participatory manner (Perkins et al., 2011) and alongside audio-visual channels such as videos (Dzanku et al., 2020). Also, usually, various household members including women listen to the radio, especially in the evenings, regardless of who owns the radio, and this makes it an effective means of targeting a vast audience.

The broadcast was based on the radio script developed during the stakeholders' workshop. Each week, we aired a live 60-min talk show in the local language, providing details about a specific agronomic practice, and allowing for live phone-ins from the listeners whose questions were answered on air. For increased interaction, listeners also responded to poll questions by sending a free SMS through the provided toll-free short code indicating their location and gender in addition to their answers. The poll questions explored constraints such as limitations to producing marketable banana bunches, and challenges faced in applying manure, and soil and water conservation practices. In total, 20,525 farmers from 56 districts responded to the poll questions, and a map of this listenership coverage is provided in Figure A1 in the online supplementary appendix. The stations recorded each talk show and aired a repeat within the same week. Throughout the week, they aired adverts encouraging listeners to tune in. Focus group discussions with farmers in the treatment sites determined the radio stations and the best time for the program, based on the stations and shows most of the farmers listened to. Each talk show featured a panel of at least three people: a research team member, an extension agent, and a farmer.

## 3.2 | Audio-visual dissemination channels

### Video shows

The research team contracted a filmmaker to produce the video drama "*Banana and I*" based on the script that was developed in the stakeholders' workshop. The video content was customized to the local context and featured native farmers in the community as role models, which stimulates the cognitive activity of the audience, and the experience of actual peers conveying messages, promotes attitude and behavior change (Bernard et al., 2015). In the 75-min drama, an extension officer trains farmers in the various banana agronomic practices including soil-improving and water conservation measures with emphasis on how and when they should be done and their benefits. Furthermore, the households that employ the practices in their plantations obtain higher yields and improve their welfare more than those that do not apply the recommended practices. This conceptualizes the linkage between adoption, higher yields, and better incomes. Video screening took place in December 2019, using a projector and speakers. There were 10 video screenings in each treatment site in communal areas like schools, churches, trading centers, and sports grounds. We had two shows per day, one in the afternoon and another in the evening. We mobilized the audience mainly through announcements aired through a megaphone moving through the villages 2 days prior to the screening. The viewers shared what they had learned and asked questions in an interactive discussion at the end of each show.

### Lecture trainings

During the stakeholders' workshop, we developed a story chart, posters, and an extension manual, which were then used to facilitate farmer classroom/lecture trainings. The manual includes modules on various agricultural technologies, such as soil improvement and water conservation measures. The story chart presents good agronomic practices for banana production in the form of a story. In each treatment site, we recruited a site coordinator with a background in agricultural extension to coordinate project activities and disseminate information using these materials alongside scaling partners. The team conducted trainings fortnightly at the parish level, mostly in communal areas such as schools, and at the premises of farmers hosting demonstration trials. The trainings took between 90 and 120 min.

## 3.3 | Hands-on dissemination channels

In our RCT, during the campaign launch in each treatment site, the farmers selected among themselves their preferred hosts for the demonstration trials. This has been observed as a vital facilitator for peer-to-peer learning among farmers (Sutherland & Marchand, 2021). We established the first set of demonstration trials in March 2018 and another in October of the same year. The research team alongside farmers and scaling partners established at least 40 demonstration plots showcasing various agronomic practices in each of the three treatment sites. The hosts and the local leaders mobilized farmers in the neighborhood 3 days before the exercise. The sessions were highly participatory, with expert and peer discussions and hands-on engagements for each innovation. After establishment, the demos were monitored monthly by the extension agents and these plots acted as learning points, where more practical sessions were conducted.

The project team worked closely with local committees involving district officials including the production department, political leaders, and scaling partners in organizing the farmer field days that took place in December 2018 and 2019. They held a radio talk show at a local station in each sub-county 2 days before the event to mobilize the farmers. This attracted between 350 and 700 farmers who participated in each treatment site. The primary objective of the farmer field days was to showcase the soil-improving and water conservation practices, their practical application and use, following site-specific recommendations. We registered[1] farmers and other participants on arrival and organized them into groups of 20, and took them through a study tour in the host farmer's plantation. There were several study points handling different conservation measures. We placed posters at each learning spot with a farmer, an extension officer, and a researcher practically demonstrating the practices.

### 3.4 | The relevance of multiple dissemination channels

The use of multiple dissemination channels in our study is imperative because we focus on several technologies involving many procedures in the production of a perennial crop (banana). Explaining procedures such as manure preparation, the adequate moisture content of manure before application, or the illustration of the dimensions and gradient of trenches necessitates visualization to facilitate knowledge retention. Explaining such intricate details via the radio may increase awareness but may not suffice in driving the point home. Previous research has shown that the radio channel is effective in creating awareness across large audiences, but may not suffice in influencing behavioral change (Dzanku et al., 2020). Furthermore, the radio talk show is restricted to just 1 hour, limiting the time available to answer questions from the audience or make clarifications compared to in-person sessions. In addition, the production of perennial crops that take more than one season to grow necessitates continuous nudges, and using different communication channels reduces the monotony and facilitates learning. Moreover, each dissemination channel facilitated adoption through a different mechanism. The video medium bolsters mindset change by portraying the adoption of the practices as a key component and prerequisite for improving household welfare. Exposure to on-farm demonstrations provides evidence of the outcomes of adoption, especially in terms of yield, and spurs broader uptake in the community through peer learning (Kondylis et al., 2017). Thus, using multiple dissemination channels provides different avenues that prompt farmers to adopt the technologies promoted.

## 4 | DATA, DESCRIPTIVE STATISTICS, AND ESTIMATION STRATEGY

### 4.1 | Data

During the socioeconomic baseline survey conducted from March to April 2017, we interviewed 471 households, 52% of which were in the treatment group. Within each of the six sub-counties, the

[1]During the campaign, attendance was recorded for each audio-visual and hands-on session indicating the name and gender of the participants and where they reside. The records indicate that those who attended demonstration trials and lecture trainings were based in the treatment sub counties. We did not observe any direct spillovers to the control group through any of these channels, since the control areas were quite distant from the treatment sites.

respondents were selected using a random sampling approach from a comprehensive list of eligible banana-growing households provided by local council chairpersons. We used structured questionnaires to collect household and plot-level data, including household demographic, social, and economic characteristics, access to agricultural extension and sources of agricultural information, and the soil-improving and natural resource conservation practices. We conducted a follow-up survey between May and June 2022, in which we interviewed 430 households implying an attrition rate of 9%. Although the attrition rate is low, we still test whether attrition bias is likely to influence the impact of the treatment as reported in the online supplementary appendix, Table A1. The coefficients are generally small in magnitude and the effect of attrition on the treatment is not statistically significant. Attrition was only slightly higher among households that own livestock. An $F$ test with a $p$-value of 0.395 indicates that we cannot reject the null hypothesis that, jointly, attrition does not differ between the treatment and control groups.

## 4.2 | Balance of randomization

Table 1 shows the descriptive statistics and presents covariate balancing tests that assess the effectiveness of the randomization procedure. Our results provide evidence that the randomization procedure was balanced across the treatment and control groups, since most of the baseline variables are not significantly different between the two groups, which implies that randomization bias, which is common in small samples, is not a major concern in our study (Athey & Imbens, 2017). Utilization of the soil-improving and water conservation measures is balanced across the treatment and control groups. Similarly, the welfare outcomes, namely yield, marketed surplus, and household incomes are also balanced in both groups. A few covariates including total land owned, ownership of a motorcycle, and the total value of assets are not balanced; hence we include baseline covariates in the analyses to improve the precision of the estimates.

Although adoption of the practices at baseline seems moderate (between 40% and 48%), less than 10% of the households were implementing the practices following the recommended guidelines. For instance, only 6% of those who were applying mulch were aware of and implementing the recommended mulch depth of 8–15 cm and placement of 1.5–2 feet away from the plants. We aimed to address such prevailing knowledge gaps through our intervention. Furthermore, there were other constraints such as low farm-gate prices limiting the adoption of practices that require cash investment. We addressed these by facilitating the organization of farmers in cooperatives/collective marketing groups to increase their bargaining power and linkage to traders who offered higher farm-gate prices than the middlemen who were exploiting them. Through these cooperatives, the farmers were also able to access credit to purchase inputs such as manure.

## 4.3 | Estimation strategy

We estimate the impact of the interventions using the single difference model, which is a comparison of the treatment and control groups in the following specification.

$$Y_{ij1} = \alpha_1 + \beta_T Treatment_j + \beta_X X_{ij0} + \gamma D_d + \varepsilon_{ij1}, \tag{1}$$

where $Y_{ij1}$ is the outcome variable of interest for farm household $i$ in subcounty $j$ at follow-up; $\beta_T$ is the intention-to-treat (ITT) effect associated with the information dissemination interventions; $X_{ij0}$ is a vector of baseline explanatory variables; $D_d$ is a vector of district level dummies, with $\gamma$ as a parameter vector to be estimated, and $\varepsilon_{ij1}$ is the error term. The ITT estimates were identified by the difference between the treatment and control groups during the intervention period. This specification is reported as the Simple Mean Difference (SMD) in the results tables (Tables 2–12).

TABLE 1 Descriptive statistics and balance tests.

| | Pooled sample | | Treatment group | | Control group | | Mean difference |
|---|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD | Treated-control |
| Outcome variables | | | | | | | |
| *Manure application (1 = Yes)* | 0.425 | 0.495 | 0.398 | 0.491 | 0.453 | 0.499 | −0.055 |
| *Mulch application (1 = Yes)* | 0.482 | 0.500 | 0.480 | 0.501 | 0.484 | 0.501 | −0.005 |
| *Dug trenches (1 = Yes)* | 0.435 | 0.496 | 0.439 | 0.497 | 0.431 | 0.496 | 0.008 |
| *ISFWC practices (1 = Yes)* | 0.144 | 0.352 | 0.118 | 0.323 | 0.173 | 0.379 | −0.055* |
| *Banana yield in ton/acre* | 3.309 | 2.930 | 3.482 | 3.300 | 3.121 | 2.457 | 0.361 |
| *Marketed surplus (banana proportion sold)* | 0.333 | 0.276 | 0.344 | 0.268 | 0.320 | 0.283 | 0.024 |
| *Annual household income (million UGX)* | 4.745 | 8.676 | 5.413 | 9.437 | 4.015 | 7.714 | 1.399* |
| Control variables | | | | | | | |
| *Household size* | 4.894 | 2.161 | 5.025 | 2.191 | 4.751 | 2.124 | 0.273 |
| *Gender of household head (1 = Male)* | 0.781 | 0.414 | 0.809 | 0.394 | 0.751 | 0.433 | 0.058 |
| *Age of household head (years)* | 50.798 | 14.882 | 50.000 | 14.126 | 51.671 | 15.652 | −1.671 |
| *Household head's years of education* | 6.342 | 4.269 | 6.289 | 4.256 | 6.400 | 4.292 | −0.111 |
| *Total land owned (acres)* | 5.616 | 9.990 | 6.636 | 10.939 | 4.501 | 8.726 | 2.136** |
| *Household head is a farmer (1 = Yes)* | 0.851 | 0.356 | 0.870 | 0.337 | 0.831 | 0.375 | 0.039 |
| *Household owns a motorcycle (1 = Yes)* | 0.195 | 0.397 | 0.244 | 0.430 | 0.142 | 0.350 | 0.102*** |
| *Household owns a bicycle (1 = Yes)* | 0.533 | 0.499 | 0.541 | 0.499 | 0.524 | 0.501 | 0.016 |
| *Household owns a phone (1 = Yes)* | 0.856 | 0.352 | 0.862 | 0.346 | 0.849 | 0.359 | 0.013 |
| *Household owns a radio (1 = Yes)* | 0.766 | 0.424 | 0.752 | 0.433 | 0.782 | 0.414 | −0.030 |
| *Household owns a television (1 = Yes)* | 0.206 | 0.405 | 0.220 | 0.415 | 0.191 | 0.394 | 0.028 |
| *Log of total value of assets* | 13.164 | 2.320 | 13.384 | 2.308 | 12.924 | 2.314 | 0.459** |
| *Tropical Livestock Units (TLU)* | 1.439 | 6.252 | 1.683 | 8.345 | 1.172 | 2.392 | 0.511 |
| *Credit access-not constrained (1 = Yes)* | 0.569 | 0.496 | 0.606 | 0.490 | 0.529 | 0.500 | 0.077* |
| *Belong to a farmer group (1 = Yes)* | 0.463 | 0.499 | 0.472 | 0.500 | 0.453 | 0.499 | 0.018 |
| Number of observations | 471 | | 246 | | 225 | | |

*Note*: SD is the standard deviation.
*, **, *** denote that the difference is at 10%, 5% and 1% level, respectively.

In instances like ours with a single baseline and follow-up survey, an analysis of covariance (ANCOVA) produces more precise estimates than the difference-in-differences (DID) method (McKenzie, 2012). The ANCOVA specification is the same as the one shown in Equation (1), except that it includes the baseline values of the outcome variable as a control. If autocorrelation is low, implying that the baseline and endline values of the outcome variable are weakly correlated, then using ANCOVA increases the power and efficiency. Through simulations, McKenzie (2012) shows that ANCOVA provides smaller standard errors and higher power when autocorrelation is below 0.5 compared to the DID. The autocorrelation of all our outcomes is low except for trenches (0.522) and marketed surplus (0.514), as shown in Table A2 in the online supplementary appendix, and this justifies our use of ANCOVA. The model is specified as follows.

$$Y_{ij1} = \alpha_1 + \beta_T Treatment_j + \beta_X X_{ij0} + \beta_Y Y_{ij0} + \gamma D_d + \varepsilon_{ij1}, \quad (2)$$

where $Y_{ij0}$ is the baseline value of the outcome, the rest of the parameters are as described in Equation (1).

The ITT estimates provide an outlook of the development impact without full compliance; hence they are important for policymakers because most development programs offer training or other services but cannot enforce full compliance. The ITT effects do not account for possible non-compliance, a situation whereby not all farming households in the communities with the interventions participate in the sessions. Non-compliance is better accounted for by the average treatment effect on the treated (ATT), which measures the actual effect of training attendance (Duflo et al., 2007). We did not observe perfect compliance in our study,[2] so we also estimate the ATT, using actual training attendance[3] as a treatment variable, and four specifications are considered. In the first specification (ATT), the training attendance dummy takes a value of one if a household attended any training/information dissemination session, and zero if they did not attend any. In the second specification (ATT 1), the training attendance dummy takes a value of one if a household attended any session offered through lecture trainings and/or video shows, and zero otherwise. In the third specification (ATT 2), training attendance is equal to one if a household participated in practical sessions offered through farmer field days, and/or demonstration trials, and zero otherwise. With the fourth specification (ATT 3), the training attendance dummy equals one if a household participated in both audio-visual and practical sessions, and zero otherwise. The decision to attend training sessions is potentially endogenous, so we use the two-stage least squares (2SLS) approach which utilizes instrumental variables (IV) to deal with the potential endogeneity bias. We rely on the random assignment into the treatment groups as a valid instrument. The ATT effects are unbiased when the offer to participate in the treatment is random (random assignment of districts to treatments) and the offer to participate in the treatments is highly correlated with actual training attendance (Angrist et al., 1996). The offer to participate in the treatment should not be correlated with the outcome, except through the actual attendance of the sessions.

We also estimate the Local Average Treatment Effect (LATE) for the conservation practices by analyzing the uptake of conservation practices as the endogenous regressor. This reveals the effect of adopting the soil-improving and water conservation practices on household welfare.

Including covariates is likely to increase the precision of the estimates, if the covariates are sufficiently correlated with an outcome (Athey & Imbens, 2017). To determine the covariates to include in the regressions, we utilize the post-double selection (PDS) least absolute shrinkage and selection operator (LASSO) procedure, which prevents $p$-hacking and overfitting the models by omitting control variables that are not sufficiently correlated with treatment status, thereby yielding more parsimonious estimates (Belloni et al., 2014). Although the PDS-LASSO[4] is often used in high-dimensional settings, it can still be used in moderate sample sizes to avoid overfitting and control for important variables provided that the number of predictors is not overwhelmingly large (Belloni et al., 2014).

A potential pitfall related to inference in our study is drawing multiple outcomes of interest from the same data set which is likely to cause a type 1 error. This is common in experimental studies where significant results may occur due to chance, even though the treatment may have no effect on any of the outcomes of interest. Therefore, the null hypothesis may be rejected when it is true, due to multiple hypotheses testing. To address this concern, we control for the false discovery rate (FDR), which is the share of null hypotheses rejections that are false positives, by applying the sharpened two-stage $q$-values approach (Anderson, 2008). We also present the results of all the hypotheses tests under randomization-based inference (RI), which enables us to estimate the exact $p$-values

[2]Twenty percent of the households in the treatment group did not participate in any session, which constitutes non-compliance.

[3]Approximately 68 percent of treatment group respondents reported listening to the campaign's radio programs, compared to 45 percent in the control group. Of those within the treatment group who participated in the sessions, 35 percent participated in the audio-visual sessions, 35 percent attended the practical sessions, whereas 42 percent participated in both.

[4]We conduct this procedure in Stata 18 using the *pdslasso* command for the ITT estimates and *ivlasso* for the ATT estimates where we instrument ex-post treatment using ex-ante assignment to treatment.

under the sharp null of no treatment effect following Young (2019). The RI $p$-values are calculated involving random reassignment of treatment and re-estimation of the coefficient multiple (2000) times. We utilize RI because it is a useful technique when the method of randomization is known and when the sample size is small, as in the present study (Young, 2019).

### 4.4 | Treatment heterogeneity

Policymakers and analysts are normally interested in heterogeneous treatment effects for policy purposes. In this study, we examine potential sources of heterogeneity in our treatment effects to determine whether the average impact of the campaign concealed any variations in response to treatment. The effects were estimated using generalized random forest, which is a machine learning technique that utilizes causal forests to detect heterogeneous treatment effects. This method yields unbiased estimates of the heterogeneous treatment effects, which are individualized predictions of treatment effects. We analyze the impact heterogeneity across all the control variables that are listed in the descriptive statistics in Table 1.

### 4.5 | Ex-post power calculations

To determine whether an experiment was designed to have sufficient power to detect a given effect size, we report the ex-post Minimal Detectable Effects (MDEs) based on the realized sample size and estimated standard errors of the effects in the study, following McKenzie and Ozier (2019) and Buehren et al. (2025). Since ANCOVA increases the power and efficiency of the estimations (McKenzie, 2012), we examine the ex-post MDEs for all our outcomes given our realized sample size per cluster and estimated standard errors at follow-up for the ANCOVA estimates. That is, given our study design of 3 clusters in the control group and 3 clusters in the treatment group, with a varying number of households in each cluster, we ask, how big of an impact we would have needed to have been powered to detect an effect, assuming a power level of 80% and significance level 0.05?

The results in Table A6 in the online supplementary appendix show that the study has adequate statistical power to detect intent-to-treat (ITT) effects on the adoption of manure, mulch, and the ISFWC package, as well as all the welfare outcomes. It was slightly underpowered for detecting the ITT effect for the uptake of trenches, possibly the reason why this effect is not significant based on conventional $p$-values. However, considering the main focus of our paper, assessing the impact of participation in the various sessions (ATT), the study was adequately powered to detect effects on all the adoption and welfare outcomes.

## 5 | RESULTS

### 5.1 | Adoption of soil-improving and water conservation measures

In this section, we report the results of our assessment of the impact of our information campaign on the uptake of the soil-improving and water conservation practices namely manure, mulch, trenches, and a package of the three combined, and denoted as ISFWC (integrated soil fertility and water conservation). Smallholder farmers decide to adopt new or improved technologies when they have adequate information about the benefits and suitability of the various integral aspects of the technologies (Abdulai, 2023; Conley & Udry, 2010). Our analysis reveals how this information translated into practice adoption across treatment and control groups. As shown in Figure 3, there was increased uptake of the soil-improving and water conservation measures between the baseline and follow-up periods in both the treatment and control groups, with the notable exception of manure,

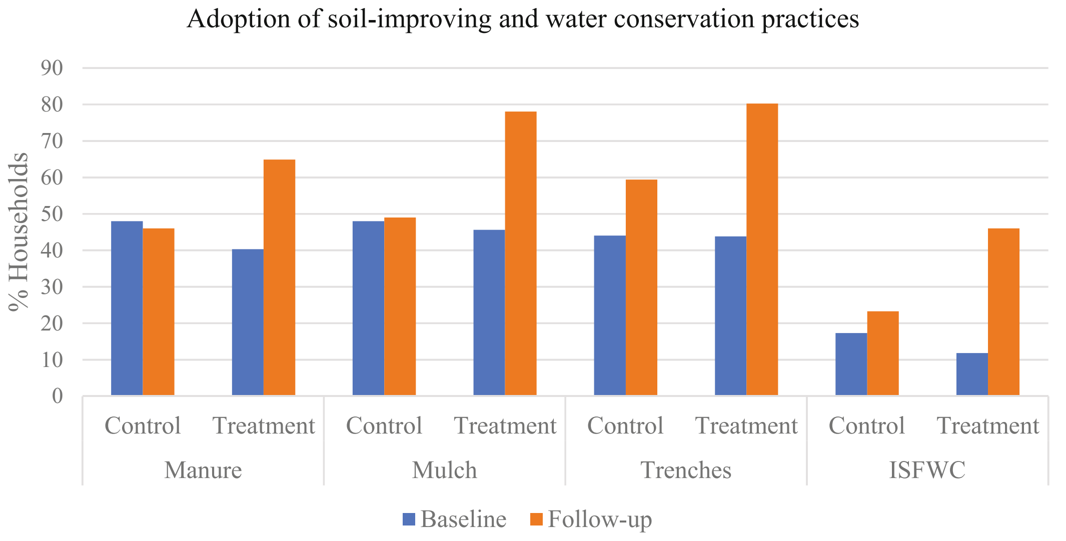


**FIGURE 3** Uptake of soil-improving and water conservation practices in treatment and control groups ($n = 430$).

where a slight decline is observed among the control group. Generally, higher levels of uptake are observed in the treatment group compared to the control. Specifically, out of the entire sample, 13%, 17%, 19%, and 18% more households in the treatment group adopted manure, mulch, trenches, and a combination of the three practices, respectively, by the time the follow-up survey was conducted. Figure 3 illustrates a consistent increase in adoption across all practices in the treatment group, with mulch showing the largest gain.

## 5.2 | Impact of information access on the uptake of the practices

Next, we present the treatment effects on the uptake of the soil-improving and water conservation practices (ITT) and the average treatment effects on the treated (ATT). Both the simple mean difference (SMD) and analysis of covariance (ANCOVA) are estimated. In all cases, inference is based on subcounty-level clustered standard errors and $p$ values adjusted for multiple hypothesis testing in curly brackets. We also present $p$-values based on randomization inference, that is, RI $p$-values in diamond brackets. Each table also contains estimates without covariate adjustment (Panel A) and with covariate adjustment (Panel B). The covariates selected through this procedure are reported in Tables A4 and A5 in the online supplementary appendix.

The ITT results in Table 2 show that agricultural information delivery through the campaign significantly influenced the adoption of the soil-improving and water conservation measures. In particular, the results of the SMD and ANCOVA are quite similar, with the ANCOVA analysis showing positive and statistically significant correlations between baseline and follow-up values of the outcome variables in most of the estimations (coefficients shown in Table A3 in the online supplementary appendix), implying that the baseline value explains a large proportion of the variance in the follow-up value. Hence, including the baseline values of the outcome variables tends to improve the power of most of the estimations in our analysis.

As shown in Table 2, on average, the information dissemination intervention increased the use of manure by between 15 and 16 percentage points (Panel A) and 19 percentage points (Panel B) all of which are statistically significant at the 1% level, even after multiple inference correction. The intervention also significantly increased the uptake of mulch by between 21 and 22 percentage points without covariate adjustment, and to 24 percentage points with covariate adjustment. Conversely, there is no significant effect on the adoption of trenches, when all the covariates are considered (Panel A) and the estimates do not survive RI correction. However, with covariate adjustment (Panel B), the effect is significant at the 1% level, and it is about five percentage points and six percentage points higher than the control for trenches. The adoption of the package of the three practices combined (ISFWC) significantly increased by between 12 and 14 percentage points without and with covariate adjustment respectively, even after accounting for FDR and RI correction. These findings are consistent with the results from Pan et al. (2018), who showed that farmers residing in eligible villages are 9.2 percentage points more likely to use manure, while Hörner et al. (2019) found that farmers in the treatment groups were 14.3–19.2 percentage points more likely to adopt compost manure and 8.4–10.9 percentage points more likely to adopt the integrated soil fertility management package compared to those in the control group.

Tables 3–6 report the ATT, which is the impact of actual participation in the sessions. The attendance of any training session (Table 3) has a positive and significant impact on the adoption of each practice and the ISFWC package without covariate adjustment (Panel A).

Participation in either audio-visual sessions (Table 4) or hands-on sessions (Table 5) increased uptake of each of the practices, as well as the package, although the effect is generally only significant at the 10% level when covariate adjustment is done alongside randomization inference correction. Furthermore, the levels of adoption of the practices are slightly higher among those who attended the audio-visual sessions than those who participated in the hands-on sessions. This finding is somewhat surprising because human beings are likely to learn better by doing (Sutherland & Marchand, 2021). However, it is important to note that the audio-visual sessions involved the continuous use of illustrations such as posters and story charts in the lecture trainings. Also, through the video medium, farmers can visualize and memorize the content shown (van Campenhout et al., 2021) and featuring their peers in the video conveying messages promotes attitude and behavior

**TABLE 2** Effects of the extension-based campaign on the adoption of soil-improving and water conservation measures.

| | Manure | | Mulch | | Trenches | | ISFWC | |
|---|---|---|---|---|---|---|---|---|
| | SMD | ANCOVA | SMD | ANCOVA | SMD | ANCOVA | SMD | ANCOVA |
| Panel A | | | | | | | | |
| *ITT* | 0.162 | 0.153 | 0.207 | 0.217 | 0.044 | 0.047 | 0.117 | 0.117 |
| | (0.031) | (0.025) | (0.016) | (0.016) | (0.027) | (0.025) | (0.025) | (0.025) |
| | [0.003] | [0.002] | [0.000] | [0.000] | [0.172] | [0.116] | [0.006] | [0.005] |
| | {0.002} | {0.001} | {0.001} | {0.001} | {0.026} | {0.017} | {0.003} | [0.002] |
| | ⟨0.003⟩ | ⟨0.001⟩ | ⟨0.000⟩ | ⟨0.000⟩ | ⟨0.166⟩ | ⟨0.103⟩ | ⟨0.005⟩ | ⟨0.007⟩ |
| *Observations* | 430 | 430 | 430 | 430 | 430 | 430 | 430 | 430 |
| *Control mean* | 0.460 | 0.460 | 0.490 | 0.490 | 0.594 | 0.594 | 0.233 | 0.233 |
| Panel B | | | | | | | | |
| *ITT* | 0.191 | 0.190 | 0.237 | 0.244 | 0.050 | 0.049 | 0.135 | 0.136 |
| | (0.002) | (0.003) | (0.001) | (0.002) | (0.000) | (0.000) | (0.000) | (0.001) |
| | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] |
| | {0.001} | {0.001} | {0.001} | {0.001} | {0.001} | {0.001} | {0.001} | {0.001} |
| | ⟨0.000⟩ | ⟨0.000⟩ | ⟨0.000⟩ | ⟨0.000⟩ | ⟨0.000⟩ | ⟨0.000⟩ | ⟨0.000⟩ | ⟨0.000⟩ |
| *Observations* | 430 | 430 | 430 | 430 | 430 | 430 | 430 | 430 |
| *Control mean* | 0.460 | 0.460 | 0.490 | 0.490 | 0.594 | 0.594 | 0.233 | 0.233 |

*Note*: ISFWC is a package combination of manure, mulch, and trenches. SMD is the Simple Mean Difference. ANCOVA is Analysis of Covariance. Standard errors (in parentheses) are clustered at the subcounty level. The *p*-values [in square brackets] are unadjusted for multiple testing; FDR-corrected "*p*-values" {i.e., *q*-values} are in curly brackets while Randomization-t *p*-values following Young (2019), based on 2000 draws, are in ⟨diamond brackets⟩. FDR denotes false discovery rate. Panels A and B contain estimates without and with covariate adjustment, respectively.

TABLE 3 Effects of participation in any training session on the adoption of soil-improving and water conservation measures.

| | Manure | | Mulch | | Trenches | | ISFWC | |
|---|---|---|---|---|---|---|---|---|
| | SMD | ANCOVA | SMD | ANCOVA | SMD | ANCOVA | SMD | ANCOVA |
| Panel A | | | | | | | | |
| *ATT* | 0.188 | 0.177 | 0.240 | 0.248 | 0.050 | 0.055 | 0.135 | 0.135 |
| | (0.032) | (0.026) | (0.015) | (0.016) | (0.028) | (0.026) | (0.026) | (0.025) |
| | [0.000] | [0.000] | [0.000] | [0.000] | [0.074] | [0.033] | [0.000] | [0.000] |
| | {0.001} | {0.001} | {0.001} | {0.001} | {0.023} | {0.011} | {0.001} | {0.001} |
| | ⟨0.000⟩ | ⟨0.000⟩ | ⟨0.000⟩ | ⟨0.000⟩ | ⟨0.025⟩ | ⟨0.010⟩ | ⟨0.000⟩ | ⟨0.001⟩ |
| *Obs* | 430 | 430 | 430 | 430 | 430 | 430 | 430 | 430 |
| *Control mean* | 0.460 | 0.460 | 0.490 | 0.490 | 0.594 | 0.594 | 0.233 | 0.233 |
| Panel B | | | | | | | | |
| *ATT* | 0.221 | 0.215 | 0.267 | 0.273 | 0.053 | 0.058 | 0.145 | 0.147 |
| | (0.004) | (0.004) | (0.004) | (0.006) | (0.005) | (0.006) | (0.005) | (0.005) |
| | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] |
| | {0.001} | {0.001} | {0.001} | {0.001} | {0.001} | {0.001} | {0.001} | {0.001} |
| | ⟨0.129⟩ | ⟨0.129⟩ | ⟨0.129⟩ | ⟨0.180⟩ | ⟨0.129⟩ | ⟨0.150⟩ | ⟨0.129⟩ | ⟨0.129⟩ |
| *Obs* | 430 | 430 | 430 | 430 | 430 | 430 | 430 | 430 |
| *Control mean* | 0.460 | 0.460 | 0.490 | 0.490 | 0.594 | 0.594 | 0.233 | 0.233 |

*Note*: ISFWC is a package combination of manure, mulch, and trenches. SMD is the Simple Mean Difference. ANCOVA is Analysis of Covariance. Standard errors (in parentheses) are clustered at the subcounty level. The *p*-values [in square brackets] are unadjusted for multiple testing; FDR-corrected "*p*-values" {i.e., *q*-values} are in curly brackets while Randomization-t *p*-values following Young (2019), based on 2000 draws, are in ⟨diamond brackets⟩. FDR denotes false discovery rate. Panels A and B contain estimates without and with covariate adjustment, respectively.

change (Baul et al., 2024; Bernard et al., 2015; Rudolf et al., 2020) This could have facilitated retention of information and subsequent adoption of the soil-improving and water conservation practices.

Attendance of both audio-visual and hands-on sessions significantly influenced the adoption of all the individual practices and the ISFWC package at the 5% level at worst, even after correcting for multiple hypothesis testing (Table 6). Participation in both kinds of sessions increased the uptake of manure use by between 21 and 22 percentage points (Panel A) and between 25 and 26 percentage points (Panel B), compared to the control group exposed to only the audio channel. Furthermore, utilization of mulch increased by between 28 and 32 percentage points, whereas the establishment of water trenches increased by 6–7 percentage points among farmers who took part in both kinds of sessions. Also, adoption of the ISFWC package increased by between 16 and 18 percentage points among these participants compared to the control group. Our results are consistent with Beaman et al. (2021) who found that the adoption of pit planting, a soil conservation practice, was between 12.6% and 39.1% higher among the treated group depending on the dissemination channel.

Overall, we observe higher adoption rates across all technologies among those who attended both audio-visual and hands-on sessions, followed by those who attended audio-visual sessions. These results are illustrated graphically in Figure A2 in the online supplementary appendix.

### 5.3 | Access to information, adoption of soil improving and water conservation measures, and household welfare

The results in the previous section reveal a significant impact of information flow on the adoption of soil-improving and water conservation practices. Uptake of practices is a direct channel through which yields, and subsequently the marketed surplus and household incomes are likely to increase.

**TABLE 4** Effects of participation in audio-visual sessions on the adoption of soil-improving and water conservation measures.

| | Manure | | Mulch | | Trenches | | ISFWC | |
|---|---|---|---|---|---|---|---|---|
| | SMD | ANCOVA | SMD | ANCOVA | SMD | ANCOVA | SMD | ANCOVA |
| Panel A | | | | | | | | |
| *ATT1* | 0.206 | 0.194 | 0.263 | 0.270 | 0.055 | 0.060 | 0.148 | 0.148 |
| | (0.033) | (0.027) | (0.017) | (0.017) | (0.031) | (0.028) | (0.028) | (0.027) |
| | [0.000] | [0.000] | [0.000] | [0.000] | [0.076] | [0.034] | [0.000] | [0.000] |
| | {0.001} | {0.001} | {0.001} | {0.001} | {0.015} | {0.008} | {0.001} | {0.001} |
| | ⟨0.000⟩ | ⟨0.000⟩ | ⟨0.000⟩ | ⟨0.000⟩ | ⟨0.025⟩ | ⟨0.012⟩ | ⟨0.000⟩ | ⟨0.000⟩ |
| *Observations* | 430 | 430 | 430 | 430 | 430 | 430 | 430 | 430 |
| *Control mean* | 0.460 | 0.460 | 0.490 | 0.490 | 0.594 | 0.594 | 0.233 | 0.233 |
| Panel B | | | | | | | | |
| *ATT 1* | 0.250 | 0.241 | 0.301 | 0.307 | 0.060 | 0.066 | 0.164 | 0.166 |
| | (0.005) | (0.004) | (0.005) | (0.007) | (0.005) | (0.006) | (0.005) | (0.005) |
| | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] |
| | {0.001} | {0.001} | {0.001} | {0.001} | {0.001} | {0.001} | {0.001} | {0.001} |
| | ⟨0.075⟩ | ⟨0.047⟩ | ⟨0.075⟩ | ⟨0.060⟩ | ⟨0.083⟩ | ⟨0.064⟩ | ⟨0.075⟩ | ⟨0.060⟩ |
| *Observations* | 430 | 430 | 430 | 430 | 430 | 430 | 430 | 430 |
| *Control mean* | 0.460 | 0.460 | 0.490 | 0.490 | 0.594 | 0.594 | 0.233 | 0.233 |

*Note*: ISFWC is a package combination of manure, mulch, and trenches. SMD is the Simple Mean Difference. ANCOVA is Analysis of Covariance. Standard errors (in parentheses) are clustered at the subcounty level. The $p$-values [in square brackets] are unadjusted for multiple testing; FDR-corrected "$p$-values" {i.e., $q$-values} are in curly brackets while Randomization-t $p$-values following Young (2019), based on 2000 draws, are in ⟨diamond brackets⟩. FDR denotes false discovery rate. Panels A and B contain estimates without and with covariate adjustment, respectively.

Table 7 reports the treatment effects of the intervention on these welfare outcomes. The campaign resulted in an increase in yields between 674 and 757 kg/acre among the treatment communities relative to the control. This corresponds to a 9.1%–10.2% increase in yield among the treated group. These gains are comparable to those observed among rice farmers in India, where productivity improved by 12%–18% following the dissemination of information on sustainable rice intensification through video-based interventions (Baul et al., 2024). Increased yields are expected to result in a higher marketed surplus. The marketed surplus, computed as the proportion of the harvest sold, increased by between 11 and 15 percentage points (panel A) and 13 and 17 percentage points (panel B) in the treatment groups as a result of the intervention. The annual incomes of the households that were exposed to the campaign increased by between 1.1 and 1.8 (panel A) and 1.2 and 2.4 million Uganda shillings (panel B), compared to those in the control group. Such increases in income are more than sufficient to cover the incremental costs of uptake of the practices as highlighted in Section 5.6. Furthermore, this effect of the campaign intervention on income is of economic significance, since it translates into an 18.8%–39.4% increment among the households in the treatment group compared to the control group.

The ATT estimates are presented in Tables 8–11. Participation in the training session resulted in significant increases in the welfare outcomes (Table 8, Panel A). However, $p$-values from the covariate adjustment (diamond brackets) suggest a statistically insignificant impact (Table 8, Panel B).

Without covariate adjustment, the increase in yield resulting from attending either audio-visual or hands-on sessions was significant at the 1% level, even after controlling for multiple hypothesis testing (Tables 9 and 10, Panel A). However, with covariate adjustment, the increment is only significant at the 10% level, after RI correction (Panel B).

**TABLE 5** Effects of participation in hands-on sessions on the adoption of soil-improving and water conservation measures.

| | Manure | | Mulch | | Trenches | | ISFWC | |
|---|---|---|---|---|---|---|---|---|
| | **SMD** | **ANCOVA** | **SMD** | **ANCOVA** | **SMD** | **ANCOVA** | **SMD** | **ANCOVA** |
| Panel A | | | | | | | | |
| *ATT 2* | 0.197 | 0.187 | 0.252 | 0.260 | 0.053 | 0.058 | 0.142 | 0.142 |
| | (0.032) | (0.027) | (0.018) | (0.020) | (0.029) | (0.026) | (0.026) | (0.025) |
| | [0.000] | [0.000] | [0.000] | [0.000] | [0.069] | [0.029] | [0.000] | [0.000] |
| | {0.001} | {0.001} | {0.001} | {0.001} | {0.014} | {0.008} | {0.001} | {0.001} |
| | ⟨0.000⟩ | ⟨0.000⟩ | ⟨0.000⟩ | ⟨0.000⟩ | ⟨0.025⟩ | ⟨0.011⟩ | ⟨0.000⟩ | ⟨0.000⟩ |
| *Observations* | 430 | 430 | 430 | 430 | 430 | 430 | 430 | 430 |
| *Control mean* | 0.460 | 0.460 | 0.490 | 0.490 | 0.594 | 0.594 | 0.233 | 0.233 |
| Panel B | | | | | | | | |
| *ATT 2* | 0.231 | 0.225 | 0.278 | 0.285 | 0.055 | 0.061 | 0.152 | 0.153 |
| | (0.004) | (0.004) | (0.004) | (0.006) | (0.005) | (0.006) | (0.005) | (0.005) |
| | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] |
| | {0.001} | {0.001} | {0.001} | {0.001} | {0.001} | {0.001} | {0.001} | {0.001} |
| | ⟨0.082⟩ | ⟨0.060⟩ | ⟨0.082⟩ | ⟨0.100⟩ | ⟨0.082⟩ | ⟨0.100⟩ | ⟨0.082⟩ | ⟨0.100⟩ |
| *Observations* | 430 | 430 | 430 | 430 | 430 | 430 | 430 | 430 |
| *Control mean* | 0.460 | 0.460 | 0.490 | 0.490 | 0.594 | 0.594 | 0.233 | 0.233 |

*Note*: ISFWC is a package combination of manure, mulch, and trenches. SMD is the Simple Mean Difference. ANCOVA is Analysis of Covariance. Standard errors (in parentheses) are clustered at the subcounty level. The *p*-values [in square brackets] are unadjusted for multiple testing; FDR-corrected "*p*-values" {i.e., *q*-values} are in curly brackets while Randomization-t *p*-values following Young (2019), based on 2000 draws, are in ⟨diamond brackets⟩. FDR denotes false discovery rate. Panels A and B contain estimates without and with covariate adjustment, respectively.

Similar to the marketed surplus estimates, the effect of attending either audio-visual or practical sessions significantly increased household incomes at the 1% level without covariate adjustment, even after controlling for FDR and RI correction (Panel A, Tables 9 and 10). With covariate adjustment, this effect is only significant at the 10% level after RI correction, except in the ANCOVA estimation of hands-on sessions where no significant effect is observed (RI $p$-value $= 0.100$).

The estimates in Table 11 show that participation in both sessions significantly increased yields by between 898 and 1013 kg/acre (Panel A) and 1067 and 1172 kg/acre (Panel B) at the 5% level with RI correction. As expected, the yield increments are higher among the farming households that attended the lecture trainings/watched the video shows and participated in the demos/farmer field days than those who only listened to the radio talk shows. The average yield increase was between 12.1% and 13.7% (panel A) and 14.4% and 15.8% (panel B). Intuitively, attending both kinds of sessions enabled farmers to not only listen but also visualize and understand the technical aspects of the practices and their potential benefits, resulting in increased adoption and higher yields (Baul et al., 2024; van Campenhout et al., 2021).

Participation in both sessions significantly increased the marketed surplus by between 15% and 21% (panel A) and 17% and 22% (panel B) as shown in Table 11. Attendance of both audio-visual and practical sessions significantly increased household incomes at the 5% level at worst, after controlling for FDR and RI (Table 11). The increment was between 1.5 and 2.4 million shillings (Panel A) and 1.6 and 3.3 million shillings (panel B) among the participating households. Overall, the highest impact on household welfare is observed when farmers participate in both audio-visual and practical sessions.

**TABLE 6** Effects of participation in both audio-visual and hands-on sessions on adoption of soil-improving and water conservation measures.

| | Manure | | Mulch | | Trenches | | ISFWC | |
|---|---|---|---|---|---|---|---|---|
| | SMD | ANCOVA | SMD | ANCOVA | SMD | ANCOVA | SMD | ANCOVA |
| Panel A | | | | | | | | |
| *ATT 3* | 0.217 | 0.206 | 0.277 | 0.284 | 0.058 | 0.063 | 0.156 | 0.156 |
| | (0.034) | (0.028) | (0.020) | (0.022) | (0.032) | (0.029) | (0.028) | (0.027) |
| | [0.000] | [0.000] | [0.000] | [0.000] | [0.071] | [0.031] | [0.000] | [0.000] |
| | {0.001} | {0.001} | {0.001} | {0.001} | {0.014} | {0.008} | {0.001} | {0.001} |
| | ⟨0.000⟩ | ⟨0.000⟩ | ⟨0.000⟩ | ⟨0.000⟩ | ⟨0.028⟩ | ⟨0.009⟩ | ⟨0.001⟩ | ⟨0.000⟩ |
| *Observations* | 430 | 430 | 430 | 430 | 430 | 430 | 430 | 430 |
| *Control mean* | 0.460 | 0.460 | 0.490 | 0.490 | 0.594 | 0.594 | 0.233 | 0.233 |
| Panel B | | | | | | | | |
| *ATT 3* | 0.262 | 0.253 | 0.316 | 0.322 | 0.056 | 0.069 | 0.167 | 0.175 |
| | (0.004) | (0.004) | (0.005) | (0.007) | (0.007) | (0.007) | (0.006) | (0.006) |
| | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] |
| | {0.001} | {0.001} | {0.001} | {0.001} | {0.001} | {0.001} | {0.001} | {0.001} |
| | ⟨0.041⟩ | ⟨0.035⟩ | ⟨0.041⟩ | ⟨0.036⟩ | ⟨0.041⟩ | ⟨0.041⟩ | ⟨0.041⟩ | ⟨0.045⟩ |
| *Observations* | 430 | 430 | 430 | 430 | 430 | 430 | 430 | 430 |
| *Control mean* | 0.460 | 0.460 | 0.490 | 0.490 | 0.594 | 0.594 | 0.233 | 0.233 |

*Note*: ISFWC is a package combination of manure, mulch, and trenches. SMD is the Simple Mean Difference. ANCOVA is Analysis of Covariance. Standard errors (in parentheses) are clustered at the subcounty level. The *p*-values [in square brackets] are unadjusted for multiple testing; FDR-corrected "*p*-values" {i.e., *q*-values} are in curly brackets while Randomization-t *p*-values following Young (2019), based on 2000 draws, are in ⟨diamond brackets⟩. FDR denotes false discovery rate. Panels A and B contain estimates without and with covariate adjustment, respectively.

## 5.4 | Local average treatment effect (LATE) for the practices

To the extent that some farmers may participate in the trainings, but not adopt the conservation practices, we also analyze the effect of the adoption of the practices on household welfare by estimating the Local Average Treatment Effect (LATE) for the practices. The estimates for the three outcomes are summarized in Table 12. For brevity, we only show the results without covariate adjustment.

The results in Table 12 indicate that the uptake of manure, mulch, and the ISFWC package had positive and statistically significant effects on household welfare. The highest impact occurs with the uptake of the package which increases yield by 6 tons/acre, more than doubles the marketed surplus, and increases household income by over 11 million Uganda shillings per annum.[5] The adoption of trenches also positively influences household welfare, although the coefficients are not statistically significant.

In particular, our findings indicate that the increments in yield ranging between 3.3 and 6.5 tons per acre and household income ranging between 5.5 and 15.6 million Uganda shillings (US $1467–4160) per annum, resulting from the adoption of the individual conservation measures and the package are more than enough to offset the costs of their implementation, which are highlighted in Section 5.6.

[5]While we expect high income effects among the compliers, particularly those that adopted the package, we interpret these results with caution, because household income is not an immediate outcome and it is measured as a composite of multiple sources, including on-farm and off-farm income.

**TABLE 7** Impact of the extension-based campaign on farmers' welfare.

| | Yield (ton/acre) | | Marketed surplus (%) | | Household income (million UGX) | |
|---|---|---|---|---|---|---|
| | SMD | ANCOVA | SMD | ANCOVA | SMD | ANCOVA |
| Panel A | | | | | | |
| *ITT* | 0.757 | 0.674 | 0.109 | 0.150 | 1.136 | 1.825 |
| | (0.169) | (0.171) | (0.011) | (0.011) | (0.313) | (0.412) |
| | [0.007] | [0.011] | [0.000] | [0.000] | [0.015] | [0.007] |
| | {0.004} | {0.005} | {0.001} | {0.001} | {0.007} | {0.004} |
| | ⟨0.005⟩ | ⟨0.010⟩ | ⟨0.000⟩ | ⟨0.001⟩ | ⟨0.011⟩ | ⟨0.007⟩ |
| *Observations* | 430 | 430 | 430 | 430 | 430 | 430 |
| *Control mean* | 7.409 | 7.409 | 0.322 | 0.322 | 6.052 | 6.052 |
| Panel B | | | | | | |
| *ITT* | 0.754 | 0.690 | 0.133 | 0.167 | 1.216 | 2.385 |
| | (0.000) | (0.020) | (0.001) | (0.005) | (0.356) | (0.177) |
| | [0.000] | [0.000] | [0.000] | [0.000] | [0.001] | [0.000] |
| | {0.001} | {0.001} | {0.001} | {0.001} | {0.001} | {0.001} |
| | ⟨0.000⟩ | ⟨0.000⟩ | ⟨0.000⟩ | ⟨0.000⟩ | ⟨0.024⟩ | ⟨0.001⟩ |
| *Observations* | 430 | 430 | 430 | 430 | 430 | 430 |
| *Control mean* | 7.409 | 7.409 | 0.322 | 0.322 | 6.052 | 6.052 |

*Note*: 1 USD = 3750 UGX (Uganda shillings). SMD is the Simple Mean Difference. ANCOVA is Analysis of Covariance. Standard errors (in parentheses) are clustered at the subcounty level. The $p$-values [in square brackets] are unadjusted for multiple testing; FDR-corrected "$p$-values" {i.e., $q$-values} are in curly brackets while Randomization-t $p$-values following Young (2019), based on 2000 draws, are in ⟨diamond brackets⟩. FDR denotes false discovery rate. Panels A and B contain estimates without and with covariate adjustment, respectively. Marketed surplus = proportion of harvested bananas sold.

## 5.5 | Treatment heterogeneity

Treatment effects logically vary across individuals or groups because people differ in their characteristics, constraints, and contexts that influence how they respond to interventions. Measuring heterogeneous treatment effects is meaningful because it reveals for whom and under what conditions an intervention is most effective. This information helps avoid one-size-fits-all policy recommendations and instead supports more targeted, efficient, and equitable interventions. By understanding these differences, policymakers and practitioners can better allocate limited resources, prioritizing support for subgroups most likely to benefit, thereby enhancing both the cost-effectiveness and the impact of development programs.

As indicated previously, we analyzed the heterogeneous impacts of the campaign using the generalized random forest approach, which is a machine learning method. The estimates of the campaign-based extension approach by pre-treatment covariates for each outcome are presented in Table 13. We tested for heterogeneity across all the control variables, but we only report statistically significant results in the interest of brevity.

The study identified several heterogeneous treatment effects across key outcomes, with variations largely shaped by resource access, ownership of media devices, and household characteristics. These findings have important implications for targeting strategies and policy design.

Access to credit emerged as a significant driver of manure adoption and market participation. Specifically, the treatment had a positive and statistically significant impact on manure adoption and marketed surplus among households that were not credit-constrained. This is intuitive, since manure is costly; access to credit allows households to purchase it. Additionally, credit enables liquidity smoothing, whereby households can borrow money to meet immediate consumption needs, and

TABLE 8 Impact of participation in any training session on farmers' welfare.

| | Yield (ton/acre) | | Marketed surplus (%) | | Household income (million UGX) | |
|---|---|---|---|---|---|---|
| | SMD | ANCOVA | SMD | ANCOVA | SMD | ANCOVA |
| Panel A | | | | | | |
| *ATT* | 0.876 | 0.778 | 0.126 | 0.176 | 1.315 | 2.121 |
| | (0.176) | (0.176) | (0.012) | (0.011) | (0.324) | (0.428) |
| | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] |
| | {0.001} | {0.001} | {0.001} | {0.001} | {0.001} | {0.001} |
| | ⟨0.001⟩ | ⟨0.001⟩ | ⟨0.000⟩ | ⟨0.000⟩ | ⟨0.003⟩ | ⟨0.003⟩ |
| *Observations* | 430 | 430 | 430 | 430 | 430 | 430 |
| *Control mean* | 7.409 | 7.409 | 0.322 | 0.322 | 6.052 | 6.052 |
| Panel B | | | | | | |
| *ATT* | 0.922 | 0.835 | 0.143 | 0.187 | 1.353 | 2.829 |
| | (0.091) | (0.110) | (0.009) | (0.007) | (0.320) | (0.368) |
| | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] |
| | {0.001} | {0.001} | {0.001} | {0.001} | {0.001} | {0.001} |
| | ⟨0.129⟩ | ⟨0.113⟩ | ⟨0.129⟩ | ⟨0.150⟩ | ⟨0.129⟩ | ⟨0.451⟩ |
| *Observations* | 430 | 430 | 430 | 430 | 430 | 430 |
| *Control mean* | 7.409 | 7.409 | 0.322 | 0.322 | 6.052 | 6.052 |

*Note*: 1 USD = 3750 UGX (Uganda shillings). SMD is the Simple Mean Difference. ANCOVA is Analysis of Covariance. Standard errors (in parentheses) are clustered at the subcounty level. The *p*-values [in square brackets] are unadjusted for multiple testing; FDR-corrected "*p*-values" {i.e., *q*-values} are in curly brackets, while Randomization-t *p*-values following Young (2019), based on 2000 draws, are in ⟨diamond brackets⟩. FDR denotes false discovery rate. Panels A and B contain estimates without and with covariate adjustment, respectively. Marketed surplus is the proportion of harvested bananas sold.

reserve part of their produce for sale in the market. These findings suggest that targeting credit-constrained households, or coupling interventions with credit programs, could enhance manure uptake and improve commercialization outcomes. Similarly, asset-rich households—measured by the value of household assets—benefited more from the information campaign in terms of yield gains. This indicates that wealthier households may be better positioned to respond to agronomic advice, likely due to their superior access to complementary inputs and risk-buffering capacity.

Ownership of communication devices was also associated with differential impacts. Households that owned a television experienced significantly higher mulch adoption, while those with a radio showed greater increases in marketed surplus. These devices were key dissemination channels during the campaign, reinforcing the importance of media access in extension delivery. This highlights the potential of leveraging existing household infrastructure for scaling information campaigns, especially where physical extension outreach is limited.

The adoption of manure was higher among households headed by more educated individuals, suggesting that education may facilitate better comprehension or greater responsiveness to agronomic information. However, the lack of significance of the education attribute regarding the other practices is likely due to the design of the campaign, which was tailored to accommodate low-literacy audiences. Sessions were delivered in local languages with practical demonstrations and extensive use of visual aids, and they were interactive with question-and-answer segments. These methods have been shown to enhance learning regardless of education level (van Campenhout et al., 2021). This suggests that carefully designed communication strategies can mitigate disparities due to low formal education.

A negative differential impact was observed in the uptake of the full suite of soil-improving and water conservation (ISFWC) practices among households whose heads primarily engage in farming.

**TABLE 9** Impact of participation in audio-visual sessions on farmers' welfare.

| | Yield (ton/acre) | | Marketed surplus (%) | | Household income (million UGX) | |
|---|---|---|---|---|---|---|
| | SMD | ANCOVA | SMD | ANCOVA | SMD | ANCOVA |
| Panel A | | | | | | |
| *ATT 1* | 0.960 | 0.853 | 0.138 | 0.195 | 1.441 | 2.313 |
| | (0.192) | (0.192) | (0.011) | (0.013) | (0.356) | (0.466) |
| | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] |
| | {0.001} | {0.001} | {0.001} | {0.001} | {0.001} | {0.001} |
| | ⟨0.000⟩ | ⟨0.001⟩ | ⟨0.000⟩ | ⟨0.000⟩ | ⟨0.001⟩ | ⟨0.001⟩ |
| *Observations* | 430 | 430 | 430 | 430 | 430 | 430 |
| *Control mean* | 7.409 | 7.409 | 0.322 | 0.322 | 6.052 | 6.052 |
| Panel B | | | | | | |
| *ATT 1* | 1.041 | 0.944 | 0.161 | 0.213 | 1.483 | 3.166 |
| | (0.103) | (0.122) | (0.010) | (0.009) | (0.343) | (0.400) |
| | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] |
| | {0.001} | {0.001} | {0.001} | {0.001} | {0.001} | {0.001} |
| | ⟨0.075⟩ | ⟨0.075⟩ | ⟨0.083⟩ | ⟨0.059⟩ | ⟨0.066⟩ | ⟨0.082⟩ |
| *Observations* | 430 | 430 | 430 | 430 | 430 | 430 |
| *Control mean* | 7.409 | 7.409 | 0.322 | 0.322 | 6.052 | 6.052 |

*Note*: 1 USD = 3750 UGX (Uganda shillings). SMD is the Simple Mean Difference. ANCOVA is Analysis of Covariance. Standard errors (in parentheses) are clustered at the subcounty level. The *p*-values [in square brackets] are unadjusted for multiple testing; FDR-corrected "*p*-values" {i.e., *q*-values} are in curly brackets while Randomization-t *p*-values following Young (2019), based on 2000 draws, are in ⟨diamond brackets⟩. FDR denotes false discovery rate. Panels A and B contain estimates without and with covariate adjustment respectively. Marketed surplus = proportion of harvested bananas sold.

Though counterintuitive, this finding likely reflects multiple, overlapping constraints typical of farm-dependent households, including limited liquidity, seasonal labor shortages, and input scarcity. These constraints may hinder their ability to adopt the full package simultaneously. Accordingly, the study recommends a phased or incremental approach to adoption, encouraging gradual integration of practices over time.

No statistically significant heterogeneous treatment effects were found for the adoption of trenches or household income outcome estimations.

## 5.6 | Robustness of results

We subjected our results to two robustness checks. First, as mentioned earlier, we assessed whether our results are robust to adjusting for multiple hypothesis testing and randomization inference across all the outcome domains considered in the paper and found that our results are robust to this concern. Second, we estimated difference-in-differences (DID) models for all the outcomes in the study. These are presented in the online supplementary appendix (Tables A7–A11). The results are generally similar to those shown in Tables 2–12, but predictably, they are estimated with less precision. Empirical evidence shows that in instances where there is only one baseline and follow-up survey, and the correlation of the outcomes in the two time periods is less than 0.5, ANCOVA has more power and generates more precise results than the DID (McKenzie, 2012). In line with this, out of all the DID estimates, relatively consistent results were observed for the Trenches and the marketed surplus outcomes. This is expected because these are the only outcomes in our study whose autocorrelations are above 0.5, though by very small magnitudes, as shown in Table A2 in the online supplementary appendix.

TABLE 10 Impact of participation in hands-on sessions on farmers' welfare.

| | Yield (ton/acre) | | Marketed surplus (%) | | Household income (million UGX) | |
|---|---|---|---|---|---|---|
| | SMD | ANCOVA | SMD | ANCOVA | SMD | ANCOVA |
| Panel A | | | | | | |
| *ATT 2* | 0.920 | 0.816 | 0.132 | 0.185 | 1.381 | 2.220 |
| | (0.186) | (0.187) | (0.013) | (0.012) | (0.334) | (0.439) |
| | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] |
| | {0.001} | {0.001} | {0.001} | {0.001} | {0.001} | {0.001} |
| | ⟨0.001⟩ | ⟨0.002⟩ | ⟨0.000⟩ | ⟨0.000⟩ | ⟨0.001⟩ | ⟨0.002⟩ |
| *Observations* | 430 | 430 | 430 | 430 | 430 | 430 |
| *Control mean* | 7.409 | 7.409 | 0.322 | 0.322 | 6.052 | 6.052 |
| Panel B | | | | | | |
| *ATT 2* | 0.962 | 0.870 | 0.149 | 0.195 | 1.427 | 2.967 |
| | (0.096) | (0.115) | (0.009) | (0.007) | (0.332) | (0.384) |
| | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] |
| | {0.001} | {0.001} | {0.001} | {0.001} | {0.001} | {0.001} |
| | ⟨0.082⟩ | ⟨0.075⟩ | ⟨0.082⟩ | ⟨0.090⟩ | ⟨0.096⟩ | ⟨0.100⟩ |
| *Observations* | 430 | 430 | 430 | 430 | 430 | 430 |
| *Control mean* | 7.409 | 7.409 | 0.322 | 0.322 | 6.052 | 6.052 |

*Note*: 1 USD = 3750 UGX (Uganda shillings). SMD is the Simple Mean Difference. ANCOVA is Analysis of Covariance. Standard errors (in parentheses) are clustered at the subcounty level. The $p$-values [in square brackets] are unadjusted for multiple testing; FDR-corrected "$p$-values" {i.e., $q$-values} are in curly brackets while Randomization-t $p$-values following Young (2019), based on 2000 draws, are in ⟨diamond brackets⟩. FDR denotes false discovery rate. Panels A and B contain estimates without and with covariate adjustment respectively. Marketed surplus = proportion of harvested bananas sold.

We expect that accounting for environmental externalities may slightly influence the results, but not significantly. Studies show that following the recommended guidelines in applying mulch, manure, and digging trenches gives rise to more environmental benefits than negative externalities (Kihara et al., 2022; Ngetich et al., 2014).

## 5.7 | Cost-effectiveness of the practices

The conservation practices we recommended, manure application, mulching, and trench establishment, are highly cost-effective. Manure use is most intensive during the establishment of a new plantation, requiring two 9 kg basins per hole. For rehabilitation, which was the focus since the plantations were already established, the requirement reduces to approximately one basin per mat or stool annually, costing roughly a quarter of the price of one banana bunch. With proper management, each mat/stool yields at least three bunches annually, making manure application economically viable. Mulching, primarily using dry banana leaves and pseudostems, partially replaces lost nutrients, but we recommend supplementing with external mulch like maize stover or elephant grass. These residues are often freely available, with farmers investing only in cutting, transporting, and applying them. This process typically costs 80,000–120,000 UGX (US $23–32) per acre per year, equivalent to the value of 8–12 banana bunches. Moreover, well-mulched plantations suppress weeds, significantly reducing labor costs. Trench establishment, though labor-intensive, requires about three person-days per acre, costing around 90,000 UGX (US $24) per acre. Maintenance, mainly involving weed removal from trenches, is straightforward and low-cost. Farmers generate between 4 and 12 million UGX (US $1067–3200) per acre annually, depending on bunch sizes and

**TABLE 11** Impact of participation in audio-visual and hands-on sessions on farmers' welfare.

| | **Yield (ton/acre)** | | **Marketed surplus (%)** | | **Household income (million UGX)** | |
|---|---|---|---|---|---|---|
| | **SMD** | **ANCOVA** | **SMD** | **ANCOVA** | **SMD** | **ANCOVA** |
| Panel A | | | | | | |
| *ATT 3* | 1.013 | 0.898 | 0.146 | 0.205 | 1.521 | 2.432 |
| | (0.204) | (0.206) | (0.013) | (0.015) | (0.369) | (0.478) |
| | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] |
| | {0.001} | {0.001} | {0.001} | {0.001} | {0.001} | {0.001} |
| | ⟨0.001⟩ | ⟨0.001⟩ | ⟨0.000⟩ | ⟨0.000⟩ | ⟨0.001⟩ | ⟨0.001⟩ |
| *Observations* | 430 | 430 | 430 | 430 | 430 | 430 |
| *Control mean* | 7.409 | 7.409 | 0.322 | 0.322 | 6.052 | 6.052 |
| Panel B | | | | | | |
| *ATT 3* | 1.172 | 1.067 | 0.169 | 0.224 | 1.573 | 3.340 |
| | (0.107) | (0.121) | (0.010) | (0.009) | (0.356) | (0.419) |
| | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] |
| | {0.001} | {0.001} | {0.001} | {0.001} | {0.001} | {0.001} |
| | ⟨0.041⟩ | ⟨0.041⟩ | ⟨0.041⟩ | ⟨0.033⟩ | ⟨0.041⟩ | ⟨0.041⟩ |
| *Observations* | 430 | 430 | 430 | 430 | 430 | 430 |
| *Control mean* | 7.409 | 7.409 | 0.322 | 0.322 | 6.052 | 6.052 |

*Note*: 1 USD = 3750 UGX (Uganda shillings). SMD is the Simple Mean Difference. ANCOVA is Analysis of Covariance. Standard errors (in parentheses) are clustered at the subcounty level. The *p*-values [in square brackets] are unadjusted for multiple testing; FDR-corrected "*p*-values" {i.e., *q*-values} are in curly brackets while Randomization-t *p*-values following Young (2019), based on 2000 draws, are in ⟨diamond brackets⟩. FDR denotes false discovery rate. Panels A and B contain estimates without and with covariate adjustment, respectively. Marketed surplus = proportion of harvested bananas sold.

market conditions, underscoring the cost-effectiveness of adopting these practices. We also emphasized the adoption of technologies in a stepwise/phased manner based on the farmers' resource outlay to ease uptake.

## 5.8 | Cost-effectiveness of the campaign intervention

Conducting a comprehensive cost-effectiveness analysis of any intervention is crucial, and it depends on detailed, high-quality cost data. Since we do not have detailed data, we rely on aggregate cost estimates and credible assumptions for our analysis. Our campaign disseminated soil and water conservation technologies through multiple channels, achieving significant outreach. We could not explicitly determine the exact number of farmers reached through each channel partly because farmers are generally hesitant to register attendance[6] while radio listenership cannot be determined with certainty. Hence, we base our analysis on conservative estimates. The radio campaign cost about \$25,000 and 25,525 farmers from 56 districts responded to radio poll questions, indicating widespread listenership since not every listener responded. Considering only the respondents to the poll questions translates to a cost of \$0.98 (= 25,000/25,525) per farmer.

The audio-visual channels comprised the video and lecture sessions. A consultant was hired to produce the drama film based on a script developed by the project team. Farmers selected from the

[6]Farmers are often unwilling to register their attendance unless they receive something tangible, such as cash, transport refund, or foodstuffs. They believe that organizers might exploit their signatures for financial gain if they register without receiving a direct benefit. This mindset, common in rural Uganda, stems from experiences at political rallies.

TABLE 12 Impact of adoption of soil-improving and water conservation practices on farmers' welfare.

| | Yield (ton/acre) | | Marketed surplus (%) | | Household income (million UGX) | |
|---|---|---|---|---|---|---|
| | SMD | ANCOVA | SMD | ANCOVA | SMD | ANCOVA |
| Manure | | | | | | |
| *LATE* | 4.664 | 4.224 | 0.671 | 0.879 | 7.002 | 11.182 |
| | (1.471) | (1.400) | (0.108) | (0.203) | (2.217) | (2.614) |
| | [0.002] | [0.003] | [0.000] | [0.000] | [0.002] | [0.000] |
| | {0.002} | {0.002} | {0.001} | {0.001} | {0.002} | {0.001} |
| | ⟨0.003⟩ | ⟨0.003⟩ | ⟨0.001⟩ | ⟨0.001⟩ | ⟨0.003⟩ | ⟨0.002⟩ |
| Mulch | | | | | | |
| *LATE* | 3.655 | 3.322 | 0.526 | 0.649 | 5.486 | 8.414 |
| | (0.896) | (0.885) | (0.056) | (0.075) | (1.548) | (1.947) |
| | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] |
| | {0.001} | {0.001} | {0.001} | {0.001} | {0.001} | {0.001} |
| | ⟨0.002⟩ | ⟨0.002⟩ | ⟨0.001⟩ | ⟨0.001⟩ | ⟨0.003⟩ | ⟨0.001⟩ |
| Trenches | | | | | | |
| *LATE* | 17.388 | 15.624 | 2.503 | 3.376 | 26.104 | 47.606 |
| | (11.961) | (11.344) | (1.551) | (1.922) | (16.597) | (29.915) |
| | [0.146] | [0.168] | [0.107] | [0.079] | [0.116] | [0.112] |
| | {0.038} | {0.044} | {0.033} | {0.025} | {0.033} | {0.032} |
| | ⟨0.051⟩ | ⟨0.063⟩ | ⟨0.033⟩ | ⟨0.025⟩ | ⟨0.034⟩ | ⟨0.031⟩ |
| ISFWC | | | | | | |
| *LATE* | 6.486 | 5.981 | 0.934 | 1.179 | 9.738 | 15.611 |
| | (2.231) | (2.177) | (0.207) | (0.251) | (3.140) | (3.881) |
| | [0.004] | [0.006] | [0.000] | [0.000] | [0.002] | [0.000] |
| | {0.004} | {0.004} | {0.001} | {0.001} | {0.002} | {0.001} |
| | ⟨0.005⟩ | ⟨0.007⟩ | ⟨0.001⟩ | ⟨0.001⟩ | ⟨0.003⟩ | ⟨0.002⟩ |
| *Control mean* | 7.409 | 7.409 | 0.322 | 0.322 | 6.052 | 6.052 |
| *Observations* | 430 | 430 | 430 | 430 | 430 | 430 |

*Note*: 1 USD = 3750 UGX (Uganda shillings). SMD is the Simple Mean Difference. ANCOVA is Analysis of Covariance. Standard errors (in parentheses) are clustered at the subcounty level. The *p*-values [in square brackets] are unadjusted for multiple testing; FDR-corrected "*p*-values" {i.e., *q*-values} are in curly brackets while Randomization-t *p*-values following Young (2019), based on 2000 draws, are in ⟨diamond brackets⟩. FDR denotes false discovery rate. The estimates shown are without covariate adjustment. Marketed surplus = proportion of harvested bananas sold.

local community in the treatment site comprised the cast. The drama was recorded on DVD. The film production cost was approximately $12,000 and the dissemination cost amounted to $1500. The video screenings attracted 2439 adults; thus the cost per farmer is $5.54 (= 13,500/2439). Before conducting the lecture sessions, 30 scaling agents (10 from each treatment site) including government and NGO extension workers and the three site coordinators attended the Training of Trainers (TOT).[7] The total cost for the 3-day TOT was approximately $3000. Each agent trains at least 30 farmers per parish and operates in at least 5 parishes. Altogether, these extension workers trained about 4950 farmers. The daily wage rate for extension officers is about $20 per day, and they spend 3 days in each parish training for about 2 h; thus, the cost of training is $9900 (= 20 × 5 × 3 × 33). This amounts to a rate of $2.61 (= (9900 + 3000)/4950) per trained farmer.

[7]The campaign facilitated the TOT for these extension workers in the treatment districts and provided them with training materials to use in their work with farmers. Only the three site coordinators were directly supported further by the project to conduct farmer training sessions.

TABLE 13 Heterogeneous treatment effects conditional on the pre-treatment characteristics.

| Variable | (1) Manure | (2) Mulch | (3) ISFWC | (4) Yield | (5) Marketed surplus |
|---|---|---|---|---|---|
| *Not credit constrained* | 0.270*** (0.100) | | | | 0.206*** (0.059) |
| *Education* | 0.027** (0.013) | | | | |
| *Own television* | | 0.256** (0.124) | | | |
| *Farming is household head's main occupation* | | | −0.302** (0.122) | | |
| *Total value of assets (log)* | | | | 0.604** (0.255) | |
| *Own radio* | | | | | 0.180** (0.077) |
| *Observations* | 430 | 430 | 430 | 430 | 430 |

*Note*: The results are generated through the generalized random forest technique using the *grf package* in *R*. Standard errors are in parentheses. ***$p < 0.01$; **$p < 0.05$.

The farmer field days and the demonstration trials constitute the hands-on approaches. The recorded attendance at field days was 2756 adult participants across three treatment sites, though the actual number was higher due to unregistered attendees.[8] The costs of organizing farmer field days include hire charges for tents, chairs, and a public address system, providing a meal for all participants, and supplying inputs for the demonstrations. Altogether, this is approximately $2500. Two field days were conducted per treatment site; hence the total cost for the three sites is $15,000. This yields a cost of $5.44 (= 15,000/2756) per field day participant. The campaign established 40 demonstration trials in total. The costs involved include farm inputs, such as mulch and manure, wages for three hired laborers who work with the host and farmers, and transport costs for two research team members. This is approximately $62 per demonstration plot. Overall, the 40 plots cost $2480 to establish. The demonstration sites registered 683 visitors, though this is underestimated, as hosts occasionally forgot to record visitors. The estimated amount spent per farmer trained is $3.63 (= 2480/683).

As expected, the audio channel had the highest coverage and lowest cost per farmer, but the costs per farmer for the other channels were also relatively low, ranging from $2.60 to $5.54. Our findings indicate that audio-visual, hands-on approaches and their combination had a greater impact on the adoption of practices, yields, sales, and household income. In value terms, yields increased by 17%–21%, 17%–20%, and 18%–24% for the audio-visual, hands-on, and combined approaches, respectively, compared to the audio channel. Additionally, household income increased by $384–845 for those who accessed information through audio-visual channels, $368–792 for those who participated in hands-on training, and $405–891 for farmers who used both channels relative to the radio. Considering these welfare improvements alongside the costs of adoption and intervention, it is evident that the campaign was cost-effective.

## 6 | CONCLUSION

Low crop yields in Sub-Saharan Africa are attributed to the effects of climate change, limited adoption of improved agricultural technologies, and impediments in information flow. Literature is

[8]We hired 500 chairs for the farmers on each field day, but these were all occupied with several other farmers sitting on the ground.

replete with information on how improved extension services enhance the uptake of improved technologies and facilitate higher yields for smallholder farming households in Sub-Saharan Africa. However, most of these studies do not employ multiple information dissemination channels, yet farmers have varying access to, and preferences for, information sources. In this study, we employed an extension-based campaign that used multiple communication channels to disseminate agricultural information to farmers in Uganda, through a randomized controlled trial. We compared the impact of utilizing audio-visual and hands-on approaches relative to audio means of communication in disseminating information pertinent to soil-improving and water conservation practices, including manure, mulch, and trenches. In Sub-Saharan Africa, where most livelihoods depend on rainfed agriculture characterized by continuous cropping without nutrient replenishment, declining soil fertility, climate change effects such as drought, and low crop productivity, employing conservation measures examined in this study helps mitigate these effects by increasing soil nutrient stocks, water infiltration, and enhancing nutrient and water use efficiency (Abdulai et al., 2011). Thus, as our findings show, the adoption of soil-improving and water conservation practices can contribute to an improvement in agricultural productivity and farmers' welfare and promote environmental sustainability, which are crucial to achieving food security and poverty alleviation goals in Sub-Saharan African countries.

The campaign-based extension approach resulted in a significant increase in the adoption of manure, mulch, trenches, and the three practices combined. The intervention also significantly increased household welfare, measured by yields, marketed surplus, and household incomes. Our findings further show positive and statistically significant effects of actual participation in both audio-visual and hands-on sessions on the adoption of the practices and the welfare outcomes as opposed to only listening to the radio program. The farmers in our RCT must have benefited from the synergistic effects of a combination of these interventions during the campaign, resulting in increased technology uptake, as well as better welfare outcomes unlike those who were only exposed to audio messages (van Campenhout et al., 2021).

Our findings provide valuable lessons for policymakers and practitioners involved in information dissemination, on the adoption of soil-improving and water conservation measures. The use of various communication channels and harnessing the ubiquity of mass media in extension systems facilitates the mobilization of larger numbers of farmers and enables the transmission of information to wider audiences. Therefore, policies that foster augmenting extension and advisory services with information communication technologies will have far-reaching effects, especially in creating awareness. Furthermore, providing farmers with details regarding the approach, attributes, costs, and benefits of each conservation technique intrigues them to adopt. Policies that promote capacity building of extension staff and the development of reference materials such as visual aids and training manuals highlighting the technicalities and benefits of technologies, will facilitate the delivery of a uniform message and this is vital not only for novel technologies, but also existing soil-improving and water conservation measures which farmers may not be implementing partly due to myths, preconceived ideas, or insufficient knowledge. Utilizing visual aids such as posters that help to illustrate the techniques taught, as well as audio-visuals in conveying the message facilitates a clearer understanding of the practices and is likely to enhance adoption as these have the potential to influence changes in attitude and behavior (Chong & La Ferrara, 2009; van Campenhout et al., 2021), as opposed to relying solely on audio radio programs. Relaying the messages in the local dialects customized to address localized information needs and contexts and involving farmers as role models, especially in the drama and radio shows, helps to convey information even to those with low literacy levels, subsequently facilitating adoption (Abate et al., 2023). Disseminating information through audio-visual and hands-on approaches proved more effective than using audio alone, as the combination enhances comprehension through visual demonstrations, reinforces learning via direct engagement, and helps overcome literacy barriers. In addition to the positive and significant impacts of the campaign on adoption, yield, sales, and income, we also provide evidence that the initiative was cost-effective. Given our experimental design, we were unable to isolate the impact of each communication channel independently or the additive benefits of combining different channels. Future experimental research could address this limitation by implementing a randomized controlled trial with multiple treatment arms. These arms should include groups exposed to each communication channel independently, as well as groups receiving combinations of channels, to allow for a rigorous assessment of both standalone and synergistic effects.

## ACKNOWLEDGMENTS

The study was conducted within the framework of the project "Improving Scalable Banana Agronomy for Small-Scale Farmers in Highland Banana Cropping Systems in East Africa" led by the National Agricultural Research Organization in conjunction with Bioversity International, funded by the Bill and Melinda Gates Foundation, Grant ID: A1272. The follow-up survey was funded by the Academy for International Agricultural Research (ACINAR). ACINAR, commissioned by the German Federal Ministry for Economic Cooperation and Development (BMZ), was carried out by ATSAF (Council for Tropical and Subtropical Agricultural Research) e.V. on behalf of the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. The authors would like to thank the three anonymous reviewers for comments and suggestions that helped in improving the manuscripts. All errors are due only to the authors. Open Access funding enabled and organized by Projekt DEAL.

## REFERENCES

Abate, Gashaw T., Tanguy Bernard, Simrin Makhija, and David J. Spielman. 2023. "Accelerating Technical Change through ICT: Evidence from a Video-Mediated Extension Experiment in Ethiopia." *World Development* 161(January): 1–14. Elsevier Ltd. https://doi.org/10.1016/j.worlddev.2022.106089.

Abdulai, Awudu. 2023. "Information Acquisition and the Adoption of Improved Crop Varieties." *American Journal of Agricultural Economics* 105: 1049–62. https://doi.org/10.1111/ajae.12419.

Abdulai, Awudu, and Renan Goetz. 2014. "Time-Related Characteristics of Tenancy Contracts and Investment in Soil Conservation Practices." *Environmental and Resource Economics* 59(1): 87–109. https://doi.org/10.1007/s10640-013-9719-y.

Abdulai, Awudu, Victor Owusu, and Renan Goetz. 2011. "Land Tenure Differences and Investment in Land Improvement Measures: Theoretical and Empirical Analyses." *Journal of Development Economics* 96(1): 66–78. https://doi.org/10.1016/j.jdeveco.2010.08.002.

Adolwa, Ivan Solomon, Stefan Schwarze, and Andreas Buerkert. 2018. "Best-Bet Channels for Integrated Soil Fertility Management Communication and Dissemination along the Agricultural Product Value-Chain: A Comparison of Northern Ghana and Western Kenya." *Journal of Agricultural Education and Extension* 24(5): 435–456. https://doi.org/10.1080/1389224X.2018.1499541.

Aker, Jenny C. 2011. "Dial 'A' for Agriculture: A Review of Information and Communication Technologies for Agricultural Extension in Developing Countries." *Agricultural Economics* 42(6): 631–647. https://doi.org/10.1111/j.1574-0862.2011.00545.x.

Anderson, Michael L. 2008. "Multiple Inference and Gender Differences in the Effects of Early Intervention: A Reevaluation of the Abecedarian, Perry Preschool, and Early Training Projects." *Journal of the American Statistical Association* 103(484): 1481–95. https://doi.org/10.1198/016214508000000841.

Angrist, Joshua D., Guido W. Imbens, and Donald B. Rubin. 1996. "Identification of Causal Effects Using Instrumental Variables." *Journal of the American Statistical Association* 91(434): 444–455. https://doi.org/10.1080/01621459.1996.10476902.

Athey, S., and G. W. Imbens. 2017. *The Econometrics of Randomized Experiments*. 73–140. Amsterdam: North-Holland. https://doi.org/10.1016/bs.hefe.2016.10.003.

Bationo, Andre, Job Kihara, Bernard Vanlauwe, Boaz Waswa, and Joseph Kimetu. 2007. "Soil Organic Carbon Dynamics, Functions and Management in West African Agro-Ecosystems." *Agricultural Systems* 94(1), 13–25. https://doi.org/10.1016/j.agsy.2005.08.011.

Baul, Tushi, Dean Karlan, Kentaro Toyama, and Kathryn Vasilaky. 2024. "Improving Smallholder Agriculture Via Video-Based Group Extension." *Journal of Development Economics* 169(June): 1–26. https://doi.org/10.1016/j.jdeveco.2024.103267.

Beaman, Lori, Ariel BenYishay, Jeremy Magruder, and Ahmed Mushfiq Mobarak. 2021. "Can Network Theory-Based Targeting Increase Technology Adoption?" *American Economic Review* 111: 1918–43. https://doi.org/10.1257/AER.20200295.

Belloni, A., V. Chernozhukov, and C. Hansen. 2014. "Inference on Treatment Effects after Selection among High-Dimensional Controls." *The Review of Economic Studies* 81(2): 608–650. https://doi.org/10.1093/restud/rdt044.

Benin, Samuel, Ephraim Nkonya, Geresom Okecho, Joseé Randriamamonjy, Edward Kato, Geofrey Lubade, and Miriam Kyotalimye. 2011. "Returns to Spending on Agricultural Extension: The Case of the National Agricultural Advisory Services (NAADS) Program of Uganda." *Agricultural Economics* 42(2): 249–267. https://doi.org/10.1111/J.1574-0862.2010.00512.X.

Bernard, Tanguy, Stefan Dercon, Kate Orkin, and Alemayehu Seyoum Taffesse. 2015. "Will Video Kill the Radio Star? Assessing the Potential of Targeted Exposure to Role Models through Video: Table 1." *The World Bank Economic Review* 29(Suppl 1): S226–S237. https://doi.org/10.1093/wber/lhv014.

Besley, Timothy. 1995. "Property Rights and Investment Incentives: Theory and Evidence from Ghana." *Journal of Political Economy* 103(5): 903–937.

Buehren, Niklas, Shyamal Chowdhury, Sreelakshmi Papineni, and Munshi Sulaiman. 2025. "Impact of Inputs, Information, and Financial Services on the Adoption of a Biofortified Crop by Women Farmers in Uganda." *American Journal of Agricultural Economics* 107: 1117–51. https://doi.org/10.1111/ajae.12540.

Cai, Tian, Lulu Rodriguez, and Eric Abbott. 2014. "The Ability of Training Approaches to Reduce Agricultural Knowledge Gaps between Men and Women in Rural Uganda." *Journal of International Agricultural and Extension Education* 21(2): 17–31. https://doi.org/10.4148/2831-5960.1229.

Chong, Alberto, and Eliana La Ferrara. 2009. "Television and Divorce: Evidence from Brazilian *Novelas*." *Journal of the European Economic Association* 7(2–3): 458–468. https://doi.org/10.1162/JEEA.2009.7.2-3.458.

Conley, Timothy G., and Christopher R. Udry. 2010. "Learning about a New Technology: Pineapple in Ghana." *American Economic Review* 100(1): 35–69. https://doi.org/10.1257/aer.100.1.35.

Duflo, Esther, Rachel, Glennerster, and Michael Kremer. 2007. "Chapter 61 Using Randomization in Development Economics Research: A Toolkit," in *Handbook of Development Economics*, 3895–3962. Amsterdam: Elsevier-North Holland. https://doi.org/10.1016/S1573-4471(07)04061-2.

Dzanku, Fred Mawunyo, Robert Darko Osei, Paul Kwame Nkegbe, and Isaac Osei-Akoto. 2020. "Information Delivery Channels and Agricultural Technology Uptake: Experimental Evidence from Ghana." *European Review of Agricultural Economics* 49: jbaa032. https://doi.org/10.1093/erae/jbaa032.

Foster, Andrew D., and Mark R. Rosenzweig. 2010. "Microeconomics of Technology Adoption." *Annual Review of Economics* 2: 395–424. https://doi.org/10.1146/ANNUREV.ECONOMICS.102308.124433.

Harou, Aurélie P., Malgosia Madajewicz, Hope Michelson, Cheryl A. Palm, Nyambilila Amuri, Christopher Magomba, Johnson M. Semoka, Kevin Tschirhart, and Ray Weil. 2022. "The Joint Effects of Information and Financing Constraints on Technology Adoption: Evidence from a Field Experiment in Rural Tanzania." *Journal of Development Economics* 155: 102707. https://doi.org/10.1016/j.jdeveco.2021.102707.

Hörner, Denise, Adrien Bouguen, Markus Frölich, Meike Wollni, and Giannini Hall. 2019. *The Effects of Decentralized and Video-Based Extension on the Adoption of Integrated Soil Fertility Management: Experimental Evidence from Ethiopia*. Cambridge, MA: National Bureau of Economic Research. http://www.nber.org/data-appendix/w26052.

Kansiime, Monica K., Rahab Njunge, Innocent Okuku, Edward Baars, Christine Alokit, Solomon Duah, Stephanie Gakuo, et al. 2022. "Bringing Sustainable Agricultural Intensification Practices and Technologies to Scale through Campaign-Based Extension Approaches: Lessons from Africa Soil Health Consortium." *International Journal of Agricultural Sustainability* 20(5): 743–757. https://doi.org/10.1080/14735903.2021.1976495.

Kihara, Job, Julius Manda, Anthony Kimaro, Elirehema Swai, Christopher Mutungi, Michael Kinyua, Patrick Okori, Gundula Fischer, Fred Kizito, and Mateete Bekunda. 2022. "Contributions of Integrated Soil Fertility Management (ISFM) to Various Sustainable Intensification Impact Domains in Tanzania." *Agricultural Systems* 203: 103496. https://doi.org/10.1016/j.agsy.2022.103496.

Kondylis, Florence, Valerie Mueller, and Jessica Zhu. 2017. "Seeing Is Believing? Evidence from an Extension Network Experiment." *Journal of Development Economics* 125(March): 1–20. https://doi.org/10.1016/j.jdeveco.2016.10.004.

Lecoutere, Els, David J. Spielman, and Bjorn Van Campenhout. 2023. "Empowering Women through Targeting Information or Role Models: Evidence from an Experiment in Agricultural Extension in Uganda." *World Development* 167(July): 1–13. https://doi.org/10.1016/j.worlddev.2023.106240.

Mabaya, E., F. Mzee, A. Temu, and M. Mugoya. 2017. *Tanzania Brief 2017—The African Seed Access Index*. Nairobi: Kenya Markets Trust. https://tasai.org/reports.

Mbabazi, Esther Gloria, Enoch M. Kikulwe, Joseph Lule Kyanjo, Nasser Mulumba, Edward Kato, and Elisabetta Gotor. 2021. "Has Continued Exposure to Banana Xanthomonas Wilt Worsened Farmers' Welfare over Time? Evidence from Banana-Producing Households in Uganda." *Journal of Agricultural Science* 13(11): 11. https://doi.org/10.5539/jas.v13n11p11.

McKenzie, David. 2012. "Beyond Baseline and Follow-Up: The Case for More T in Experiments." *Journal of Development Economics* 99(2): 210–221. https://doi.org/10.1016/j.jdeveco.2012.01.002.

McKenzie, David, and Owen Ozier. 2019. "Why Ex-Post Power Using Estimated Effect Sizes Is Bad, but an Ex-Post MDE Is Not." *Development Impact World Bank Blog*. May 16.

MoFA. 2019. *Medium Term Expenditure Framework (MTEF) for 2019–2022*. Ghana: Accra.

Ngetich, K. F., M. Mucheru-Muna, J. N. Mugwe, C. A. Shisanya, J. Diels, and D. N. Mugendi. 2014. "Length of Growing Season, Rainfall Temporal Distribution, Onset and Cessation Dates in the Kenyan Highlands." *Agricultural and Forest Meteorology* 188(May): 24–32. https://doi.org/10.1016/j.agrformet.2013.12.011.

National Planning Authority (NPA). 2018. *Policy Paper for Presidential Economic Council (PEC) 'Towards a Hunger Free Ugandan Society': Policy Implications for Increasing Food and Nutrition Security*. Kampala: National Planning Authority.

National Planning Authority (NPA). 2020. *Third National Development Plan (NDPIII) 2020/21–2024/25*. Kampala: National Planning Authority.

Pan, Yao, Stephen C. Smith, and Munshi Sulaiman. 2018. "Agricultural Extension and Technology Adoption for Food Security: Evidence from Uganda." *American Journal of Agricultural Economics* 100 (4): 1012–31. https://doi.org/10.1093/ajae/aay012.

Parsa, Soroush, Stephen Morse, Alejandro Bonifacio, Timothy C. B. Chancellor, Bruno Condori, Verónica Crespo-Pérez, Shaun L. A. Hobbs, et al. 2014. "Obstacles to Integrated Pest Management Adoption in Developing Countries." *Proceedings of the National Academy of Sciences* 111(10): 3889–94. https://doi.org/10.1073/pnas.1312693111.

Perkins, K., D. Ward, and M. Leclair. 2011. *Participatory Radio Campaigns and Food Security: How Radio Can Help Farmers Make Informed Decisions*. Washington DC: USAID. https://farmradio.org/wp-content/uploads/2020/09/farmradio-prcreport20111-1.pdf.

Rekhy, Reetica, and Robyn McConchie. 2014. "Promoting Consumption of Fruit and Vegetables for Better Health. Have Campaigns Delivered on the Goals?" *Appetite* 79(August): 113–123. https://doi.org/10.1016/j.appet.2014.04.012.

Rudolf, Katrin, Miriam Romero, Rosyani Asnawi, Bambang Irawan, and Meike Wollni. 2020. "Effects of Information and Seedling Provision on Tree Planting and Survival in Smallholder Oil Palm Plantations." *Journal of Environmental Economics and Management* 104(November): 102361. https://doi.org/10.1016/j.jeem.2020.102361.

Shiferaw, Bekele, Melinda Smale, Hans-Joachim Braun, Etienne Duveiller, Mathew Reynolds, and Geoffrey Muricho. 2013. "Crops That Feed the World 10. Past Successes and Future Challenges to the Role Played by Wheat in Global Food Security." *Food Security* 5(3): 291–317. https://doi.org/10.1007/s12571-013-0263-y.

Sutherland, Lee-Ann, and Fleur Marchand. 2021. "On-Farm Demonstration: Enabling Peer-to-Peer Learning." *The Journal of Agricultural Education and Extension* 27(5): 573–590. https://doi.org/10.1080/1389224X.2021.1959716.

Tambo, Justice A., Aliamo Caroline, Tamsin Davis, Idah Mugambi, Dannie Romney, David O. Onyango, Monica Kansiime, Christine Alokit, and Stephen T. Byantwale. 2019. "The Impact of ICT-Enabled Extension Campaign on Farmers' Knowledge and Management of Fall Armyworm in Uganda." *PLoS One* 14(8), 1–15. https://doi.org/10.1371/journal.pone.0220844.

Uganda Bureau of Statistics (UBOS). 2020. *Uganda Annual Agriculture Survey 2018*. Kampala: Uganda Bureau of Statistics.

Uganda Bureau of Statistics (UBOS). 2021. *Uganda National Household Survey 2019/2020*. Kampala: Uganda Bureau of Statistics.

van Asten, P. J. A., A. M. Fermont, and G. Taulya. 2011. "Drought Is a Major Yield Loss Factor for Rainfed East African Highland Banana." *Agricultural Water Management* 98(4): 541–552. https://doi.org/10.1016/J.AGWAT.2010.10.005.

van Campenhout, Bjorn. 2021. "The Role of Information in Agricultural Technology Adoption: Experimental Evidence from Rice Farmers in Uganda." *Economic Development and Cultural Change* 69(3): 1239–72. https://doi.org/10.1086/703868.

van Campenhout, Bjorn, David J. Spielman, and Els Lecoutere. 2021. "Information and Communication Technologies to Provide Agricultural Advice to Smallholder Farmers: Experimental Evidence from Uganda." *American Journal of Agricultural Economics* 103(1): 317–337. https://doi.org/10.1002/ajae.12089.

Vasilaky, Kathryn, Aurélie Harou, Katherine Alfredo, and Ishita Kapur. 2023. "What Works for Water Conservation? Evidence from a Field Experiment in India." *Journal of Environmental Economics and Management* 119(May): 1–20. https://doi.org/10.1016/j.jeem.2023.102802.

Wairegi, Lydia W. I., Piet J. A. van Asten, Moses M. Tenywa, and Mateete A. Bekunda. 2010. "Abiotic Constraints Override Biotic Constraints in East African Highland Banana Systems." *Field Crops Research* 117(1): 146–153. https://doi.org/10.1016/J.FCR.2010.02.010.

Young, Alwyn. 2019. "Channeling Fisher: Randomization Tests and the Statistical Insignificance of Seemingly Significant Experimental Results." *The Quarterly Journal of Economics* 134(2): 557–598. https://doi.org/10.1093/qje/qjy029.

## SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

**How to cite this article:** Mbabazi, Esther Gloria, Awudu Abdulai, Enoch M. Kikulwe, and Elisabetta Gotor. 2025. "Information Flow and the Adoption of Soil-Improving and Water Conservation Measures, and Household Welfare: Insights from a Randomized Controlled Trial in Uganda." *American Journal of Agricultural Economics* 1–30. https://doi.org/10.1111/ajae.70032