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The effect of agricultural information provision on smallholders' technology adoption and yield: experimental evidence from Ethiopia

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Introduction: Lack of sufficient agricultural information has led smallholders' to rely on traditional agricultural farming technologies in Sub-Saharan African countries, resulting in low adoption of modern inputs and low yield. Understanding the effect of information dissemination is essential for smallholder farmers in rural areas. Therefore, this study aimed to examine the effect of a randomized agricultural information provision on technology adoption and yield of cassava producers in Sodo Zuria, Offa, and Kindo Koysha Woredas in Wolaita Zone, South Ethiopia Regional Sate.

Methods: The study utilized panel data collected in two rounds from 1040 farmers in 2021 and 2023. A Randomized control trial (RCT) design was applied to evaluate the effect agricultural information provision on technology adoption and yields, comparing the results between treatment and control groups. The study employed three related information interventions for beneficiaries of the Ethiopian Rural Productive Safety Net Program: (i) agronomic technical information, (ii) productivity and profitability information, and (iii) pooled information on both treatments.

Results and discussion: The study found that agricultural information provision increases the adoption of modern agricultural technologies, land allocated to cassava, and yield. The provision of agricultural information is negatively related to access to media exposure, access to cell phones, and access to infrastructure while positively associated with participation in social groups, farm size, and farm income. Further policy research and evaluation are needed to assess the effectiveness of information intervention in different contexts and settings and factors that influence the improved cassava adoption and yield.

KEYWORDS

agricultural information provision, cassava, technology adoption, RCT, yield

1 Introduction

In Sub-Saharan African countries, smallholder farmers face significant challenges due to limited access to and timely agricultural information delivery systems (Freeman and Qin, 2020; Gao et al., 2020; Veettil et al., 2021). Accurate and timely agricultural information on improved seed varieties, fertilizers, and best agricultural practices is essential to make cognizant decisions and improve their productivity. Yet, due to limited infrastructure, inadequate extension services, imperfect information and its utilization, and innovative farming techniques, many smallholder farmers struggle to maximize the yields and improve their income and livelihoods (Nwankwo et al., 2009; Maredia et al., 2018; Mugonya et al., 2021). These factors, in addition to the information gap, constrained smallholders' adoption of the latest farming techniques and technologies, forcing smallholders to rely on traditional methods of production, which are less productive and result in lower yields and reduced income for the farmers in the region.

Policymakers, government-owned research centers, non-governmental organizations (NGOs), private seed dealers, and seed traders play a role in agricultural information dissemination (Mugonya et al., 2021; Ndimbwa et al., 2021).

However, smallholders did not obtain accurate information because of lack of access to information. In most cases, their information was often delivered after the farming season had already begun, creating missed opportunities for cassava growers to benefit from the latest agricultural information. This delay in information provision hampered the potential effectiveness of efforts to promote the adoption of modern agriculture inputs and technologies (Purnomo and Kusnandar, 2019; Olawuyi and Mushunje, 2020). Yet, evidence on the provision of agricultural information and its contribution to the adoption of improved varieties, yield, and production is scarce in Sub-Saharan African countries.

Several studies focused on agricultural technology adoption and information provision relations. One such area of research centered on text message-based information delivered through cell phones. For example, Cole and Fernando (2021), Dzanku et al. (2021), Krell et al. (2021), Larochelle et al. (2019), and Nakasone and Torero (2016) conducted research on the connected and interrelated ideas adoption, knowledge transfer, and farm outputs. These studies explore the utilization of information delivered through text messages on mobile phones. Other studies have utilized video-based experiments to explore the adoption of information, for example, studies by Abate et al. (2023), Lecoutere et al. (2023), Maredia et al. (2018), and Van Campenhout et al. (2021). These studies have employed video as a medium to evaluate how farmers respond to and adopt technology through information. Moreover, other pieces of literature applied the training approach only to disseminate information and analyze the adoption of new technology innovations (Shikuku et al., 2019; Pratiwi and Suzuki, 2020; Arouna et al., 2021; Barrett et al., 2022; Wonde et al., 2022). The outputs of these studies have practical implications for implementing effective communication strategies and interventions to promote the adoption of new technologies. Our study contributes to the current literature by incorporating a comprehensive approach that applies various information interventions, such as agronomic technical information, productivity and profitability information, and a combination of both agronomic technical and productivity and profitability information, to treatment group farmers. The effects of these interventions were then compared to a control group. This multifaceted approach confirms that farmers receive a diverse range of knowledge regarding the adoption of improved cassava varieties (ICVs) by comparing the treatment and control groups.

In Ethiopia, there is an insufficient agricultural information-delivering system. This is due to the fact that there are few institutions or datasets that deliver the latest agricultural information to rural farmers. In addition to this, most farmers lack cell phones, radio, and television to obtain the latest agricultural information (Haile et al., 2019). They use social networks, including connections with neighbors, friends, and relatives, as sources of information (Chikuni and Kilima, 2019).

In this study, we provided information to cassava-producing farmers by employing three complementary modes. These are (i) agronomic technical information from the field visit at the farm site, (ii) productivity and profitability information using a video-based approach about improved cassava varieties, and (iii) pooled information (combining both agronomic technical information and productivity and profitability information) via traditional extension information in the classroom in the farmers training centers (FTCs). We conducted a randomized control trial (RCT) among 1,040 cassava-producing households in South Ethiopia Regional State to establish causal relationships between the interventions and their outcomes, providing an understanding of their effectiveness (Duflo et al., 2007; White, 2013; Shikuku et al., 2019).

The current paper contributes to the existing literature in four ways. First, we contribute to the existing literature by relaxing the effect of agronomic technical information on adoption and yield via field visits at the farm site. Previous studies have focused more on extension approaches. For example, Dhehibi et al. (2022) conducted research on the impact of improved agricultural extension approaches by utilizing RCT in rural Tunisia. They found that intensive agricultural training can significantly improve the adoption of Kounouz. Ayalew et al. (2022) examined the targeted extension, which leads farmers to align with recommended levels of fertilizer and impacts productivity in Ethiopia. This study focused on agronomic technical information specifically, the agronomic practices information such as improved cassava varieties selection, stem cutting and spacing, row planting, and use of fertilizer on the farm field on the treatment groups, and compared the impact of the information with both treatment and control groups.

Second, we provided the productivity and profitability information to the treatment group and compared the effect of information on adoption and yield with control groups. The productivity and profitability information was provided using mobile-based educational videos to farmers in the treatment group. The most recent works of literature in this area encompass a study by Naika et al. (2021) focusing on digital extension services; Van Campenhout et al. (2021) explored ICT-based agricultural advice, and Maredia et al. (2018) compared video-based information delivery and traditional information delivery methods for farmers. Our study aimed to analyze how agronomic technical, productivity, and profitability information affect the adoption decisions and yield of ICVs.

Third, we pooled agronomic technical information with productivity and profitability information through the traditional extension approach in the classroom. The provision of information by the traditional extension method is straightforward and one of the most familiar extension methods in the area. We assumed that this treatment could easily increase farmers' knowledge of adoption and yield. Wonde et al. (2022) analyzed the impact of training on productivity and income by using propensity score matching in Ethiopia. The study found training increased the wheat yield by 26.6%, whereas maize yield increased by 10.10%. Dhehibi et al. (2022) examined the impact of improved agricultural approaches on technology adoption. They applied the randomized trial control method focusing on training plus other related variables in Tunisia. The current study compares the effect of dissemination of agricultural information between treatment group and the control group.

2 Theoretical framework

Various theories have been applied to understand the adoption concepts of agricultural technology in the field of agriculture since the pioneering study of Ryan and Gross (1943) and Rogers (1983). These theories are categorized into three paradigms. The first paradigm involves diffusion theories such as diffusion of innovation theory (DIT) and technology lifecycle theory (Rogers, 1983). The theories focus on the relationships among technology, the environment, and organizations (Dissanayake et al., 2022). The opponents of this model, such as Feder (Feder et al., 1985), criticize the applicability of Rogers's categorization of adoption as "adoption" or "non-adoption" because it occurs on the continuum.

The second paradigm is the theory of user acceptance. The user acceptance theory includes the theory of reasoned action (TRA) developed by Fishbein and Ajzen in 1975 (Ajzen, 1991), the theory of planned behavior (TPB), the technology acceptance model (TAM), and its extensions such as TAM1, TAM2, and TAM3 (Taherdoost, 2018). This paradigm focuses on intrinsic factors such as knowledge, attitudes, and perceptions, along with extrinsic factors such as household characteristics and technological and environmental factors that can impact farmers' decisions regarding technology adoption. The user acceptance paradigm also focuses on the utility maximization of a household; however, compared to the decision-making paradigm, the utility level may expand beyond only focusing on financial aspects.

The third paradigm involves decision-making theories, such as decision-making under uncertainty and risk management theories, which focus on rational organizational and management interests (Hillmer, 2009). This paradigm also focuses on the economic constraints that farmers propose for utility maximization when adopting technologies. However, this paradigm fails to capture the effects of the cultural aspect of an innovation (Ruzzante et al., 2021). The technology adoption theories explained above can provide some insights to practitioners and researchers on the factors affecting technology adoption dynamics in agriculture. In this study, we employed adoption theories to analyze the effect of agricultural information provision on improved cassava adoption and yield in rural Ethiopia by interpreting the intervention predictors and adoption and yield outcomes.

3 Agricultural information, technology adoption, and production

Access to basic agricultural inputs and technology are central to today's changing agricultural system. In the context of rural farmers in developing countries, information access plays a central role in empowering rural farmers to make informed decisions on improved input and agricultural technologies (Adegbola and Gardebroek, 2007; Van Campenhout et al., 2021). To keep farmers with the most recent information, access to accurate and updated information is important to help them obtain the latest information on the availability of inputs (seeds, fertilizers, and pesticides). The information on inputs is also essential for optimizing crop yield and farm productivity (Olawuyi and Mushunje, 2020; Balew et al., 2023).

Several pieces of literature focus on the provision of information on adoption and yield. For example, Arouna et al. (2021) examined the effectiveness of mobile personalized advisory services in Nigeria and found that personalized advice increased farmers' yield by 7% and profit by 10%. Dzanku et al. (2021) investigated the impact of mobile phone reminders on agricultural outcomes and found that mobile phone reminders reduced on-farm cereal losses and increased the adoption of improved grain storage technology. Maredia et al. (2018) analyzed the effect of mobile-based animated videos on adoption and learning in mobile in Burkina Faso and found that video-based training was as effective as the traditional method in inducing learning and understanding. Gao et al. (2020) evaluated the impact of new agricultural technologies extension mode improved the technology adoption level of farmers in China. Moreover, Yitayew et al. (2021) found a positive effect of improved agricultural extension service on wheat yield in Ethiopia.

The effect of information delivery on technology adoption has been studied widely in literature (Liu et al., 2004; Adegbola and Gardebroek, 2007; Nwankwo et al., 2009; Haile et al., 2019; Freeman and Qin, 2020). Another group of studies (Mugonya et al., 2021; Veettil et al., 2021) identified qualities, sharing, and utilization of information. Some of the literature (Nwankwo et al., 2009; Haile et al., 2019) studied the effect of information access on the welfare of smallholders by using mobile phones and social connectivity as information tools of smallholders. However, to our knowledge, few research outputs have examined the effect of information provision intervention on the adoption of improved cassava varieties and yield in the study area. In this study, we add to the literature a new approach by conceptualizing an alternative hypothesis of information delivery through farmer-targeted modes.

3.1 Theory of change

We formulate the assumption that agricultural information provision is a very important factor in enhancing the adoption decision and yield of rural smallholder farmers. We derived the following basic assumptions. First, we assumed that providing agronomic technical information at the farm site can significantly increase farmers' understanding and knowledge of ICVs. This assumption, in turn, helps farmers by equipping them with comprehensive technical information about the characteristics, benefits, and utilization of ICVs. Second, we assumed that providing productivity and profitability information by showing mobile-based educational videos enhances the likelihood of adopting ICVs. By providing this information, it is expected that farmers are more likely to have a clearer understanding of the productivity and profitability of adopting improved cassava varieties (ICVs). Third, the study assumed that agronomic technical information plus productivity and profitability information via traditional extension medium in farmer training center (FTC) classrooms can better understand the adoption of ICVs. This intervention has long been recognized as an effective means of knowledge provision among farmers and can lead farmers to acquire the necessary knowledge and confidence in adopting ICVs.

Finally, we assumed that farmers who receive agricultural information will have a better understanding and knowledge of the adoption and its ability to increase adoption knowledge and yield than farmers who do not receive the interventions. In formulating these

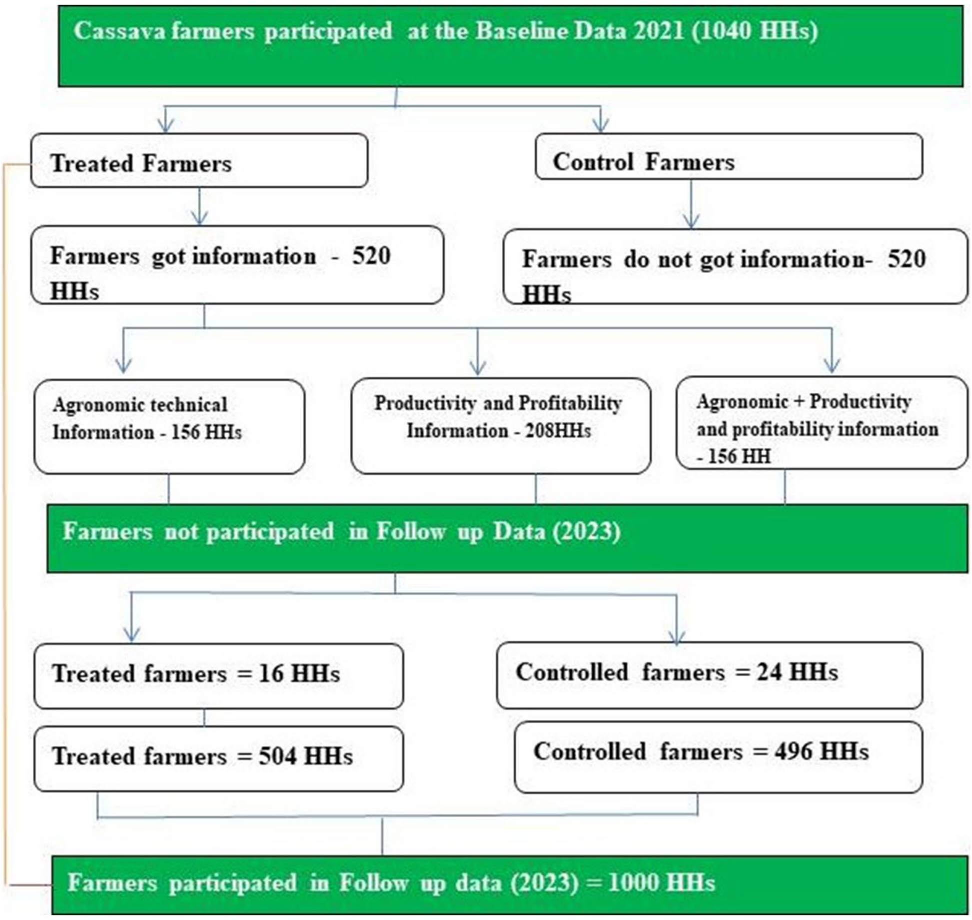

FIGURE 1
Theory of change.

assumptions, we aimed to address the knowledge gap of the information delivery approach, it is possible to empower rural smallholder farmers and derive positive change in the adoption of ICVs in the study area (Figure 1).

4 Methods

4.1 The study area and context

4.1.1 The study area

Wolaita Zone is situated at a central position in the South Ethiopia region. It shares its boundaries with Kembata Tambaro and Hadiya to the north, Sidama Region to the east, Dawro Zone to the West, Gamo, and Gofa Zones to the south, and Oromia Region to the northwest. The total population of the Wolaita Zone was 2,142,063 and a population density of 520.8 km^2 (WZPDD, 2020). It encompasses 16 rural woredas and 7 urban town administrations and is characterized by three distinct agroecological zones: "Dega" (9%), "Woina Dega" (56%), and "Kola" (35%), each contributing unique characteristics to the zone's agricultural potential.

In general, the rural households in the study areas depend on mixed agriculture (crop- and livestock-based) to sustain their livelihoods (see Table 1). The farming system is mainly dominated by cassava crops for food consumption and the market. Crops such as maize, teff and red bean, sweet potatoes, and taro are highly produced in the study areas in addition to cassava. This study was carried out in Sodo Zuria, Offa, and Kindo Koysha woredas in Wolaita Zone, South Ethiopia (Cochrane and Gecho, 2018).

4.1.2 The context of the study

The study was conducted in South Ethiopia Regional State where Cassava is majorly produced (Figure 2). Cassava (*Manihot esculenta* Crantiz) is a type of tuber and root crop known for its versatility and environmental friendliness. It has unique characteristics that allow it to adapt to climate change. The crop thrives in agroecological areas and seasons where other cereal crops fail. This makes the product preferable for cassava farmers who value year-round availability and its ability to tolerate low soil fertility (Kondo et al., 2020; Legg et al., 2022). Moreover, cassava plays a significant role in the food system providing a starchy and carbohydrate-rich source of calories, ranking third after rice and maize in Sub-Saharan African countries.

Cassava serves as a vital food source for nearly 800 million people across Africa, Asia, and Latin America. The total global cassava production reached 302 million tons covering approximately 28 million hectares in 2020, Africa led the way, contributing 193 million tons, followed by Asia with 81 million tons, and South America with 26 million (FAO, 2022). Cassava

TABLE 1 Basic socioeconomic information of the study area.

Districts	Average annual rainfall (from 2018 to 2022) mm [min, max)	Average annual temperature (from 2018 to 2022) (′C) [min, max]	Dominant livelihoods	Annual average production (in hectares)	Annual average cassava yield (in quintals) [max, min]	Astronomical location (in degree)
Sodo Zuria	[14, 23.7]	[16, 26]	Mixed agriculture (crop and livestock production)	1,056	[140, 220]	Lat 6.43–6.57 N and Long 37.35–37.51 E
Offa	[10.4, 18.7]	[15.2, 22.45]	Mixed agriculture (crop and livestock production)	960.68	[146, 234]	Lat 6.37–6.48 N and Long 37.24–37.39E
Kindo Koysha	[8.2, 16.6]	[17, 31]	Mixed Agriculture (crop and livestock production)	326	[110,152]	Lat 6.47–7.02 N and Long 37.24–37.37 E

Source: Wolaita Zone Plan Development Department (WZPDD, 2020).

production benefits farmers in terms of adaptation, nutrition, and economic significance (Kassa et al., 2021; Masamba et al., 2022). Currently, cassava is cultivated in 40 African countries where approximately 70% of content's cassava output is harvested in Nigeria, the Democratic Republic of Congo, and Tanzania. This concentration of production indicates its pivotal role in ensuring food security and economic stability and its potential to achieve the SDGs, particularly Goals 1 and 2, to end hunger and extreme poverty (Legg et al., 2022; Mihretie et al., 2022). However, the adoption of new agricultural technologies in Sub-Saharan African countries remains low. It is harder to increase agricultural productivity and achieve economic sustainability without the adoption of cutting-edge agricultural technologies, such as improved seed technology application, increased agricultural mechanization, and the use of chemical fertilizers, pesticides, and herbicides (Olayide et al., 2021; Zegeye et al., 2022).

Ethiopia is endowed with various crops, including cereals, fruits, vegetables, root crops, pulses, and oil seeds. However, limited outreach and adoption of agricultural technology along with the absence of mechanized agricultural systems lead many smallholder farmers to rely on local varieties of crops, rather than improved variety. This preference for local crops over improved seeds is marked by a significant difference among farmers in Ethiopia. For instance, according to the Central Statistical Agency's annual report from 2022, the local seed used by farmers is estimated to be 13,379,273 hectares and 10,435,162 quintals, whereas improved seed used was unitized at 2,228,608 hectares and 1,169,508 quintals in the production year of 2020/21 (CSA, 2021).

The cassava crop is largely produced in South Ethiopia (Tafesse et al., 2021), and the Wolaita Zone is one of the areas with the highest potential for cassava production (see Figure 2). For example, according to Wolaita Zone Agricultural Development Office report, the total area coverage of cassava is 5,882.62 hectares; production is 2,964,630 quintals, and the average yield is 270 quintals per hectare in 2021/2022 production year (WZADDO, 2022).

4.2 Sampling, experiment design, and interventions

4.2.1 Sampling techniques

A three-stage sampling technique was applied to select farmers in the study area. In stage 1, Sodo Zuria, Offa, and Kindo Koysha districts were randomly selected out of six districts that have high potential in cassava production in the Wolaita Zone[1] in South Ethiopia Regional State. In stage 2, we found a list of all farm households' data from each Woreda Agricultural Office, and we randomly selected two kebeles from each district (see Appendix).

In the third stage, we selected a total of 32 villages[2] and randomly assigned them into two groups: the treatment group and the control

1 Zone is the third hierarchical administration level next to woredas and kebeles.

2 Villages are the fourth hierarchical level next to kebeles.

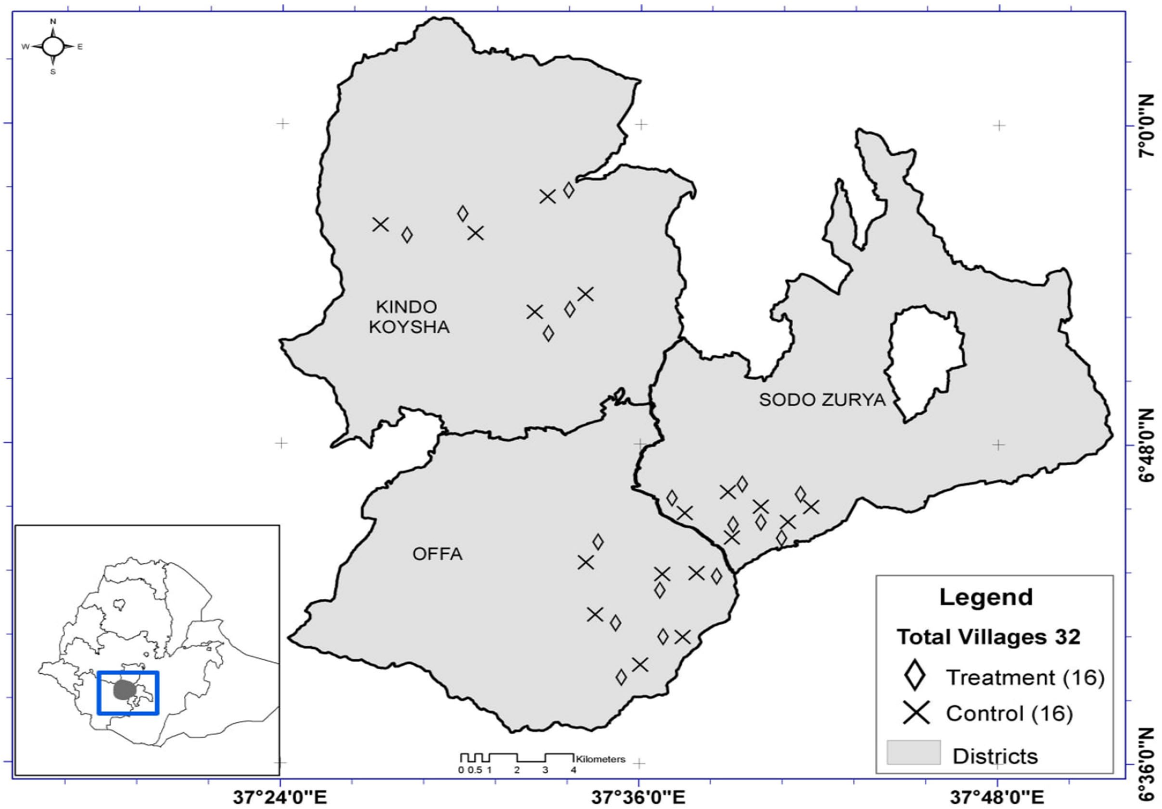

FIGURE 2
Map of the study area.

group (see Figure 1). The basic reason we employed random assignment is that it helps us to ensure the unbiased allocation of villages to each group. As a result of this random assignment, the study achieved its balanced distribution, with an equal number of households in each group, that is, 520 in the treatment group and 520 in the control group. By doing this, we aimed to increase the validity and reliability that enabled us to come up with more accurate conclusions about our impact interventions (see Figures 1, 2). Moreover, the treatment villages were randomly assigned to three treatment arms. Within villages, we randomly assigned 208 households to receive agronomic technical information (T1), 156 households to receive productivity and profitability information (T2), and 156 households to have productivity, profitability, and agronomic technical information (T3).

We performed power calculation taking the cassava yield as the outcome variable and a minimum effect size of 20% increase in yield, which is equivalent to a standardized minimum detectable effect of 0.3 based on the mean 287 quintals per hectare (28,000Kg/ha) and standard deviation of 26.56 for cassava yields in the study area (the data derived from WZADDO, 2022) (WZPDD, 2020). At a power of 90% and a 5% significant level of 0.5 intra-class correlation, we reached 32 sample villages and 1,040 sample households using STATA software version 17.

4.2.2 The experiment design

We employed information experiments in the field in our study (Janvry et al., 2017; Dzanku et al., 2021; Van Campenhout et al., 2021). Our experiment mainly focused on the Ethiopian Rural Safety Net Program phase five ($RPSNP_5$)[3] list to select our participants. The study identified the beneficiaries of this program as the target group for this study. It is important to note that the program is currently actively operating in the study area, which encompasses the three selected districts: Sodo Zuria, Ofa, and Kindo Koysha in Wolaita Zone South Ethiopia (see Figure 1). Concentrating on these districts, we aimed to obtain potential data for our experiment from farmers. To do this, we collaborated with the local government of the Wolaita Zonal Administration, NGOs, Wolaita Sodo University (WSU), and other stakeholders. The eligibility criteria of households were being RPSNP members. However, for the sake of impact analysis we measured the eligibility as (i) farm landholding between 0.125 and 0.25 hectares of cassava and (ii) highly interested and able to produce improved cassava new varieties. This study employed a randomized control trial (RCT) approach (Duflo et al., 2007; Barrett et al., 2022). Household-level clustered randomized control trial method was implemented in three woredas (Figure 1).

3 Rural Productive Safety Net Program Phase Five (RPSNP-5) is Ethiopia's largest social protection program that supports around 8 million poor food insecure households (FAO, 2020). The program was launched to sustain social protection and risk management systems to minimize food insecurity challenges in the country.

4.2.3 The information interventions and indicators

In the study area, a large portion of farmers, approximately 80% of the farmers rely on local cassava varieties (LCVs). However, only a small fraction, 19.8% of cassava farmers utilized improved cassava varieties (ICVs) (WZADDO, 2022). This significant gap in the adoption of improved cassava varieties can be due to a lack of knowledge and access to up-to-date information on cassava technology packages. To bridge this gap, we implemented three cassava farmer-targeted interventions aimed at providing vital information to cassava–producing farmers. The content of information and the delivery mechanism of that information are different in each intervention, as described below.

4.2.3.1 Intervention 1

The first intervention (T1) was information on agronomic technical activities aimed at building the technical knowledge of cassava-producing farmers in the field at the farm site. The agronomic technical information of ICVs is associated with agronomic activities, such as ICV selection, stem cutting and spacing, and row planting. Participants received information about ICVs by observing the agronomic activities physically on the field visit day at the FTC at the kebele level.

4.2.3.2 Intervention 2

The second intervention was information on the productivity and profitability of improved cassava through an educational video (T2), which was designed precisely and to the point, farmer-friendly, taking 5 to 7 min. The videos were methodically crafted to offer detailed information on improved cassava varieties' expected productivity and profitability. The video-induced intervention was loaded on a Samsung smartphone and screened by DAs for each farmer.

4.2.3.3 Intervention 3

The third intervention (T3) was a combination of T1 and T2 designed to provide information to participants through the traditional information provision approach. In this intervention, the information content includes technical knowledge and skills (agronomic practices information) and productivity and profitability (video-based information) about ICVs. This intervention was presented by development agents (DAs) manually in the classroom of Farmers Training Centers (FTCs) following an adult learning approach. This intervention aims to educate (inform) farmers about ICVs and allow us to organize and structure the delivery of information locally and contextually. This intervention took place at the kebele level; the farmers in local communities can easily access and benefit from the information provided that helps effectively educate them about ICVs.

4.3 Control group

The control groups were designed with no information about improved cassava varieties. The group received other information such as nutritional and post-harvest information on cassava supported by local music (Wolaitigna), which made our participants interested. The local music was not related to our objectives during the study.

The information provision mechanisms were held at the village level by gathering the participants to the nearest (FTC)[4] to ensure efficient access to information. The information provision process is managed by development agents (DAs),[5] who are part government structure, have crop-based specialties, and have been working with the nearby local kebele communities. DAs received refresher training before getting engaged in the experiment.

4.4 Data collection

The baseline data were collected by using a household survey questionnaire, which included household and agricultural, socioeconomic, and institutional characteristics; following these questions, we asked farmers about how much information they have about ICVs, their level of understanding and knowledge on adoption, production, and yield rate of ICVs. The information provision commenced in February 2021 and concluded in April 2021, occurring biweekly basis (Figure 3). In addition to the baseline data, we collected the end-line data in two rounds. The first round of the end-line data (Panel A) was collected in April 2021. The second round of data (Panel B) was collected from March to May 2023 (see Figure 3).

In both rounds, the questionnaire was administered face-to-face in the field. The content of the questionnaire includes three components: household and farm characteristics (gender, age, family size, farm size, education, experience, production, and yield); institutional variables (credit access, access to training, extension, cooperative membership, and market access), economic variables (TLU, ownership of cellphone, farm income, and off-farm income), and psychological and social variables (participation in social network and perception on ICVs) indicators. In addition to this, the study compared the before and after data by asking the households about the adoption knowledge indicators of ICVs (such as variety selection, spacing, row planting, and fertilizer utilization). We also asked the farmers about their understanding of the usage level of improved cassava seeds and fertilizers (inorganic and organic). We finally collected the data about how much the intervention changed farmers' adoption intensity, measured by the share of cassava land from total farmland, amount of cassava production, yield, and cassava income.

4.5 Empirical specification

This study aimed to estimate the effect of information on the adoption and yield by employing three information interventions: agronomic technical information at the site; productivity and profitability information via videos; and pooled information of both treatments through a traditional extension approach in the classroom.

4 FTCs are farmers training centers in which agricultural demonstrations are held as school for farmers in rural Ethiopia.

5 In the Ethiopian context, DAs serve as agricultural extension (Development) agents. The DAs are categorized into crop-based, livestock-based, and natural resource-based specializations in Ethiopia. For this study, we used a crop-based specialization type of development agent for our experiment.

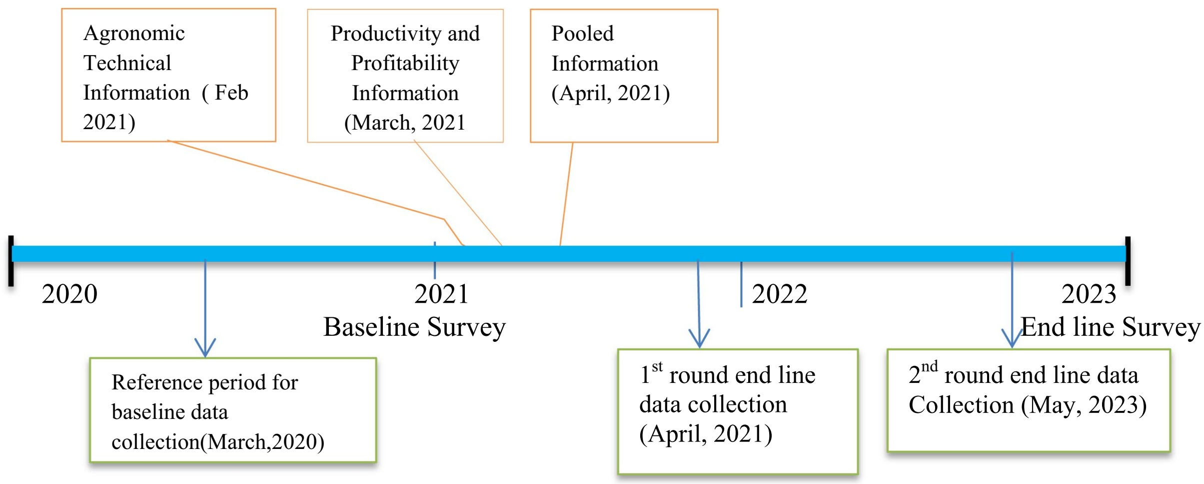

FIGURE 3
Timeline of the research.

By delivering the agronomic technical information through (site) field visits, their understanding of agronomic characteristics of ICVs and other necessary technical knowledge for adopting the crop is increased. Additionally, by providing productivity and profitability information, household knowledge of the productivity and profitability of ICVs will be expected to increase.

If a farmer gains agronomic technical knowledge from a field visit, their understanding will be enhanced, leading to increased knowledge of agronomic characteristics and other technical aspects necessary for adopting the cassava crop. Similarly, if a farmer receives information through both approaches via a traditional extension system, the farmer is expected to cultivate and use improved cassava varieties on their farm. By delivering information, it is anticipated that there would be a change (impact) in the adoption decision and yield. We start estimating the adoption decision estimation using the basic model in Equation 1

$$Y_i = \alpha + \beta X_i + \varepsilon_i \tag{1}$$

where Y_i is the probability of adoption of improved cassava varieties for a household *i:* X_i is the variable that indicates the value of 1 if the farmer *i* is in the treatment group and 0 otherwise.

To estimate the average treatment effect of each intervention on farmers' adoption, Equation 2 was used to estimate the effects of the interventions.

$$Y_{it} = \alpha + \beta_1 T1_{it} + \beta_2 \mathrm{T}2_{it} + \beta_3 \mathrm{T}3_{it} + \beta_4 \mathrm{T_t} + \varepsilon_{it} \tag{2}$$

where Y_i represents the observed outcome variable which is the adoption of ICVs of household head i in year t. $T1_{it}$, $T2_{it}$, and $T3_{it}$ are treatment dummies; $T1_{it}$ refers to agronomic technical information and it equals 1 if the farmer is assigned for this intervention; 0 otherwise; $T2_{it}$ refers to productivity and profitability information via video, which equals 1 if the household was assigned to see the video and 0 otherwise. Similarly, $T3_{it\ i}$ denotes the pooled information through the traditional extension approach and is equal to 1 if the household is assigned to take the pooled information (T1 and T2) and 0 otherwise. α is an average outcome in the control group.

In this regression (Equation 2), we used a probit regression model to estimate binary outcome variables and ordinary least squares (OLS) to estimate continuous outcome variables at fixed effects. β_1 estimates the average treatment effect of information by site-specific technical information, β_2 estimates the average treatment effect of information through video, and β_3 estimates the average treatment effect of traditional extension information. $\mathrm{T_t}$ is a year dummy for the 2021 fixed effect. ε_{it} is a random error term clustered at the household group level at year t. Given our focus on studying the impact of information provision on the adoption of ICVs through three information delivery experiments, we controlled household characteristics, socioeconomic, and institutional compositions of independent variables from our main model.

5 Results and discussions

5.1 Sources and types of information for cassava producers

The baseline data collected in 2020 provide an overview of the sources and types of information available to cassava growers as depicted in Figures 4, 5. Figure 4 focuses on the primary source of information for cassava producing farmers. It is interesting to note that local meetings emerge as the primary source of information, which accounts for 25.15% of cassava growers relying on this channel. This finding underlines the importance of face-to-face interactions and community engagement in disseminating information among cassava-producing farmers. Development agents also play a vital role, with 21.15% relying on their guidance and expertise from these professionals at the kebele level. Moreover, mass media platforms such as local radios and televisions prove to be influential information sources, capturing cassava producers' attention with 15.77%. On the other hand, training programs; agricultural demonstrations and shows; and social media (particularly cell phones), research

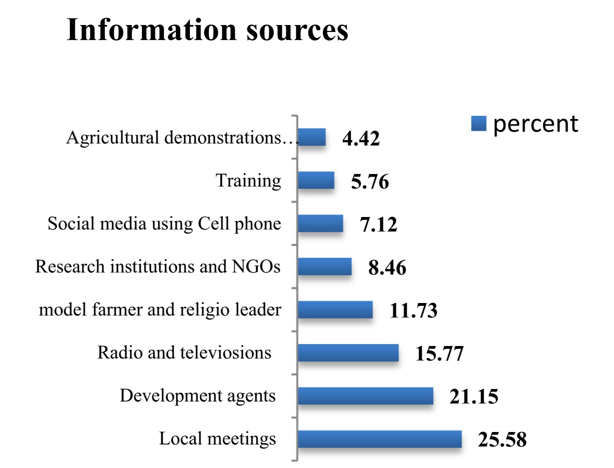

FIGURE 4
Sources of information.

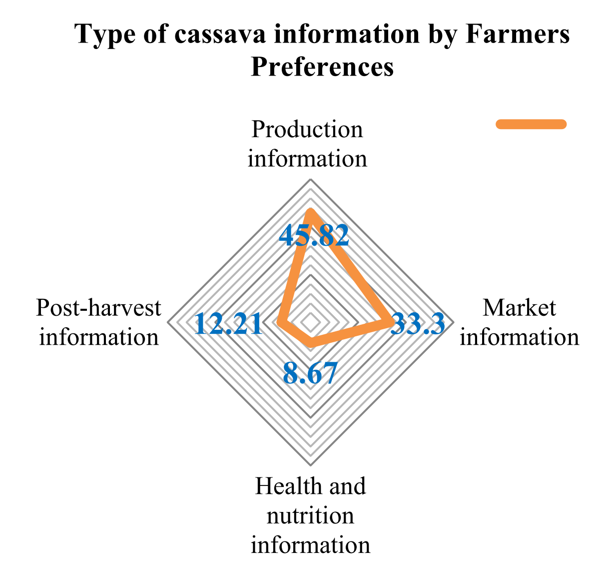

FIGURE 5
Types of information.

institutions, and NGOs are reported as the least-used sources of cassava information by growers in South Ethiopia (Figure 4).

Similarly, the data presented in Figure 5 reveal the dominant type of information cassava growers prefer and utilize to adopt improved cassava variety. Production information emerged as the most preferred and utilized type of information with 45.82% of the sampled households. This indicates the importance of accessing knowledge and resources related to the production of improved cassava variety. Market information was the next focus of cassava producers with 33.3% of the sampled respondents understanding the dynamics of the market, prices, and demands of consumers' information. Piabuo et al. (2020) analyzed the effect of information on market price and profit in Cameroon. Similarly, 12.21% of sampled households utilized post-harvest information, and only 8.67% of respondents sought health and nutrition information to adopt and produce improved cassava varieties.

5.2 Determining factors of agricultural information provision

In Table 2, the results of the binary probit model and its marginal effect analysis are reported in columns 1 and 2. The outcome of this analysis shows that four variables, namely, media exposure and access to cell phones, access to infrastructure and perception of farmers to ICVs, and extension support have negatively influenced the information delivery of ICVs and farmers' adoption decisions. On the other hand, variables such as participation in the social groups, farm size, and the logarithm of farm income positively affect the provision of an agricultural information approach.

The negative sign of the variable media exposure indicates that there is a lack of access to media exposure to cassava growers, and this circumstance could negatively affect the likelihood of information being provided to farmers. The average marginal effect output indicates that all things remain constant; a unit percentage of lack of media exposure caused a 15.8% decrease in the agricultural information delivery process, and this finally affected the adoption of improved cassava variety in the study area. Due to the lack of exposure to media such as local radio and television, cassava producers may face challenges in accessing information for the most productive and high-yield varieties of cassava to grow. Similarly, the lack of access to cell phones negatively affected the provision of information to farmers. Cell phone ownership and access to it form the base for rural farmers to obtain information on agricultural inputs, advisory services, and market prices. Hence, lack of access to cell phones may lead to a lack of information about new and improved cassava varieties that are relevant to producers. The study result is similar to Babu et al. (2019).

In addition, our findings reveal that access to infrastructure affected the information provision with a marginal effect of 7.1%. This shows that limited access to necessary infrastructure impedes the effective delivery of information to farmers. Moreover, the perception of cassava growers on the use of information for ICVs also played a negative role in receiving information from farmers, showing a significant average marginal effect of 5%. Our finding highlights the importance of addressing infrastructure-related factors and increasing farmers' perception of the value of information. In doing so, it is possible to improve the information provision methods to farmers.

The study also provides some insights into the factors that positively influence the provision of information. It was found that farm size was the highest determinant, with a significant marginal effect of 12%. This shows that larger farm sizes led farmers to be more likely to adopt new technologies and practices (Musara and Musemwa, 2020). Active participation in social network issues also appeared as a significant factor, with a marginal effect of 6%, showing the importance of participation in social networks in equipping farmers with the necessary information knowledge, and skills to implement the adoption of ICVs are crucial. The result matches with (Ikuemonisan et al., 2020). Finally, annual income from cassava production was found to have a considerable marginal effect of 19.1%, highlighting the role of financial capacity in promoting information delivery interventions (Table 2).

TABLE 2 Determining factors of agricultural information provision.

Variables	Coefficients (1)	Average marginal effect (2)
Social networks (1/0)	0.279***	0.060***
	(0.101)	(0.021)
Exposure to media (1/0)	−0.731***	−0.158***
	(0.215)	0.045
Gender (1/0)	0.017	0.003
	(0.105)	0.022
Access to phone (1/0)	−0.610***	−0.131***
	(0.104)	0.021
Perception of ICVs [Likert (1–5)]	−0.026	−0.005
	(0.045)	0.009
Farm size (ha)	0.557***	0.120***
	(0.138)	0.029
Education (categorical)	0.019	0.004
	(0.066)	0.014
Infrastructure access (yes = 1)	−0.330***	−0.071***
	(0.103)	0.022
Extension support (1/0)	−0.247	−0.053***
	(0.211)	0.045
Log of farm income (ETB)	0.989***	0.191***
	(0.087)	(0.014)
Constant	−2.677***	
	(0.222)	
Observations	1,039	
Log-likelihood	−398.615	
LR chi2 (11)	597.47	
Prob > chi2	0.0000	
Pseudo R2	0.4284	

Source: Model output, 2024. Standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

5.3 Balance of randomization and comparisons

In Table 3, the study provides a balance of randomization among the three information interventions. Column 1 reports the mean of the control group; columns 2 to 4 report the mean differences between the control and the treatment groups. Columns 5 to 7 report the *p*-values of the treatment groups.

To check the success of randomization and statistical independence among the covariates, we report the balance of randomization by balancing the test using the two-sample *t*-test with equal variance. The households who planted the improved cassava variety and shared their land with ICV between placebo and treatment groups are balanced. In addition to this, agricultural outcomes covariates such as TLU, production, yield, and yearly income from cassava production are statistically independent and are balanced in all three treatments.

On average, each household farm size stands at 0.651 hectares, referring to relatively small households holding share of 0.243 hectares in the previous year (2021). Additionally, our study found that 48.1% of the sampled households used extension support in the last cropping season. Our study observed that 45.3% of households have access to a mobile phone and a few households (approximately 23.9%) of sampled households used an improved variety of cassava. In addition to these findings, cassava growers produce 294.11 quintals of cassava on average and yield 264.63 quintals per hectare in the cropping year of 2021, which is slightly lower than the National Agricultural Ministry report of 2020 in control groups.

Table 3 provides a detailed summary of the mean values of each intervention at the household level, allowing us to a comprehensive measurement of the impact of information on the adoption, and yield of both treatment and control groups. The result reveals significant progress in the adoption of ICVs among households that received the information interventions. Specifically, households that received the agronomic technical information showed a 23.9% progress on the adoption of ICVs compared to control groups. This shows that providing technical information can play a central role in encouraging the adoption of improved cassava varieties.

TABLE 3 Balancing and comparison of control and treatment groups of RCT.

Covariates	Control Mean	Mean differences			*p*-values		
	(C)	(T1-C)	(T2-C)	(T3-C)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
HHs farm size (ha)	0.651	(0.029)	0.056	0.080*	0.375	0.109	0.007
	(0.012)	(0.033)	(0.035)	(0.0299)			
Share of land by cassava (ha)	0.243	0.044***	0.107***	0.055***	0.000	0.000	0.000
	(0.005)	(0.012)	(0.013)	(0.011)			
Gender (1/0)	0.628	0.043**	−0.036	0.002	0.041	0.404	0.940
	(0.016)	(0.041)	(0.043)	(0.037)			
Age of the household (years)	41.634	1.416*	0.105	0.143	0.063	0.894	0.834
	(0.297)	(0.764)	(0.795)	(0.682)			
HHs who used improved variety (1/0)	0.194	0.239***	0.139***	0.064*	0.000	0.000	0.067
	(0.010)	(0.035)	(0.031)	(0.034)			
HHs who have market access (1/0)	0.219	0.101**	−0.056	0.038	0.004	0.130	0.231
	(0.014)	(0.035)	(0.037)	(0.032)			
HHs who have access to phone (1/0)	0.453	0.076*	0.024	0.0368	0.067	0.565	0.319
	(0.017)	(0.041)	(0.043)	(0.0370)			
Tropical Livestock Unit (TLU)	1.363	0.318**	0.192*	0.100	0.004	0.097	0.313
	(0.044)	(0 0.111)	(0.116)	(0.099)			
HHs who have access to credit (1/0)	0.468	0.016	0.017	−0.096*	0.703	0.695	0.009
	(0.017)	(0 0.042)	(0.043)	(0.037)			
Extension support (1/0)	0.481	0.019	−0.042	−0.026	0.632	0.320	0.467
	(0.017)	(0.041)	(0.043)	(0.036)			
Distance to market (Km)	11.359	0.591	0.066	0.079	0.116	0.865	0.812
	(0.145)	(0.376)	(0.392)	(0.336)			
Production (Quintal)	294.117	79.374***	126.58***	80.41***	0.000	0.000	0.000
	(5.685)	(15.627)	(15.57)	(13.69)			
Yield (Quintal/ha)	264.630	53.507***	151.56***	78.32***	0.000	0.000	0.000
	(5.079)	(15.039)	(14.79)	(13.35)			
Annual Income from cassava (ETB)	125,014.15	119,929.3***	186532.5***	137604.5***	0.000	0.000	0.000
	(4,492.945)	(9996.69)	(9913.55)	(8648.06)			
Observations	496	148	136	179			

Source: Household Baseline (2021) and End line (2023) survey. Column 1 reports the mean of the control group; columns 2 to 4 report the mean differences between the control groups and the treatment groups. Columns 5 to 7 report the p-values of the treatment groups. The mean difference is two-sample *t*-tests with equal variance. Standard errors in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0$.

Similarly, households who received productivity and profit information showed progress with a 13.9% increase in the adoption of ICVs compared to control groups. Moreover, households that received information on both agronomic and productivity received a change of 6.4% in the adoption of ICVs compared to the control groups. These findings underscore the significance of providing targeted information through site visits, video education, and traditional extension approaches can contribute to enhancing agricultural productivity, improving food security, and promoting sustainable agricultural practices.

Our observation also revealed noteworthy progress in cassava yield for the treatment groups compared to the control groups. Specifically, households obtained agronomic information experienced an increase in the yield of cassava crops by 53.5 quintals per hectare. Similarly, cassava growers who received productivity and profitability information significantly increased by 151.5 quintals per hectare compared to non-adopters. In addition to this, households that received both treatments of information observed a rise of 78.3 quintals per hectare. The finding underscores information provision interventions have a positive impact on cassava yield for treatment groups compared to control groups.

In addition to the cassava yield improvement, the annual income households in treatment groups have shown significant growth. The households who received agronomic technical information showed a remarkable increase of ETB 119,929.3 in their annual income compared to the control groups. Similarly, cassava producers who

TABLE 4 The effect of information treatment on recommended technologies knowledge.

Treatments	Knowledge of recommended technologies			
	Improved variety selection (yes =1)	Stem cutting and spacing (yes =1)	Use of row planting (yes = 1)	Use of inorganic fertilizer (yes =1)
	(1)	(2)	(3)	(4)
Panel A: Year 2021				
Agronomic technical information (T1)	0.086**	−0.019	−0.066	0.025
	(0.039)	(0.041)	(0.040)	(0.043)
Productivity and profitability information (T2)	0.083**	0.000	−0.060*	0.057
	(0.033)	(0.034)	(0.034)	(0.037)
Pooled information (T1 + T2) = T3	0.025	−0.079**	−0.026	0.054
	(0.037)	(0.040)	(0.036)	(0.041)
Baseline control mean	0.182	0.302	0.250	0.348
Observations	2,069	2,069	2,072	2,072
p-values				
p-value of T1	0.027	0.818	0.863	0.554
p-value of T2	0.012	0.420	0.060	0.119
p-value of T3	0.491	0.048	0.463	0.194
Panel B: Year 2023				
Agronomic technical information (T1)	0.165***	0.054	0.027	0.129***
	(0 0.034)	(0.041)	(0.040)	(0.040)
Productivity and profitability information (T2)	0.164***	0.109***	−0.014	0.165***
	(0.029)	(0.035)	(0.034)	(0.034)
Pooled information (T1 and T2) = T3	0.104***	0.009	0.036	0.158***
	(0.033)	(0.039)	(0.038)	(0.038)
Baseline control mean	0.115	0.289	0.253	0.221
	(0.008)	(0 0.011)	(0.011)	(0.010)
Observations	2,060	2,069	2,072	2,072
p-values				
p-value of T1	0.000	0.189	0.494	0.001
p-value of T1	0.000	0.002	0.680	0.000
p-value of T3	0.002	0.803	0.344	0.000

T1–T3 are indicate treatments. The coefficients of parameters are estimated by the probability linear model.
Standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

obtained productivity and profit information saw a rise in ETB 186,532.5 and 137,604.5, respectively. This finding highlights the effectiveness of the information delivery positively impacting the financial wellbeing of the treated groups compared to placebo groups. A significant increase in income for cassava growers refers to the potential of these interventions to contribute to economic empowerment within the community.

5.4 The effect of information treatments on recommended technologies knowledge

We shifted our focus to information treatment effect analysis. Table 4 reports the effect of information treatments on farmers' knowledge of recommended technologies of ICV adoption using panel A (2021) and panel B (2023) in comparison between treatment and control groups. We specifically highlight the effect of agronomic technical information (T1) on adoption knowledge of ICV use, stem cutting and spacing, use of raw planting, and application of fertilizers.

The results in Table 4 show that treatments 1 and 2 had positive effects on cassava growers' knowledge of improved cassava variety use. The data report that farmers' knowledge of using ICVs increased by 8.6% due to T1 and 8.3% due to T2 in panel A. However, we found that the *p*-values of other recommended cassava technologies such as stem cutting, row planting, and inorganic fertilizer use in the year 2021 (panel A) were insignificant. This indicates that our treatments did not immediately affect the knowledge of cassava growers within 1 year of intervention, while increasing the knowledge of new technology among farmers may take longer.

The output in panel B indicates that the agronomic technical information at the field (T1) has significantly improved the

TABLE 5 The effect of information treatment on improved cassava seed use.

Treatments	Improved cassava seeds		
	Hawasa-04 (yes = 1)	Chichu (yes =1)	Qulle/Kello (Yes = 1)
	(1)	(2)	(3)
Panel A: Year 2021			
Agronomic technical information (T1)	0.067*	0.075*	0.067**
	(0.038)	(0.038)	(0.033)
Productivity and profitability information (T2)	−0.060*	0.049	0.031
	(0.033)	(0.032)	(0.028)
Pooled information (T1 + T2) = T3	−0.120***	−0.043	−0.018
	(0.037)	(0.036)	(0.032)
Baseline control mean	0.155	0.241	0.249
	(0.009)	(0.011)	(0.011)
Observations	2,060	2,060	2,060
p-values			
p-value T1	0.082	0.050	0.044
p-value T2	0.069	0.131	0.276
p-value of T3	0.001	0.036	0.572
Panel B:Year 2023			
Agronomic technical information (T1)	0.239***	0.122***	0.128***
	(0.035)	(0.037)	(0.034)
Productivity and profitability information via (T2)	0.139***	0.111***	0.117***
	(0.031)	(0.032)	(0.029)
Pooled information (T1 + T2) = T3	0.064*	0.014	0.021
	(0.034)	(0.036)	(0.033)
Baseline control mean	0.194	0.223	0.177
	(0.010)	(0.010)	(0.009)
Observations	2,060	2,060	2,060
p-values			
p-value of T1	0.000	0.001	0.000
p-value of T2	0.000	0.001	0.000
p-value of T3	0.067	0.681	0.517

Standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$, Ns indicates not significant.

know-how of treated cassava growers', regarding the selection of improved cassava varieties by 16.5% compared to control groups. Compared to the data in Panel A, column 1, this intervention has resulted in a double increase in farmers' knowledge. Specifically, in column 1 of Panel A, the farmers' knowledge rate was 8.6% for the treatment groups. However, after 2 years (in 2023) in panel B, farmers' knowledge of the selection of improved cassava variety increased to 16.5%, indicating that intervention T1 led to a 50% increase in farmers' knowledge of adoption. In addition, this intervention caused a significant effect of 12.9% improvement in organic fertilizer use knowledge of treatment groups in Panel B compared to control groups at a 1% level of significance. This study is consistent with research conducted by Ayalew et al. (2022) who found the effect of site-specific agronomic information on adoption in Ethiopia.

The productivity and profitability information (T2) also positively impacted farmers' knowledge of improved cassava variety adoption. It increased the estimated knowledge of treatment groups by 16.4% in the use of cassava variety, 10.9% in stem cutting and spacing, and 16.5% in fertilizer use of treatment groups compared to controlled groups. Similarly, the third intervention (T3) had a significant impact on the understanding of recommended technologies. Treatment groups that took both agronomic and productivity and profitability showed an estimated increase in the likelihood of adoption of ICV by 10.4% and an understanding of fertilizer use by 15.8% compared to control groups. In general, our analysis indicates that rather than short-term information interventions, long-term panels may increase rural farmers' understanding and knowledge level in the use of recommended technologies (Maredia et al., 2018; Van Campenhout et al., 2021).

TABLE 6 The effect of information intervention on recommended fertilizer use.

Treatments	Recommended fertilizers		
	DAP	UREA	Compost
	(1)	(2)	(3)
Panel A:Year 2021			
Agronomic technical information (T1)	0.042	0.007	0.224***
	(0.034)	(0.034)	(0.044)
Productivity and profitability information via (T2)	0.027	0.047	0.154***
	(0.029)	(0.030)	(0.037)
Pooled information (T1 + T2) = T3	0.014	0.018	0.172***
	(0.033)	(0.033)	(0.042)
Baseline control mean	0.185	0.190	0.471
	(0.008)	(0.008)	(0.012)
Observations	2,072	2,072	2,072
p-values			
p-value of T1	0.222	0.824	0.000
p-value of T2	0.358	0.111	0.000
p-value of T3	0.674	0.579	0.000
Panel B:Year 2023			
Agronomic technical information (T1)	0.107***	0 0.007	0.370***
	(0.036)	(0.034)	(0.041)
Productivity and profitability information (T2)	0.069**	0.054*	0.306***
	(0.031)	(0.029)	(0.035)
Pooled information (T1 + T2) = T3	0.093*	−0.018	0.303***
	(0.035)	(0.033)	(0.039)
Baseline control mean	0.216	0.181	0.331***
	(0.010)	(0.009)	(0.012)
Observations	2,072	2,072	2,072
p-values			
p-value of T1	0.003	0.834	0.000
p-value of T2	0.029	0.068	0.000
p-value of T3	0.008	0.572	0.000

Source: Model output, 2024.
Standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

5.5 The effect of information treatment on improved cassava seeds use

Table 5 presents the information provision treatments on the utilization of improved cassava seeds in panels A and B. Our study found a heterogeneous effect of interventions on the usage of ICV across different treatment groups in panel A. We observed that the agronomic information (T1) resulted in a modest increase of less than 10% in the utilization of improved seed among farmers, specifically concerning the use of Hawassa-04 ICV (see Table 5). Oppositely, we found a negative effect of our interventions in T2 and T3. This indicates that the productivity and profitability information did not change the usage of ICV among farmers. It becomes evident that the farmers in panel A were not willing to apply (use) ICVs despite the interventions.

However, in panel B, after 2 years (in 2023), our information interventions resulted in a positive and significant impact on the use of improved cassava seeds (Table 5). Providing agronomic technical information in the field (T1) positively affects the use of improved cassava seeds. The output indicates a substantial increase in the utilization of Hawassa-04 seed by 23.9%, Chichu seed by 12.2%, and Qulle/Kello seed by 12.8%.

Similarly, the productivity and profitability information positively impacted cassava growers' adoption of improved cassava seeds. This intervention showed a change or improvement in the utilization of Hawassa-04 by 13.9%, Chichu seed by 11.1% and Qulle/Kello seed by 11.7%.

Furthermore, pooled information had a lesser effect on farmers to the use of improved cassava seeds. The intervention created an impact on farmers to use Hawassa-04 seed by 6.4%, Chichu by 1.4%, and Qulle/

Kello by 2.1%. This indicates that farmers tended more to agronomic information and profitability information, rather than pooled interventions. In summary, our findings indicate that agronomic information had a higher effect than productivity and profitability information provision. These findings provide insights for agricultural organizations and policymakers to understand the role of utilizing innovative information provision approaches to enhance the adoption of improved cassava seeds among cassava-growing farmers.

5.6 The effect of information interventions on recommended fertilizer use

Moving forward, we directed our attention to analyzing the effect of our information provision interventions on recommended fertilizer use, as presented in Table 6. In panel A, the data we gathered revealed that our interventions did not significantly change the utilization of recommended fertilizers such as DAP and UREA. However, in examining Table 6, column 3, we find that our interventions had a substantial effect only on compost utilization. This was witnessed by an increase in compost usage of 22.4, 17.1, and 15.4% for T1, T2, and T3, respectively, compared to control groups for panel A (Table 6).

In panel B, we found that treatment one significantly increased the utilization of DAP and compost among cassava growers. Compared to placebo groups, farmers who received agronomic information increased their utilization of DAP by 10.7% and compost by 37% at a 1% level of significance. This result is in line with Balew et al. (2023) who studied incentivizing and nudging approaches to diffuse integrated pest management knowledge to farmers in Ethiopia.

Productivity and profitability information treatment (T2) have shown varying levels of significance for improved fertilizer usage. DAP utilization has increased by 6.9% at a 5% significance level, while UREA utilization increased by 5.4% at a 10% significance level. In addition, compost utilization has increased by 30.6% at a 1% level of significance compared to control groups.

Similarly, both agronomic and productivity and profitability interventions had a greater effect on compost use. Farmers who received these interventions increased their compost utilization by 30.3% at a 1% significance level. Then, the treatment had an impact on the use of DAP, increasing it by 9.3% at a 10% significance level.

When examining the effectiveness of our treatments in encouraging the use of improved fertilizers in cassava production, we observed that the treated groups typically relied on compost compared to untreated groups in Panels A and B. The reason for the preference for applying compost can be attributed to the ease of compost preparation using locally available animal–plant-based materials that were accessible around their home garden. In addition, compost has proven to be an economical choice compared to other organic fertilizers (Omotilewa et al., 2019; Adong et al., 2020; Barrett et al., 2022; Balew et al., 2023).

5.7 The effect of information treatments on production outcomes

Table 7 presents the effect of information treatments on production outcomes and practices, focusing on the area planted per hectare, production per household, and the yield per quintal of cassava among treatment groups in comparison to placebo groups in panel A (year 2021) and panel B (year 2023).

In panel A, the provision of agricultural information treatments had a significant impact on the share of land, the production, and the yield of cassava producers. By providing the agronomic technical information, the cassava area harvested increased by 5.5%, the production by 104.35 quintals per household, and the yield by 122.70 quintals per hectare compared to the control groups (Table 7). Similarly, the productivity and profitability information increased by 2.5% in harvested cassava area, 72.64 quintals per household in production, and the yield by 61.35 quintals per hectare compared to the control groups. Moreover, the pooled information helped farmers increase the area planted by 3.5% compared to untreated groups. It also increased the production farmers' ability by 72.64 quintals per household and the yield by 50.73 quintals per hectare compared to control groups.

In pane B, the agronomic technical information at the field visit significantly impacted the share of land to cassava, production, and yield at a 1% level of significance. The data indicated that those farmers who received this intervention increased their share of land to cultivate improved cassava variety by 0.107 hectares. In addition, the treated farmers produced a surplus of 126.58 quintals of cassava over the control groups in the given cropping year. Moreover, the yield of cassava in the treatment group exceeded the control group by 151.56 quintals per hectare. This result is supported by Arouna et al. (2021) who studied the digital delivery of personalized extension advice in Nigeria.

Similarly, productivity and profitability information by video-show intervention also had a significant impact on the area covered by improved cassava varieties (ICVs). The intervention had resulted in an increase of 0.055 hectares compared to control arms. Over the 2 years (2021–2023), there was a difference of 80.41 quintals between the treatment and control groups. Yield output indicates that 78.32 quintals per hectare difference was recorded among the treatment arms. This indicates that our intervention affected the production outcomes. This confirms the finding of (Abate et al., 2023) who identified a video-mediated extension approach to accelerate the technical performance of farmers through ICT in Ethiopia.

On the other hand, pooled information provision had a significant effect only on production and yield outcomes at a 1% level of significance. In this intervention, households who received the treatment increased the production of cassava by 79.37 quintals compared to control groups. Similarly, the yield increased by 53.50 quintals per hectare compared to untreated groups. The findings resonate with Barrett et al. (2022) who found that training positively and significantly affected households' rice yield, profit, and wellbeing in Madagascar.

6 Conclusion and policy recommendations

We employed information intervention to study the adoption of improved cassava varieties using two-round panel data in Ethiopia. We provided agronomic technical information, productivity and profitability information, and pooled information to treated farmers and compared them with farmers who did not receive any information using a randomized control trial (RCT) approach in 32 villages. We found that information provision interventions positively affected

TABLE 7 The effect of information treatments on production outcomes.

Treatments	Area planted per HHs (ha)	Production per HHs (Quintals)	Yield (Quintal/ha)
	(1)	(2)	(3)
Panel A: Year 2021			
Agronomic technical information (T1)	0.055***	104.35***	122.70***
	(0.013)	(15.33)	(13.74)
Productivity and profitability information (T2)	0.025***	72.64***	61.35***
	(0.011)	(13.48)	(11.35)
Pooled information (T1 + T2) = T3	0.035***	75.10***	50.73***
	(0.012)	(15.58)	(15.00)
Baseline control mean	0.231	268.58	250.61
	(0.006)	(4.61)	(5.12)
p-values			
p-value of T1	0.000	0.000	0.000
p-value of T2	0.000	0.000	0.000
p-value of T3	0.000	0.000	0.001
Observations	2072	1,447	1,109
Panel B: Year 2023			
Agronomic technical information (T1)	0.107***	126.58***	151.56***
	(0.013)	15.577	14.793
Productivity and profitability information (T2)	0.055***	80.41***	78.32***
	(0.011)	(13.69)	(13.35)
Pooled information (T1 + T2) = T3	0.044	79.37***	53.50***
	(0.012)	(15.62)	(15.03)
Baseline control mean	0.207	297.552	265.25
	(0.003)	(8.92)	(7.59)
p-values			
p-value of T1	0.000	0.000	0.000
p-value of T2	0.000	0.000	0.000
p-value of T3	0.000	0.000	0.000
Observations	2060	1,143	1,109

Source: Model output, 2024.
Standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

the understanding and knowledge of improved cassava varieties adoption among farmers. We also found a heterogeneous effect of our interventions on the use of ICVs across different treatment groups in our panels. Our interventions did not have a significant impact on the adoption of recommended fertilizers such as DAP and UREA, but they resulted in a positive effect on compost utilization among treatment groups in a short time (in panel A). However, we found a positive effect after the second intervention. Information provision interventions have had a significant effect on increasing the share of land allocated to cassava, production, and yield.

Media exposure, access to cell phones, access to infrastructure, perception of farmers to ICVs, and extension support were factors that negatively influenced the information delivery of ICVs and farmers' adoption decisions. On the other hand, variables such as participation in social groups, farm size, and the logarithm of farm income positively affect the provision of agricultural information. Further policy research and evaluations are needed to assess the effectiveness of information intervention in different contexts and settings and factors that influence the improved cassava adoption and yield. Additional farmer-targeted information and education provision programs are needed on the benefit and proper utilization of improved seeds and fertilizers to enhance cassava growers' yield.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by Wolaiata Sodo University (WSU) ethics committee. Written informed consent to participate in this study was provided by the participants.

Author contributions

SSW: Conceptualization, Data curation, Methodology, Investigation, Writing – original draft. BKS: Conceptualization, Data curation, Supervision, Investigation, Writing – review and editing. SZW: Conceptualization, Investigation, Methodology, Writing – review & editing. WAK: Data curation, Software, Validation, Visualization, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

Abate, G. T., Bernard, T., Makhija, S., and Spielman, D. J. (2023). Accelerating technical change through ICT: evidence from a video-mediated extension experiment in Ethiopia. *World Dev.* 161:106089. doi: 10.1016/j.worlddev.2022.106089

Adegbola, P., and Gardebroek, C. (2007). The effect of information sources on technology adoption and modification decisions. *Agric. Econ.* 37, 55–65. doi: 10.1111/j.1574-0862.2007.00222.x

Adong, A., Tinker, J., Levine, D., Mbowa, S., and Odokonyero, T. (2020). Encouraging fertilizer adoption through risk free sales offer: a randomized control trial in Uganda. *World Dev. Perspect.* 19:100230. doi: 10.1016/j.wdp.2020.100230

Ajzen, (1991). The theory of planned behavior. *Organ. Behav. Hum. Decis. Process.* 50, 179–211. doi: 10.1016/0749-5978(91)90020-T

Arouna, A., Michler, J. D., Yergo, W. G., and Saito, K. (2021). One size fits all? Experimental evidence on the digital delivery of personalized extension advice in Nigeria. *Am. J. Agric. Econ.* 103, 596–619. doi: 10.1111/ajae.12151

Ayalew, H., Chamberlin, J., and Newman, C. (2022). Site-specific agronomic information and technology adoption: a field experiment from Ethiopia. *J. Dev. Econ.* 156:102788. doi: 10.1016/j.jdeveco.2021.102788

Babu, S. C., Babu, S. C., and Glendenning, C. J. (2019). "Information needs of farmers: a systemic study based on farmer surveys" in Agricultural extension reforms in South Asia: Status, challenges, and policy options. eds. S. C. Babu and P. K. Joshi (Amsterdam: Elsevier Inc.).

Balew, S., Bulte, E., Abro, Z., and Kassie, M. (2023). Incentivizing and nudging farmers to spread information: experimental evidence from Ethiopia. *Am. J. Agric. Econ.* 105, 994–1010. doi: 10.1111/ajae.12346

Barrett, C. B., Islam, A., Mohammad Malek, A., Pakrashi, D., and Ruthbah, U. (2022). Experimental evidence on adoption and impact of the system of Rice intensification. *Am. J. Agric. Econ.* 104, 4–32. doi: 10.1111/ajae.12245

Chikuni, T., and Kilima, F. T. M. (2019). Smallholder farmers' market participation and mobile phone-based market information services in Lilongwe, Malawi. *Electron. J. Inf. Syst. Dev. Ctries.* 85, 1–13. doi: 10.1002/isd2.12097

Cochrane, L., and Gecho, Y. (2018). Data on the demographics, education, health and infrastructure: Wolaita zone, Ethiopia. *Data Brief* 21, 2095–2102. doi: 10.1016/j.dib.2018.11.063

Cole, S. A., and Fernando, A. N. (2021) 'Mobile'izing Agricultural Advice Technology Adoption Diffusion and Sustainability. *The Economic Journal.* 131, 192–219. doi: 10.1093/ej/ueaa084

CSA (2021). Federal democratic republic of Ethiopia. Central statistical agency. Agricultural sample survey, volume II, report on livestock and livestock. In Central statistical agency (CSA), Addis Ababa, Ethiopi. Available at: https://www.scirp.org/journal/articles.aspx?searchcode=CSA+(Central+Statistics+Agency)+(2015)+Agricultural+Sample+Survey+2014%252F15.+Volume+II+Report+on+Livestock+and+Livestock+Characteristics+(Private+Peasant+Holdings)%252C+Central+Statistical+Agency+(C)

Dhehibi, B., Dhraief, M. Z., Ruediger, U., Frija, A., Werner, J., Straussberger, L., et al. (2022). Impact of improved agricultural extension approaches on technology adoption: evidence from a randomised controlled trial in rural Tunisia. *Exp. Agric.* 58, 1–16. doi: 10.1017/S0014479722000084

Dissanayake, C. A. K., Jayathilake, W., Wickramasuriya, H. V. A., Dissanayake, U., Kopiyawattage, K. P. P., and Wasala, W. M. C. B. (2022). Theories and models of technology adoption in agricultural sector. *Hum. Behav. Emerg. Technol.* 2022, 1–15. doi: 10.1155/2022/9258317

Duflo, E., Glennerster, R., and Kremer, M. (2007). Chapter 61 using randomization in development economics research: a toolkit. *Handb. Dev. Econ.* 4, 3895–3962. doi: 10.1016/S1573-4471(07)04061-2

Dzanku, F. M., Osei, R., and Osei-Akoto, I. (2021). The impact of mobile phone voice message reminders on agricultural outcomes in Mali. *Agric. Econ.* 52, 789–806. doi: 10.1111/agec.12654

FAO (2020). The state of food security and nutrition in the world 2020. Rome: FAO.

FAO (2022). World food and agriculture – statistical yearbook 2022. Rome: FAO.

Feder, G., Just, R. E., and Zilberman, D. (1985). Adoption of agricultural innovations in developing countries: a survey. *Econ. Dev. Cult. Change* 33, 255–298. doi: 10.1086/451461

Freeman, K., and Qin, H. (2020). The role of information and interaction processes in the adoption of agriculture inputs in Uganda. *Agronomy* 10, 1–16. doi: 10.3390/agronomy10020202

Gao, Y., Zhao, D., Yu, Y., and Yang, H. (2020). Influence of a new agricultural technology extension mode on farmers' technology adoption behavior in China. *Journal of Rural Studies* 76, 173–183. doi: 10.1016/j.jrurstud.2020.04.016

Haile, M. G., Wossen, T., and Kalkuhl, M. (2019). Access to information, price expectations and welfare: the role of mobile phone adoption in Ethiopia. *Technol. Forecast. Soc. Chang.* 145, 82–92. doi: 10.1016/j.techfore.2019.04.017

Hillmer, U. (2009). "Existing theories considering technology adoption" in Technology Acceptance in Mechatronics. ed. U. Hillmer (Berlin: Springer).

Ikuemonisan, E. S., Mafimisebi, T. E., Ajibefun, I., and Adenegan, K. (2020). Cassava production in Nigeria: trends, instability and decomposition analysis (1970–2018). *Heliyon* 6:e05089. doi: 10.1016/j.heliyon.2020.e05089

Janvry, A., Sadoulet, E., and Suri, T. (2017). "Field experiments in developing country agriculture" in Handbook of economic field experiments. ed. A. Banerjee (Amsterdam: Elsevier Ltd.).

Kassa, Y., Giziew, A., and Ayalew, D. (2021). Determinants of adoption and intensity of improved faba bean cultivars in the central highlands of Ethiopia: a double-hurdle approach. *CABI Agric. Biosci.* 2, 1–12. doi: 10.1186/s43170-021-00045-8

Kondo, K., Cacho, O., Fleming, E., Villano, R. A., and Asante, B. O. (2020). Dissemination strategies and the adoption of improved agricultural technologies: the case of improved cassava varieties in Ghana. *Technol. Soc.* 63:101408. doi: 10.1016/j.techsoc.2020.101408

Krell, N. T., Giroux, S. A., Guido, Z., Hannah, C., Lopus, S. E., Caylor, K. K., et al. (2021). Smallholder farmers' use of mobile phone services in Central Kenya. *Clim. Dev.* 13, 215–227. doi: 10.1080/17565529.2020.1748847

Larochelle, C., Alwang, J., Travis, E., Barrera, V. H., and Dominguez Andrade, J. M. (2019). Did you really get the message? Using text reminders to stimulate adoption of agricultural technologies. *J. Dev. Stud.* 55, 548–564. doi: 10.1080/00220388.2017.1393522

Lecoutere, E., Spielman, D. J., and Van Campenhout, B. (2023). Empowering women through targeting information or role models: evidence from an experiment in agricultural extension in Uganda. *World Dev.* 167:106240. doi: 10.1016/j.worlddev.2023.106240

Legg, J. P., Diebiru-Ojo, E., Eagle, D., Friedmann, M., Kanju, E., Kapinga, R., et al. (2022). "Commercially sustainable cassava seed Systems in Africa" in Root, tuber and banana food system innovations. eds. G. Thiele, M. Friedmann, H. Campos, V. Polar and J. W. Bentley (Cham: Springer).

Liu, J., Chen, K., and Shi, M. (2004). Access to information and the adoption of hybrid maize: evidence from China's poor areas. *Jpn. J. Rural Econ.* 6, 13–19. doi: 10.18480/jjre.6.13

Maredia, M. K., Reyes, B., Ba, M. N., Dabire, C. L., Pittendrigh, B., and Bello-Bravo, J. (2018). Can mobile phone-based animated videos induce learning and technology adoption among low-literate farmers? A field experiment in Burkina Faso. *Inf. Technol. Dev.* 24, 429–460. doi: 10.1080/02681102.2017.1312245

Masamba, K., Changadeya, W., Ntawuruhunga, P., Pankomera, P., Mbewe, W., and Chipungu, F. (2022). Exploring farmers' knowledge and approaches for reducing post-harvest physiological deterioration of cassava roots in Malawi. *Sustainability (Switzerland)* 14:2719. doi: 10.3390/su14052719

Mihretie, A. A., Abebe, A., and Misganaw, G. S. (2022). Adoption of Tef (Eragrostis Tef) production technology packages in Northwest Ethiopia. *Cogent Econ. Finance* 10:2013587. doi: 10.1080/23322039.2021.2013587

Mugonya, J., Kalule, S. W., and Ndyomugyenyi, E. K. (2021). Effect of market information quality, sharing and utilisation on the innovation behaviour of smallholder pig producers. *Cogent Food Agric.* 7:1948726. doi: 10.1080/23311932.2021.1948726

Musara, J. P., and Musemwa, L. (2020). Impacts of improved sorghum varieties intensification on household welfare in the mid-Zambezi Valley of Zimbabwe. *Agrekon* 59, 254–267. doi: 10.1080/03031853.2020.1721306

Naika, M. B. N., Kudari, M., Devi, M. S., Sadhu, D. S., and Sunagar, S. (2021). "Digital extension service" in Food technology disruptions. ed. C. M. Galanakis (Cambridge, MA: Academic Press), 285–323.

Nakasone, E., and Torero, M. (2016). A text message away: ICTs as a tool to improve food security. *Agri. Econ. (United Kingdom)* 47, 49–59. doi: 10.1111/agec.12314

Ndimbwa, T., Mwantimwa, K., and Ndumbaro, F. (2021). Channels used to deliver agricultural information and knowledge to smallholder farmers. *IFLA J.* 47, 153–167. doi: 10.1177/0340035220951828

Nwankwo, U. M., Peters, K. J., and Bokelmann, W. (2009). Information access and relevance affects adoption decision: rethinking adopter categorization. *Res. J. Agric. Biol. Sci.* 5, 411–422.

Olawuyi, S. O., and Mushunje, A. (2020). Information acquisition and adoption of conservation agriculture by smallholder farmers in south-West Nigeria: recursive bivariate probit estimation. *Afr. J. Sci. Technol. Innov. Dev.* 12, 715–725. doi: 10.1080/20421338.2019.1701774

Olayide, O. E., Obisesan, D., Nitturkar, H., Adesida, A., Alegieunu, B., and Obisesan, O. (2021). Cassava seedpreneurship, determinants of varietal adoption, profitability, and women empowerment in Nigeria. *Resour. Environ. Sustain.* 6:100041. doi: 10.1016/j.resenv.2021.100041

Omotilewa, O. J., Ricker-Gilbert, J., and Ainembabazi, J. H. (2019). Subsidies for agricultural technology adoption: evidence from a randomized experiment with improved grain storage bags in Uganda. *Am. J. Agric. Econ.* 101, 753–772. doi: 10.1093/ajae/aay108

Piabuo, S. M., Yakan, H. B., Puatwoe, J. T., Nonzienwo, V. Y., and Mamboh, T. R. (2020). Effect of rural farmers' access to information on price and profits in Cameroon. *Cogent Food Agric.* 6. doi: 10.1080/23311932.2020.1799530

Pratiwi, A., and Suzuki, A. (2020). Does training location matter? Evidence from a randomized field experiment in rural Indonesia. *Agric. Food Econ.* 8:3. doi: 10.1186/s40100-019-0146-4

Purnomo, S. H., and Kusnandar. (2019). Barriers to acceptance of information and communication technology in agricultural extension in Indonesia. *Inf. Dev.* 35, 512–523. doi: 10.1177/0266666918767484

Rogers. (1983). Diffusion of innovations. S. P. Marshall and VenA. H. Van de In The Oxford handbook of organizational change and innovation. Oxford: Oxford University Press.

Ruzzante, S., Labarta, R., and Bilton, A. (2021). Adoption of agricultural technology in the developing world: a meta-analysis of the empirical literature. *World Dev.* 146:105599. doi: 10.1016/j.worlddev.2021.105599

Ryan, B., and Gross, N. C. (1943). The diffusion of hybrid seed corn in two Iowa communities. *Rural. Sociol.* 8:15.

Shikuku, K. M., Pieters, J., Bulte, E., and Läderach, P. (2019). Incentives and the diffusion of agricultural knowledge: experimental evidence from northern Uganda. *Am. J. Agric. Econ.* 101, 1164–1180. doi: 10.1093/ajae/aaz010

Tafesse, A., Mena, B., Belay, A., Aynekulu, E., Recha, J. W., Osano, P. M., et al. (2021). Cassava production efficiency in southern Ethiopia: the parametric model analysis. *Front. Sustain. Food syst.* 5:758951. doi: 10.3389/fsufs.2021.758951

Taherdoost, H. (2018). A review of technology acceptance and adoption models and theories. *Procedia Manuf.* 22, 960–967. doi: 10.1016/j.promfg.2018.03.137

Van Campenhout, B., Spielman, D. J., and Lecoutere, E. (2021). Information and communication technologies to provide agricultural advice to smallholder farmers: experimental evidence from Uganda. *Am. J. Agric. Econ.* 103, 317–337. doi: 10.1002/ajae.12089

Veettil, P. C., Raghu, P. T., and Ashok, A. (2021). Information quality, adoption of climate-smart varieties and their economic impact in flood-risk areas. *Environ. Dev. Econ.* 26, 45–68. doi: 10.1017/S1355770X20000212

White, H. (2013). An introduction to the use of randomised control trials to evaluate development interventions. *J. Dev. Eff.* 5, 30–49. doi: 10.1080/19439342.2013.764652

Wonde, K. M., Tsehay, A. S., and Lemma, S. E. (2022). Training at farmers training centers and its impact on crop productivity and households' income in Ethiopia: a propensity score matching (PSM) analysis. *Heliyon* 8:e09837. doi: 10.1016/j.heliyon.2022.e09837

WZADDO (2022). Wolaita Zone Agriculturao Development Department Report, 2022. Montreal: WZADDO.

WZPDD (2020). Annual Statistical Abstract. Dublin: WZPDD.

Yitayew, A., Abdulai, A., Yigezu, Y. A., Deneke, T. T., and Kassie, G. T. (2021). Impact of agricultural extension services on the adoption of improved wheat variety in Ethiopia: a cluster randomized controlled trial. *World Dev.* 146:105605. doi: 10.1016/j.worlddev.2021.105605

Zegeye, M. B., Fikire, A. H., and Assefa, A. B. (2022). Impact of agricultural technology adoption on food consumption expenditure: evidence from rural Amhara region, Ethiopia. *Cogent Econ. Finance.* 10:2012988-201. doi: 10.1080/23322039.2021.2012988

 10.3389/fsufs.2024.1421442

Appendix

TABLE A1 Stratification (clustering) of sample sizes by each woreda (district) and kebeles.

Woreda	Kebele	Total population	Sample households
Sodo Zuria	Wachiga Busha	4,204	208
	Tome Gerera	3,672	172
Offa	Wachiga Esho	3,328	180
	Sere Esho	4,080	196
Kindo Koysha	Sere Finchawa	2,772	116
	Fajena mata	2,160	168
	Total	20,216	1,040

Source: Wolaita Zone Agriculture Development Office (WZADDO, 2022).