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Article

Knowledge and Adoption of Complex Agricultural Technologies: Evidence from an Extension Experiment

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Abstract

In most of Sub-Saharan Africa, agricultural extension models have become more decentralized and participatory and thus rely on effective farmer-to-farmer learning, while increasingly including nontraditional forms of education. At the same time, agricultural technologies become more complex and are now often promoted as integrated packages, which are likely to increase the complexity of the diffusion process. Based on a randomized controlled trial, this study assesses the effects of "farmer-to-farmer" extension and a video intervention on adoption of a complex technology package among 2,382 smallholders in Ethiopia. Both extension-only and extension combined with video increase adoption and knowledge of the package, especially of its more complex components; on average, however, the video intervention has no additional effect on adoption. Knowledge and the number of adopted practices also increase among farmers not actively participating in extension activities, which suggests information diffusion. For this group, the additional video intervention has a reinforcing effect, and particularly fosters adoption of the integrated package.

JEL classification: D83, O13, O22, O33, Q16

Keywords: randomized controlled trial, integrated soil fertility management, technology diffusion, agricultural extension systems, rural development

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1. Introduction

The slow adoption of new agricultural technologies is an important factor in explaining persistent productivity deficits and poverty among the rural population in developing countries, especially in Sub-Saharan Africa (SSA). Recent evidence shows in particular that farmers delay the uptake of integrated system technologies, that is, packages of agricultural practices that should be jointly applied in order to deploy their full productivity-enhancing potential (Noltze, Schwarze, and Qaim 2012; Sheahan and Barrett 2017; Ward et al. 2018). Integrated system technologies are typically knowledge-intensive, as they require the understanding of at least basic underlying biological functions and processes and the adaptation of practices to local agri-environmental conditions (Vanlauwe et al. 2015; Jayne et al. 2019). While information and knowledge constraints are frequently cited barriers to the adoption of agricultural innovations in general (Foster and Rosenzweig 1995; Magruder 2018), they are also likely to play a key role in explaining incomplete adoption or nonadoption of complex system technologies (Takahashi, Muraoka, and Otsuka 2019).

Based on a randomized controlled trial, this study analyzes the effects of “farmer-to-farmer extension” on knowledge and adoption of an integrated system technology. The effectiveness of information spillovers is analyzed as a key principle of farmer-to-farmer extension models by estimating differential effects for those who actively participate in the extension activities and those who, at most, benefit indirectly. The study further evaluates whether an additional intervention in the form of a video can counterbalance incomplete information diffusion (which is likely to occur in farmer-to-farmer extension set-ups) and thus foster the wider adoption of the system technology.

Agricultural extension services aim at transferring knowledge to farmers in order to bridge knowledge and capacity gaps. In recent decades, agricultural extension approaches in SSA have become more decentralized. In this approach, extension agents train a small number of selected farmers (often referred to as “model farmers”) in the application of new techniques. These model farmers are then expected to pass their knowledge on to other farmers in the village, who are usually organized in groups to facilitate participatory learning processes. This goes along with a shift in perspective from a “top-down” to a more inclusive “bottom-up” strategy, which is often referred to as “farmer-to-farmer extension” (Takahashi, Muraoka, and Otsuka 2019). Eventually, exposure to on-farm demonstrations, to trained model farmers, and to group members is supposed to spur broader technology adoption in the community (Gautam 2000; Swanson 2008).

A growing body of literature has analyzed the effectiveness of decentralized extension models in facilitating innovation and knowledge diffusion. There is now substantial evidence that directly training selected farmers spurs knowledge and adoption among them (Godtland et al. 2004; Davis et al. 2012; Kondylis, Mueller, and Zhu 2017). There is also some evidence that subsequent diffusion to other farmers takes place (Fisher et al. 2018; Nakano et al. 2018; Takahashi, Mano, and Otsuka 2019). In contrast, several studies conclude that knowledge gains among trained individuals hardly trickle down to neighboring farmers (Rola, Jamias, and Quizon 2002; Feder, Murgai, and Quizon 2004; Tripp, Wijeratne, and Piyadasa 2005), and that increased technology adoption among trained farmers does little to change the behavior of their nontrained peers (Van den Berg and Jiggins 2007; Kondylis, Mueller, and Zhu 2017).

A relatively new strand of research focuses more explicitly on the determinants of diffusion processes in farmer-to-farmer extension set-ups. These studies find that successful diffusion is shaped by model farmers’ motivation and familiarity with the technology (Fisher et al. 2018), incentives attached to information dissemination (BenYishay and Mobarak 2019; Shikuku et al. 2019) and the social distance between communicators and target farmers (BenYishay and Mobarak 2019; Shikuku 2019), as well as other context-specific forms of social capital (Pamuk, Bulte, and Adekunle 2014). In addition, some studies suggest that farmers need to learn from multiple sources before they adopt (Beaman et al. 2018; Fisher et al. 2018). Most of these studies, however, focus on the adoption of (several) individual practices, while recent extension efforts in SSA increasingly concentrate on integrated system technologies (Takahashi, Muraoka, and Otsuka 2019).

This paper contributes to the literature by focusing on the integrated adoption of a complex system technology, rather than on the uptake of individual practices, an issue that has been largely understudied to date (Sheahan and Barrett 2017; Jayne et al. 2019). The study was implemented in the context of a large-scale farmer-to-farmer extension program promoting "Integrated Soil Fertility Management" (ISFM) in three rural regions of Ethiopia. ISFM is a knowledge-intensive system technology widely promoted in SSA as a strategy to sustainably intensify agricultural productivity, combat land degradation, and enhance rural livelihoods (Jayne et al. 2019). A fundamental feature of ISFM is the integrated use of improved seeds together with inorganic and organic soil amendments. In addition, ISFM aims at generally improving agronomic techniques adapted to local conditions (Place et al. 2003).

By estimating differential effects for direct and indirect beneficiaries of the extension intervention, this paper adds to the scarce literature on information spillovers in the context of integrated system technologies. For the case of complex technologies, previous studies document substantial information losses along the transmission chain from extension agents to farmers (Niu and Ragasa 2018; Maertens, Michelson, and Nourani 2020). Yet literature also suggests that reminders of commonly neglected knowledge dimensions can help to offset incomplete information diffusion (Hanna, Mullainathan, and Schwartzstein 2014; Niu and Ragasa 2018). This could potentially be achieved through video messages, since previous research has shown that video, as an information delivery channel, can increase knowledge and technology adoption in farming communities (Bernard et al. 2016; Van Campenhout, Spielman, and Lecoutere 2020).

This study expands the existing evidence on the effectiveness of video interventions, particularly focusing on their role in offsetting incomplete information diffusion in farmer-to-farmer extension settings. In this context, the video intervention is intended to remind farmers of commonly neglected knowledge dimensions, in particular emphasizing the importance of the holistic concept of the system technology (joint application of practices), and additionally explaining the underlying principles of the components. While extension activities often aim at providing awareness for improved practices and instructions on how to implement them, these practices frequently disregard the importance of providing sufficient information on *why* certain practices are beneficial (Rogers 1995; Anderson and Feder 2007). This study explicitly focuses on the role of different types of knowledge, including knowledge on the underlying principles, as potential drivers of adoption.

The paper is structured as follows. Section 2 describes the experimental design, section 3 the empirical data and empirical strategy. Section 4 presents the main results; section 5 discusses the implications of the findings, and section 6 concludes.

2. Experimental Design

The study builds on a randomized controlled trial (RCT) with two treatment arms and a control group. The first treatment consists of an extension intervention; the second treatment combines the extension intervention with a video intervention. Microwatersheds (mws) were used as units of randomization, which are common implementation units for natural resource–related interventions in Ethiopia.[1] The extension intervention was part of the Integrated Soil Fertility Management Project (ISFM+ project) carried out by the German Agency for International Cooperation (GIZ) in three rural regions of

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[1] Microwatersheds are the smallest hydrological entity, i.e., subunits of major watersheds, defined by the topography of the land, and typically consist of around 250 to 300 households in one or several communities that share a common rainwater outlet.

Ethiopia: Amhara, Oromia, and Tigray.[2] During the initial phase of the ISFM+ project, from 2015 to 2018, the use of five so-called quickwin technologies, including compost, blended fertilizers,[3] improved seeds, line seeding (as opposed to broadcasting), and lime application, was promoted for the major cereal crops: maize, wheat, teff, barley, and sorghum. Lime is promoted only in regions where soils suffer from acidity, which is true of Amhara and Oromia, but not Tigray. The project encourages the joint application of these individual components as a key feature of ISFM.

Treatment Description

The core elements of the extension intervention are the following: In each treatment mws, three so-called farmer research and extension groups (FREG) were formed, each consisting of 16 or 17 members, leading to a total of around 50 FREG members per mws. FREG farmers were selected in a nonrandom manner by extension agents and village heads, based on farmers' interest and social involvement. The FREGs conduct regular meetings, typically once or twice per month, to discuss agricultural topics. Each group is led by three of its members, called model farmers, whose central activity is the establishment and maintenance of demonstration plots. For this purpose, model farmers receive trainings on ISFM from public extension agents and are provided with all necessary inputs. Demonstration plots are on-farm trials on which the package of ISFM practices is applied, next to plots that are managed according to traditional farming practices. Hence, the benefits of ISFM in comparison to traditional practices, such as yield improvements, become clearly visible to farmers (see S1 in the Supplementary Online Appendix). In each mws, farmer field days are conducted twice per harvest cycle: at critical stages around midseason and just before harvest. During these field days, model farmers share and discuss their experience with FREG members; extension agents are present to complement information. Field day activities are mainly targeted at FREG members, although in some communities, other farmers also participate. Overall, the extension treatment aims at creating awareness and know-how about ISFM through a knowledge-sharing process from extension agents to model farmers, and from model farmers to other FREG members. FREG members are then encouraged to share the information with the broader population of farmers in the communities. Hence, this model heavily relies on peer-to-peer learning. While information diffusion to model farmers and other FREG members is facilitated through regular meetings, farmer field days, and visits to demonstration plots, information sharing with the broader community is not formalized or incentivized in any particular way.

The video intervention has been designed to provide an additional stimulus for adoption by exposing farmers to information about the ISFM concept, in order to overcome potential knowledge gaps on key dimensions of the approach. The video provides farmers with information on *why* each component is important, that is, explanations about the underlying principles and mechanisms of ISFM, and emphasizes the positive synergy effects of applying the practices jointly on the same plot. The movie is composed of two parts: a narrative and documentary part that presents the example of a farmer couple who have successfully implemented the ISFM quickwin technologies and visibly increased yields, serving as (potential) role models for treated farmers. Given cultural, linguistic and agroecological differences between Tigray, Amhara, and Oromia, three different farmer couples were featured in the versions for the respective region. Beyond smaller local adaptations, all three versions strictly follow the same script in order to convey the same messages. The second component of the film consists of animations that visualize processes taking place in the soil—such as hydrological and soil nutrient cycles—and how these relate to

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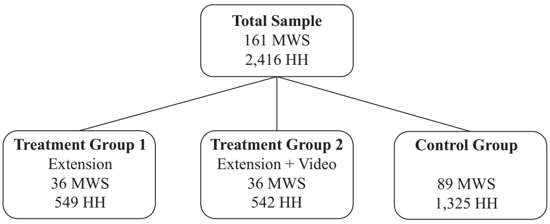
[2] The ISFM+ project is a component of GIZ's contribution to the Ethiopian Sustainable Land Management Programme (SLMP) and operates only in districts where physical land rehabilitation measures (stabilization of hillsides, erosion control measures) have been successfully introduced by the SLMP. Beginning of 2018, the SLMP has been replaced by the successor program, Sustainable Use of Rehabilitated Land for Economic Development (SURED).

[3] Blended fertilizers are inorganic fertilizers composed in accordance with a specific location's soil type.

Figure 1. Diagrammatic Illustration of the Full Sample



Source: Authors' illustration.
Note: MWS stands for microwatershed, HH for household.

ISFM. Ultimately, farmers should gain a better understanding of why the integrated use of all techniques is important to improve soil fertility and productivity.

Sampling and Randomization Strategy

Since the participatory extension approach draws on the establishment of community-based farmer groups and demonstration sites, the study applied a cluster randomization approach using microwatersheds (mws) as sampling units. The full sampling frame consists of 161 mws located in 18 districts (in Ethiopia called Woredas), equally distributed among the three regions Tigray, Amhara and Oromia.[4] From this list, a sample of treatment mws was drawn randomly—stratified by region and Woreda—so that in each Woreda four mws were selected, resulting in a total of 72 treatment mws. Half of the 72 treatment mws were assigned to the additional video intervention. Consequently, 36 mws received the extension treatment only (in the following referred to as T1), and another 36 mws received the extension treatment plus the additional video intervention (T2). The remaining 89 mws serve as a control group (C).

For the survey, complete lists of households living in the respective mws were compiled using administrative village lists of registered households. From these lists, 18 households were randomly selected in each mws; 15 to be interviewed and three as potential replacements.[5] Thus, in treatment mws, the proportions of non-FREG and FREG farmers in the sample should on average represent their distribution in the population. The full original sample consists of 2,416 households and is graphically depicted in fig. 1.

Treatment Implementation

Figure 2 depicts a timeline of the treatment implementation and the survey data collection. While the ISFM+ project was launched by the German Agency for International Cooperation (GIZ) in mid-2015, the above-described extension activities only started in the following main cropping season, that is, in April 2016.[6] Since then, extension activities in the treatment mws are on-going and implemented each year during the main growing season.

The video screenings were conducted in T2 mws in early 2017, around six weeks prior to the start of the main growing season. The video was shown in public spaces such as farmer training centers, health posts or schools, and followed by group discussions facilitated by extension agents. In each of the T2 mws, the 15 households from the sample were invited by village heads a few days prior to the screenings orally and with written invitation cards. In the case of double-headed households we invited both spouses,

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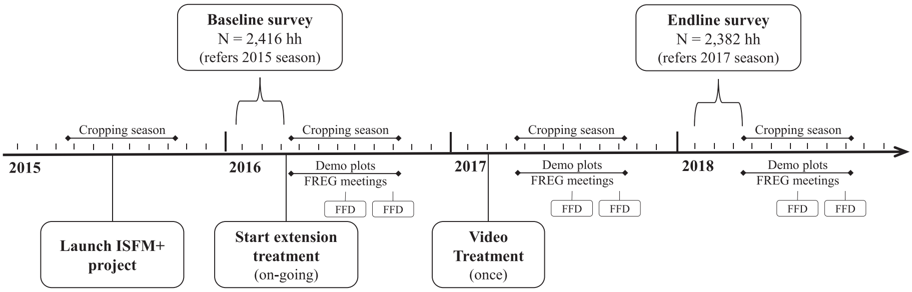
[4] The list of target mws was compiled based on the criteria (1) benefiting from the Sustainable Land Management Programme and (2) no/minimal previous exposure to soil fertility interventions.

[5] Households were replaced only if they refused to participate in the survey or could not be found. If household members were currently unavailable, the enumerator would return at a later time for the interview.

[6] In the first months, the project's main activities were establishing partnerships and conducting planning workshops.

Figure 2. Timeline of Treatment and Survey Implementation



Source: Authors' illustration.
Note: FFD stands for farmer field day.

otherwise only household heads. Farmers participating in the video screenings were registered by name to document attendance.[7]

3. Data and Empirical Strategy

Data

In order to assess the interventions' impact, two rounds of survey data were collected (compare fig. 2). A baseline survey took place in early 2016, immediately before the start of the 2016 main growing season. The endline survey was carried out among the same rural households in early 2018, that is, before the start of the 2018 main growing season. Data in both rounds were collected through tablet-based face-to-face interviews with the household head or spouse, using a structured questionnaire. The attrition rate was remarkably low, since 2,382 (98.6 percent) of the 2,416 baseline sample households could be re-interviewed during endline, and no nonrandom patterns were detected in this.

The surveys collected data on household sociodemographic characteristics, income and assets, farming practices, agricultural production, and exposure to agricultural extension. Data were elicited retrospectively for the previous 12 months; thus, the agricultural data cover the preceding cropping season: that is, the baseline survey refers to the 2015 season and the endline survey to the 2017 season. Accordingly, the impact assessment measures adoption in the 2017 cropping season while extension activities were ongoing, and after farmers had been exposed to one full cycle of extension activities during the 2016 growing season.

To maintain comparability, the endline survey assessed most information in the exact same way as in the baseline. Yet for the adoption of ISFM practices we had to adapt the mode of measurement slightly, because the information collected at baseline was not detailed enough for the intended analyses. While at baseline agricultural information was elicited at the farm level, plot-level information was obtained in the endline, which made it possible to assess the integrated adoption of ISFM at the plot level. In addition, the endline survey contained measures to increase the reliability of the self-reported data. For compost, enumerators inspected and measured the compost pit or heap, and assessed detailed questions on the production process and quality of the end product to avoid simple yes/no questions that tend to be more susceptible to response bias (see S2 in the Supplementary Online Appendix). For inorganic fertilizers, enumerators used pictures to identify the type of fertilizer used by the farmer

[7] Individuals from other mws were not allowed to attend the screenings. However, this situation did not occur in the field, because the video screenings were not broadly announced. After the endline data collection, the video became freely available for extension staff to be used in T1 as well as control communities.

and in addition checked the labels on fertilizer bags.[8] For lime, they also inspected the respective bags. In order to verify the use of improved seeds, the survey contained detailed questions on the original source of the seed and for how long it had been reused. If seeds had been reused for more than four seasons, they are not considered improved seeds in the analysis, because improved traits get lost over generations.[9]

The endline survey further included questions on the participation in ISFM+ extension activities as well as a detailed knowledge test on ISFM technologies. Enumerators first assessed farmers' awareness by asking them which ISFM components they actively remembered, and in a second step asked them which practices they recognized when read to them off a list by name.[10] Subsequently, questions on their underlying principles and purpose ("principles knowledge") as well as their mode of implementation ("how-to knowledge") were posed. The survey combined different types of knowledge questions, including open-ended and multiple-choice questions, to minimize fatigue effects (for details of the knowledge exam, see S3 in the Supplementary Online Appendix).

For the survey, a team of 34 enumerators was recruited and intensively trained during a 10-day training period. Questionnaire contents were carefully translated into the three local languages and pretested in several rounds. In addition to the farm household survey, the survey team administered two community-level questionnaires to key informants at the Woreda and mws levels, in order to collect data on infrastructure, availability of extension services, rainfall, and temperature, as well as other contextual characteristics.

Table 1 depicts descriptive statistics for selected variables at baseline using data from the balanced panel of 2,382 households, including tests for covariate balancing between the three treatment groups to verify the success of the randomization process.[11] Overall, households in the three groups seem largely balanced on a series of sociodemographic and economic indicators. Yet they exhibit a few differences regarding agricultural production–related characteristics, which need to be considered in the outcome estimation framework. Moreover, ISFM practices are not necessarily new to farmers, since some were used prior to the interventions, though mostly to a modest extent.

Key Outcome Variables

Since the key concern of this study is the increase in ISFM adoption, it measures how many ISFM practices households adopted in the preceding harvest cycle (2017), and therefore assessed the *number of ISFM technologies adopted*, ranging from 0 to 5. This variable is used despite the fact that lime is not relevant in one of the regions (and thus, no farmer in Tigray reaches a value of 5), but provides robustness checks verifying that implications do not change, if the study excludes lime and employs a 0 to 4 measure instead. Since the complementary use of the practices is pivotal to ISFM, the second main outcome is the *integrated adoption of the full ISFM package*, assessed with a binary variable that measures whether a farmer has used all four quickwin practices in combination on at least one plot. This variable excludes the use of lime,

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[8] Even if bags are empty, farmers usually keep them for other purposes, e.g., to sit on them or to store other things.

[9] Please note that visual inspections in the field were not possible for the practices of improved seeds and line seeding, because at the time of the survey, packaging material of seeds was usually not available anymore and fields had already been harvested.

[10] Inspired by Kondylis, Mueller, and Zhu (2015), this list included a placebo practice ("seeding in circles") to get a sense for possible response bias, which does not appear to threaten the results since yes answers regarding this practice are close to zero.

[11] Table 1 shows the variables that are used as additional covariates in the adoption and knowledge regressions. Table S4.1 in the Supplementary Online Appendix presents further balance checks on selected household, farming, and community characteristics.

Table 1. Baseline Descriptive Statistics and Balance between Treatment Groups

	Overall	T1 (extension)	T2 (extension + video)	C (control)	T1 − T2	T1 − C	T2 − C
Panel A: Household characteristics							
Age HH head (in years)	47.03	46.27	47.32	47.22	–1.05	–0.95	0.10
	[14.61]	[14.61]	[14.54]	[14.64]	(1.02)	(0.85)	(0.94)
Gender HH head (1 = male)	0.85	0.86	0.84	0.85	0.02	0.01	–0.00
					(0.02)	(0.02)	(0.02)
Education HH head (grades compl.)	2.15	2.19	2.42	2.03	–0.23	0.15	0.39
	[3.36]	[3.36]	[3.61]	[3.24]	(0.37)	(0.32)	(0.28)
Nonfarm family business (1 = yes)	0.19	0.21	0.18	0.18	0.03	0.02	–0.00
					(0.04)	(0.03)	(0.03)
Off-farm wage employment (1 = yes)	0.19	0.18	0.23	0.18	–0.05	–0.00	0.05
					(0.03)	(0.02)	(0.03)
No. of HH members over age 14	3.06	3.08	3.11	3.03	–0.03	0.05	0.08
	[1.31]	[1.34]	[1.31]	[1.29]	(0.11)	(0.10)	(0.08)
No. of organizations involved (0–12)	4.47	4.53	4.38	4.49	0.15	0.05	–0.1
	[1.87]	[1.91]	[1.78]	[1.90]	(0.21)	(0.19)	(0.18)
Basic assets score (0–4)	1.84	1.79	1.91	1.83	–0.13	–0.04	0.09
	[0.89]	[0.84]	[0.90]	[0.90]	(0.10)	(0.09)	(0.09)
No. of TLU owned	3.39	3.26	3.48	3.42	−0.22	−0.16	0.06
	[2.83]	[2.61]	[2.93]	[2.87]	(0.29)	(0.26)	(0.25)
Radio owned (1 = yes)	0.29	0.27	0.29	0.30	−0.02	−0.03	−0.01
					(0.03)	(0.03)	(0.03)
Cellphone owned (1 = yes)	0.52	0.53	0.53	0.51	−0.00	0.02	0.02
					(0.04)	(0.03)	(0.04)
Contracted any credit (1 = yes)	0.34	0.38	0.35	0.32	0.03	0.06**	0.03
					(0.04)	(0.03)	(0.06)
Eligible for formal credit (1 = yes)	0.73	0.71	0.73	0.75	−0.02	−0.04	−0.02
					(0.05)	(0.04)	(0.05)
Food insecurity score (0–12)	2.34	2.29	2.08	2.46	0.21	−0.18	−0.39
	[2.99]	[3.05]	[2.71]	[3.07]	(0.31)	(0.27)	(0.26)
Walking dist. to nearest FTC (min)	33.30	33.34	32.94	33.42	0.40	−0.09	−0.48
	[25.55]	[26.21]	[25.31]	[25.40]	(3.84)	(3.03)	(3.29)
Walking dist. to nearest (all-season) road (min)	27.36	25.56	22.34	30.14	3.22	−4.58	−7.80**
	[29.47]	[23.66]	[25.98]	[32.50]	(3.34)	(3.02)	(3.56)
Walking dist. to nearest market (min)	74.17	67.03	67.91	79.65	−0.88	−12.63*	−11.74*
	[48.15]	[44.82]	[46.86]	[49.31]	(7.84)	(6.96)	(6.47)
Panel B: Agricultural production characteristics							
Total land size (in ha)	1.34	1.37	1.40	1.30	−0.03	0.07	0.10
	[1.11]	[1.16]	[1.18]	[1.06]	(0.18)	(0.15)	(0.14)
Grows main crop (1 = yes)	0.94	0.94	0.95	0.93	−0.01	0.01	0.02*
					(0.01)	(0.02)	(0.01)
No. of adopted quickwins (0–5)	1.40	1.51	1.53	1.30	−0.02	0.21*	0.23**
	[0.99]	[1.00]	[0.97]	[0.99]	(0.14)	(0.13)	(0.11)
Compost applied (1 = yes)	0.36	0.34	0.39	0.37	−0.05	−0.03	0.02
					(0.06)	(0.05)	(0.05)
Blended fertilizer applied (1 = yes)	0.014	0.009	0.021	0.014	−0.011	−0.004	0.007
					(0.011)	(0.007)	(0.011)
Improved seeds used (1 = yes)	0.57	0.64	0.59	0.53	0.04	0.11**	0.07
					(0.06)	(0.05)	(0.05)
Plants crops usually in lines (1 = yes)	0.45	0.52	0.52	0.39	−0.00	0.13*	0.13*
					(0.09)	(0.07)	(0.07)
Lime applied (1 = yes)	0.008	0.009	0.009	0.007	0.000	0.002	0.003
					(0.007)	(0.005)	(0.005)

Table 1. Continued.

	Overall	T1 (extension)	T2 (extension + video)	C (control)	T1 − T2	T1 − C	T2 − C
DAP applied (1 = yes)	0.70	0.76	0.74	0.66	0.02	0.09*	0.07
					(0.05)	(0.05)	(0.05)
Used irrigation (1 = yes)	0.19	0.17	0.19	0.20	−0.03	−0.03	−0.00
					(0.05)	(0.04)	(0.04)
Last season was bad (1 = yes)	0.48	0.46	0.45	0.51	0.02	−0.04	−0.06
					(0.08)	(0.07)	(0.07)
No. of times talked to extension agent in last year	5.53 [10.97]	5.76 [11.06]	6.42 [14.35]	5.07 [9.20]	−0.66 (1.23)	0.69 (0.90)	1.35 (1.06)
Attended agric. training in last year (1 = yes)	0.27	0.30	0.34	0.23	−0.03 (0.05)	0.08** (0.04)	0.11*** (0.04)
Panel C: Community-level characteristics							
Mean annual temperature 2017 (°C)	20.56 [4.10]	20.45 [4.21]	20.40 [4.24]	20.68 [4.00]	0.05 (1.00)	−0.23 (0.82)	−0.28 (0.83)
Mean annual rainfall 2017 (mm)	1108.84	1140.53	1140.11	1083.12	0.42	57.40	56.98
	[396.23]	[381.88]	[380.26]	[406.66]	(90.84)	(77.59)	(77.13)
Distance to Woreda capital (km)	14.62	13.66	15.52	14.65	−1.86	−0.99	0.87
	[15.42]	[16.31]	[13.69]	[15.69]	(3.67)	(3.27)	(2.85)
N	2,382	539	532	1,311	1,071	1,850	1,843

Source: Authors' analyses based on baseline survey data.

Note: HH stands for household. Basic asset score comprises the following: HH has modern roof, improved stove, modern lighting, toilet facility. TLU stands for tropical livestock unit. Calculation of food insecurity score based on self-experienced events of food insecurity, based on Household Food Insecurity Access Scale (HFIAS). FTC stands for farmer training center. Main crops are maize, wheat, teff, barley, sorghum. Temperature and rainfall assessed at endline. For means, standard deviations in brackets; for mean comparisons, robust standard errors in parentheses, clustered at the mws level. Significance levels: ***p<0.01, **p<0.05, *p<0.1.

since adoption would otherwise always be 0 in Tigray.[12] Furthermore, the adoption of the individual ISFM quickwin components is of interest, which are *compost*, *blended fertilizer*, *improved seeds*, *line seeding*, and *lime*. For each technology, a dummy variable taking the value of 1 defines if the household has applied the respective practice in the 2017 main cropping season on any plot and for any crop type.

An *overall ISFM knowledge* score is constructed based on questions on each of the individual ISFM components (excluding questions on lime). It ranges from 0 to 1, with 1 standing for full knowledge, that is, having answered all questions correctly.[13] Since the aim of the video treatment was to increase farmers' knowledge on *why* ISFM is important (and not on *how* to implement it), the study also constructs two individual indicators for *principles* and *how-to knowledge*, depending on whether a question was on the purpose (the "why") of a technology, or its mode of implementation (the "how-to"), which also range from 0 to 1. For the how-to score, twice the weight is given to knowledge on how to correctly produce compost, since this is a more complicated process than the implementation of the other ISFM practices. The principles score gives equal weights to all ISFM components, and includes one indicator for the

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[12] To check sensitivity of the results with respect to this definition, several alternative measures are also used. First, a variable that equals 1 when at least four out of five practices (including lime) are adopted jointly. Second, a measure for the joint adoption of compost, blended fertilizer, and line seeding, that is, excluding improved seeds, which might possibly be concentrated around a certain crop type. And last, a region-specific measure that requires all five practices to be adopted in Amhara and Oromia, but only four in Tigray. These analyses are restricted to plots planted with main crops, i.e., wheat, maize, teff, barley, and sorghum, which are the main focus of the interventions.

[13] Since the number of questions is not the same for all practices, the study first calculates a knowledge score for each component individually and then combines it to an overall score, so that each ISFM dimension is included with the same weight. Farmers who were not aware of a practice in the first place, were immediately given a value of 0 in the respective follow-up questions.

general understanding of the necessity to integrate organic and inorganic soil inputs.[14] For the analyses, the household heads' knowledge score is used.

Estimation Strategy for Intent-to-Treat Effect Using RCT Design

In order to assess the effects of the experimental interventions on ISFM adoption and knowledge, regressions of the following form are estimated:

$$Y_{ij} = \alpha + \beta T1_j + \lambda T2_j + \epsilon_{ij} \tag{1}$$

where Y_{ij} denotes the respective outcome variable for household or individual i in mws j, measured at endline. $T1_j$ is a dummy variable indicating whether the mws was assigned to the extension intervention, and $T2_j$ indicates whether the mws was assigned to the combined extension + video treatment; ϵ_{ij} represents an individual-level error term that is clustered at the mws level to allow for arbitrary correlation of households and individuals within clusters.

Although treatment indicators should be orthogonal to further explanatory variables due to randomization, all models are re-estimated including additional covariates in order to increase precision of the estimates and to control for small-sample imbalances:

$$Y_{ij} = \alpha + \beta T1_j + \lambda T2_j + \gamma X^0_{ij} + \varphi W_j + \nu Y^0_{ij} + \epsilon_{ij} \tag{2}$$

In these models, X^0_{ij} represents a vector of control variables related to farmer and household characteristics captured at baseline, while W_j, adds community-level indicators for rainfall, temperature, and remoteness. When available, the inclusion of the baseline level of an outcome Y^0_{ij} in the equation should reduce the overall variance, since some degree of path dependency on previously gained experience with a technology is assumed. This treatment-effect model is appropriate in this case, since for some outcomes, baseline and endline measures are not completely identical, or baseline data is not available at all.[15] In addition, this specification has been shown to be more powerful than the difference-in-difference estimator in the presence of relatively low autocorrelation (McKenzie 2012a; De Brauw et al. 2018), which can at least be stated for some of the outcome variables. The main estimators of interest are β and λ, capturing the intent-to-treat effect (ITT). One-sided equality tests evaluate the additional impact of the video intervention, by testing whether the coefficient of T2 is significantly larger than that of T1.

Differential Effects for Members and Non-Members of "Farmer Research And Extension Groups"

Beyond average effects, it is also interesting to assess potentially differential effects of the treatments on the primary beneficiary group, that is, FREG members, and those who might only benefit indirectly, that is, non-FREG farmers. Since FREG membership is not randomized, the estimation strategy needs to consider that FREG members and nonmembers are likely to be systematically different. Propensity score matching should reduce potential bias resulting from self-selection into FREGs (see, e.g., Cameron and Trivedi 2005; Frölich and Sperlich 2019). In a first step, a probit regression is estimated to predict FREG membership:

$$K_i = \delta + \theta Z_i + \mu_i \tag{3}$$

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[14] This is based on the respondent selecting the following statement as being correct: "The soil needs both organic and inorganic inputs to be healthy and fertile."

[15] Baseline data are available for adoption of compost, blended fertilizer, improved seeds, and lime. Regarding blended fertilizer, the study additionally controls for ex ante use of any inorganic fertilizer, since during the time of baseline, blended fertilizer was largely unavailable; instead, farmers used the widely available DAP fertilizer (see table 1). In the two years between baseline and endline, NPS/NPK fertilizer blends largely replaced other inorganic fertilizer types. Line seeding can only be proxied, since it was assessed on a more general level during baseline, by asking farmers how they *usually* plant crops, but not at the plot level. Knowledge variables were not measured in the baseline survey.

where Z_i denotes a vector of farmer and household covariates assumed to influence farmer *i's* participation K_i, and μ_i is the error term. Based on this estimation, a propensity score is calculated, which is then used to match each real FREG member in the treatment group with their most similar counterfactual from the control group (referred to as "matched controls") via one-to-one nearest-neighbor matching without replacement. The analysis proceeds analogously for the nonmembers. Subsequently, treatment effects on the core outcome variables within the two mutually exclusive subsamples are re-estimated: the *FREG sample*, consisting of actual FREG members and their matched controls (in treatment and control mws, respectively) and the *non-FREG sample*, consisting of actual non-FREG members in treatment mws and their matched controls.

Applying this matching algorithm to the sample leads to a high level of common support, since only one treated observation is off support (see S4 in the Supplementary Online Appendix).[16] Balance checks between the treatment groups for the constructed FREG and non-FREG samples show that samples are well balanced, with only few exceptions (see tables S4.3 and S4.4 in the Supplementary Online Appendix). Propensity score matching makes it possible to control for selection on observables as well as a portion of unobserved heterogeneity that is correlated with these observables. Nonetheless, FREG and non-FREG members may still differ in terms of unobserved characteristics that were not captured by the matching procedure and are therefore also not reflected in the selected matches from the control group. Matching results can also be sensitive to variable selection and the choice of the matching algorithm. Therefore, a number of robustness checks are carried out.[17] Findings reveal that results remain robust to alternative model specifications and matching algorithms (see tables S4.5 to S4.10 in the Supplementary Online Appendix).

4. Main Results

Treatment Participation

Among the two treatment groups, 82 farmers (8 percent of T1 and T2) were active model farmers in the 2017 cropping season; that is, they were leading members of a FREG and were responsible for the implementation and maintenance of an ISFM demonstration plot, for which the project provided them with inputs. In addition to model farmers, 120 farmers (around 12 percent of T1 and T2) are active FREG members, meaning they belong to a FREG and have participated in field day activities along the course of the preceding season. In addition, 77 (8 percent) of the treatment farmers who are not FREG members state that they participated in a field day in 2017, plus 39 (3 percent) of the control group farmers. Regarding the visit of demonstration plots, 55 treatment farmers (6 percent of T1 and T2) not belonging to a FREG report that they have visited a demonstration site on their own behalf, that is, independently of a field day, in addition to 39 farmers in the control group (3 percent of C). Consequently, although only to a small extent, there are indications of treatment spillovers—both within and across groups—which also means that ITT estimates might suffer from a slight downward bias due to "contamination" of the control group.

Compliance in the video intervention was remarkably high, 499 (94 percent) of T2 households attended the screenings. Considering that in double-headed households both spouses were invited to the sessions, compliance at the individual level was 83 percent, equal to 804 participants. None of the households from T1 or the control group were present during the video screenings.

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[16] See table S4.2 for first-stage propensity score matching regression results and figs. S4.1 and S4.2 for histograms of the estimated propensity scores.

[17] First, a different set of matching variables is used, namely the same set of covariates used in the ITT regressions. Second, nonparametric kernel matching is performed for both FREGs and non-FREGs with the control group, and the calculated kernel weights are used in the outcome regressions. And lastly, instead of FREG membership, field day attendance is used to construct the two subsamples.

Table 2. ITT Effects on Number of Adopted ISFM Technologies and Integrated Adoption of the Full ISFM Package

	Number of ISFM technologies adopted						Integrated adoption of full ISFM package	
	OLS		Poisson		Oprobit			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
T1 (extension)	0.683***	0.448***	0.688***	0.468***	0.542***	0.529***	0.103**	0.084***
	(0.184)	(0.080)	(0.178)	(0.088)	(0.136)	(0.085)	(0.043)	(0.025)
p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.016	0.001
T2 (extension + video)	0.840***	0.569***	0.822***	0.551***	0.671***	0.671***	0.137***	0.109***
	(0.174)	(0.079)	(0.164)	(0.088)	(0.134)	(0.086)	(0.043)	(0.024)
p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000
Test T1 > = T2 (*p*-value)	0.216	0.087	0.216	0.177	0.206	0.080	0.242	0.185
Endline control mean	2.222						0.152	
Additional controls	No	Yes	No	Yes	No	Yes	No	Yes
(Pseudo) R-squared	0.071	0.531	0.016	0.122	0.025	0.223	0.023	0.271
Observations	2,382	2,382	2,382	2,382	2,382	2,382	2,160	2,160

Source: Authors' analyses based on baseline and endline survey data.

Note: Poisson and probit models (columns (3), (4), (7), and (8)) show average marginal effects (AME). Number of ISFM technologies adopted ranges from 0 to 5. Integrated adoption of full ISFM package is a dummy variable. Additional baseline control variables at household level are age, gender, and education (in completed years) of HH head; whether HH participated in off-farm work or a nonfarm business activity; number of HH members above age 14; walking distances to nearest farmer training center, paved road and market (in minutes); number of local organizations involved; use of irrigation, total land size in ha, tropical livestock units (TLU), a basic assets score, a food insecurity score, whether HH is eligible for formal credit and has contracted a credit in the last farming season; whether HH had a below-average preceding farming season; number of times HH had contact with an extension agent and whether HH has participated in agricultural training; whether HH grew main crops (teff, wheat, barley, maize, sorghum) and used any kind of inorganic fertilizer. Community level covariates are rainfall, temperature, and distance to Woreda capital (in km). Two region dummies for Oromia and Amhara included. One-sided equality tests of T1 and T2 are F-tests or Wald tests. Robust standard errors in parentheses, clustered at the mws level. Significance levels: ***p<0.01, **p<0.05, *p<0.1.

ISFM Adoption Decision

Aggregated Adoption Measures

The ITT effects of the two treatment arms on the first core outcome, the number of adopted ISFM quick-win technologies (0–5) are obtained with three different regression specifications (see columns (1) to (6) of table 2). Since the dependent variable is essentially a count variable, a Poisson model is estimated. Yet, considering that it can also be perceived as either an underlying continuous or ordered process, a linear as well as an ordered probit model is run to underline the robustness of the findings.

The results of all models indicate positive and highly statistically significant effects of both treatments on the number of adopted practices, which are robust to the inclusion of baseline control variables. Furthermore, all models lead to larger point estimates for T2 compared to T1. Findings from the linear model show that farmers in T1 adopt an additional .448 practices, while households in T2 communities on average adopt .569 more practices than those in the control group (column (2)).[18] Yet, across specifications, *p*-values of the test that T1 > = T2 are insignificant or only marginally significant, and thus do not provide consistent evidence of T2 having a larger effect on the number of adopted ISFM practices.[19]

With respect to the integrated adoption of the full quickwin package, the estimated ITT effects are also positive and statistically significant (columns (7) and (8)of table 2). Households in T1 are on average 8.4 percentage points more likely than control group households to adopt the full set of practices on the

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[18] Results of the Poisson and the ordered probit regressions are well in line with those of the OLS specifications and will therefore not be explicitly discussed.

[19] Rough power calculations show that the minimum detectable effect size in the comparison T1 versus T2 is about 24 percent of a std. deviation. Accordingly, the estimated difference between the two coefficients is likely too small to detect significant additional effects of the video intervention. Implications of these results do not change when using the 0–4 measure (excluding lime), see table S4.11 in the Supplementary Online Appendix.

same plot, while the likelihood for farmers in T2 is 10.9 percentage points above the control group mean. However, again the difference between the effect sizes of T1 and T2 is not statistically significant.[20]

In order to test whether the estimated treatment effects might be driven by the 82 model farmers in the sample who have been trained by extension agents and provided with inputs, ITT models on the two adoption outcomes are re-estimated excluding these 82 model farmers. All treatment effects remain highly statistically significant with only a slight decrease in magnitude suggesting that the interventions affect farmers in treatment communities beyond model farmers (see table S4.13 in the Supplementary Online Appendix).

Adoption of Individual Components

To further explore which components are the main drivers of increased ISFM adoption, ITT effects on the decision to adopt each of the five quickwin practices individually are analyzed. Average marginal effects, presented in table 3, indicate that both the extension-only and the combined intervention exert positive and statistically significant effects on the decisions to adopt compost, improved seeds, line seeding, and lime. In contrast, effects on blended fertilizer are not significant (T1) or do not remain significant with the inclusion of additional controls (T2).

To account for the probability of false discoveries in multiple outcome testing, the study follows Sankoh, Hugue, and Dubey (1997) and Aker et al. (2016) and uses a version of the Bonferroni correction, which corrects for inter-outcome correlations for families of outcomes (see Supplementary Online Appendix S5) (McKenzie 2012b). With this form of adjustment, *p*-values of the estimated coefficients of both T1 and T2 increase (respectively remain) above the .10 threshold for blended fertilizer and improved seeds, while results for compost, line seeding, and lime remain significant for both treatment arms.

For these robust results, the estimated effect sizes of the extension-plus-video intervention are larger than those of the extension-only intervention, which is in line with the findings on the aggregated ISFM adoption measures. However, again there are no statistically significant differences between the effects of T1 and T2 on technology adoption (see adjusted *p*-values of one-sided equality tests in columns (2), (8) and (10)).

In summary, results indicate significant ITT effects of the extension intervention on the adoption of ISFM, both on aggregated measures as well as on some of its individual components. Yet, despite consistently larger point estimates, findings provide little significant evidence for an additional “video effect.”

Differential Effects for FREG Members

Next, the study investigated whether the extension treatment has an effect on ISFM adoption beyond FREG membership—or whether the estimated ITT is solely concentrated among FREG farmers—and whether the additional video treatment might influence FREG members and non-FREG members differently. This is analyzed using the matching approach outlined above.

In both subsamples, treatment effects of the two interventions regarding the number of adopted ISFM practices remain positive and statistically significant (table 4). Yet both the linear and the Poisson specification indicate that the effects of the treatments are substantially larger in the FREG sample than in the non-FREG one. While in the non-FREG sample, being assigned to T1 on average increases the number of applied technologies by .278, this coefficient is 1.232 in the FREG sample. Similarly, T2 is estimated to increase average adoption by .483 practices in the non-FREG sample, but by 1.117 technologies in the FREG sample (OLS results in columns (2) and (4)). Further, for non-FREGs, coefficients of the combined treatment are significantly larger than those of the extension-only treatment, pointing towards a reinforcing effect of the video for this group of farmers (see columns (2) and (6)).

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[20] Table S4.12 in the Supplementary Online Appendix shows results for the three alternative specifications. Although effect sizes naturally vary with the choice of this measure, results remain qualitatively unaltered.

Table 3. ITT Effects on Adoption of Individual ISFM Components

	Adopted compost		Adopted blended fertilizer		Adopted improved seeds		Adopted line seeding		Adopted lime	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
T1 (extension)	0.150***	0.143***	0.097	0.039	0.129**	0.065*	0.157***	0.091***	0.222***	0.214***
	(0.057)	(0.028)	(0.062)	(0.042)	(0.058)	(0.036)	(0.057)	(0.029)	(0.042)	(0.029)
Unadjusted *p*-value	0.008	0.000	0.118	0.348	0.027	0.070	0.006	0.002	0.000	0.000
Adjusted *p*-value	0.025	0.000	0.334	0.749	0.092	0.225	0.022	0.007	0.000	0.000
T2 (extension + video)	0.219***	0.192***	0.111**	0.046	0.129**	0.067*	0.204***	0.112***	0.254***	0.239***
	(0.054)	(0.025)	(0.055)	(0.037)	(0.058)	(0.040)	(0.057)	(0.030)	(0.042)	(0.028)
Unadjusted *p*-value	0.000	0.000	0.043	0.218	0.027	0.093	0.000	0.000	0.000	0.000
Adjusted *p*-value	0.000	0.000	0.132	0.539	0.092	0.291	0.000	0.000	0.000	0.000
Robust to Adjustment?	**Yes**		**No**		**No**		**Yes**		**Yes**	
Test T1 > = T2 (unadjusted *p*-value)	0.141	0.058	0.421	0.442	0.501	0.467	0.245	0.250	0.226	0.194
Test T1 > = T2 (adjusted *p*-value)	0.382	0.173	0.829	0.848	0.914	0.891	0.638	0.647	0.548	0.488
Endline control mean	0.405		0.596		0.574		0.624		0.040	
Additional controls	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
(Pseudo) R-squared	0.027	0.361	0.009	0.220	0.014	0.257	0.033	0.388	0.137	0.336
Observations	2,382	2,382	2,382	2,382	2,382	2,382	2,382	2,382	1,464	1,464

Source: Authors' analyses based on baseline and endline survey data.

Note: Average marginal effects (AME) of binary probit models. For lime, Tigray is excluded since it is not recommended in this region and adoption is 0. Additional control variables identical to those listed in notes of table 2. Bonferroni-adjusted *p*-values taking into account correlations between outcomes. One-sided equality tests of T1 and T2 are Wald tests. Robust standard errors in parentheses, clustered at the mws level. Significance levels indicated as following: ***$p<0.01$, **$p<0.05$, *$p<0.1$.

Table 4. ITT Effects on Number of Adopted ISFM Technologies and Integrated Adoption of the Full ISFM Package, FREG- and Non-FREG Samples Separately

	Number of ISFM technologies adopted								Integrated adoption of full package			
	OLS				Poisson							
	Non-FREG sample		FREG sample		Non-FREG sample		FREG sample		Non-FREG sample		FREG sample	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
T1 (extension)	0.322*	0.278***	1.257***	1.232***	0.329*	0.293***	1.260***	1.228***	0.030	0.034	0.273***	0.280***
	(0.193)	(0.080)	(0.200)	(0.123)	(0.194)	(0.088)	(0.193)	(0.128)	(0.048)	(0.024)	(0.058)	(0.048)
p-value	0.097	0.001	0.000	0.000	0.090	0.001	0.000	0.000	0.528	0.161	0.000	0.000
T2 (extension + video)	0.550***	0.483***	1.140***	1.117***	0.540***	0.478***	1.161***	1.131***	0.079*	0.084***	0.231***	0.231***
	(0.181)	(0.082)	(0.184)	(0.137)	(0.173)	(0.086)	(0.183)	(0.147)	(0.046)	(0.025)	(0.066)	(0.043)
p-value	0.003	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.082	0.001	0.001	0.000
Test T1 > = T2 (*p*-value)	0.145	0.009	0.711	0.803	0.144	0.014	0.712	0.775	0.176	0.040	0.719	0.795
Endline control mean	2.444		2.775		2.444		2.775		0.168		0.225	
Additional controls	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
(Pseudo) R-squared	0.031	0.496	0.224	0.570	0.006	0.094	0.030	0.077	0.007	0.285	0.059	0.299
Observations	1,606	1,606	400	400	1,606	1,606	400	400	1,606	1,606	400	400

Source: Authors' analyses based on baseline and endline survey data.

Note: Poisson and probit models (columns (5) to (12)) show average marginal effects (AME). Number of ISFM technologies adopted ranges from 0 to 5. Integrated adoption of full ISFM package is a dummy variable. FREG stands for Farmer research and extension group. FREG- and non-FREG samples consist of actual FREG respectively non-FREG farmers in treatment mws, and their matched controls. Additional control variables identical to those listed in notes of table 2. One-sided equality tests of T1 and T2 are F-tests or Wald tests. Robust standard errors in parentheses, clustered at the mws level. Significance levels indicated as following: ***p<0.01, **p<0.05, *p<0.1.

Table 5. ITT Effects on Different Knowledge Outcomes

	Overall knowledge		Principles knowledge		How-to knowledge	
	(1)	(2)	(3)	(4)	(5)	(6)
T1 (extension)	0.050***	0.036***	0.030*	0.020	0.068***	0.052***
	(0.015)	(0.013)	(0.016)	(0.014)	(0.015)	(0.013)
p-value	0.001	0.006	0.062	0.152	0.000	0.000
T2 (extension + video)	0.082***	0.068***	0.063***	0.054***	0.091***	0.073***
	(0.013)	(0.011)	(0.014)	(0.011)	(0.016)	(0.013)
p-value	0.000	0.000	0.000	0.000	0.000	0.000
Test T1 > = T2 (*p*-value)	0.014	0.008	0.018	0.007	0.102	0.103
Endline control mean	0.448		0.522		0.382	
Additional controls	No	Yes	No	Yes	No	Yes
R-squared	0.034	0.219	0.012	0.155	0.048	0.221
Observations	2,334	2,334	2,334	2,334	2,334	2,334

Source: Authors' analyses based on baseline and endline survey data.

Note: OLS regressions of household heads' knowledge scores, ranging from 0 to 1, and calculated based on the number of correct answers relative to the total number of questions in a respective domain. Additional control variables are age, gender, education (in completed years), whether respondent had access to off-farm work or a non-farm family business, whether hh adopted the ISFM quickwin package at baseline, whether hh has a cell phone and radio, number of times hh had contact with an extension agent, whether hh has participated in agricultural training, number of local organizations involved, and walking distance to nearest farmer training center. Two region dummies for Oromia and Amhara included. One-sided equality tests of T1 and T2 are F-tests. Robust standard errors in parentheses, clustered at the mws level. Significance levels indicated as following: ***p<0.01, **p<0.05, *p<0.1.

With regard to integrated adoption of the ISFM package, estimation results show that both interventions significantly increase the likelihood of adoption in the FREG sample in comparison to their matched controls by 28 and 23 percentage points, respectively (column (12) of table 4). In contrast, in the non-FREG sample, the extension-only treatment does not lead to a significant increase in integrated adoption. Only if extension is complemented by the video (T2), do results show a significant treatment effect for non-FREG farmers, with an increase in the likelihood of adopting the full package of 8 percentage points compared to their matched controls (column (10)).

These findings lead to the following two conclusions: First, the effect of the extension treatment is substantially larger for FREG members—even after taking into account that they may already be better farmers. This is expected because they are the farmers directly benefitting from the extension activities. Yet the extension intervention also shows a positive influence on non-FREG farmers when it comes to the number of adopted ISFM practices at the household level, pointing towards the presence of diffusion effects. However, most interestingly, the findings indicate that extension alone does not significantly affect non-FREG farmers when it comes to *integrated* adoption, that is, using the practices together on the same plot. By contrast, it seems that the video intervention has a significant complementary effect for non-FREG farmers, in particular when it comes to the integrated adoption of the practices.

ISFM Knowledge

Treatment Effects on Knowledge

Positive and significant ITT estimates show that T1 on average seems to increase overall ISFM knowledge by around 3.6 percentage points, while T2 increases farmers' overall knowledge score by almost 7 percentage points in comparison to the control group mean (column (2) of table 5). The *p*-value of .008 indicates that extension-plus-video has a significantly stronger effect on knowledge than extension alone and thus points towards an additional effect of the video regarding ISFM knowledge formation. The study also assesses the ITT effects on the two distinct domains, principles, and how-to knowledge. Regarding principles knowledge, the positive coefficient of extension alone does not remain statistically significant with the introduction of further covariates, whereas extension combined with video on average increases this knowledge score by 5.4 percentage points on a highly significant level (column (4) of table 5). Thus, the video, which explicitly sought to explain the underlying principles of ISFM, was successful in conveying some of this knowledge. How-to knowledge seems to be positively affected by both T1 and T2, with no statistical difference regarding their effect sizes (see column (6)).

In order to understand the contribution that these gains in ISFM knowledge make to the adoption decision, a formal causal mediation analysis is conducted (see S6 in the Supplementary Online Appendix). Findings show that gains in knowledge are indeed a relevant driver of adoption. Increases in how-to knowledge account for 16 percent to 23 percent of the treatment effects on adoption. Gains in principles knowledge explain 6 percent to 7 percent of the T2 effect on adoption, but no portion of the T1 effect (table S6.1). This makes sense, given that the video had a particular focus on conveying principles knowledge, and indeed seems to positively affect this knowledge domain.

Differential Effects for FREG Members

Next, the study follows the earlier approach and disaggregates the sample into a FREG and a non-FREG sample. The significant difference between the effect sizes of T1 and T2 on overall knowledge persists in the non-FREG sample, but is much less pronounced in the FREG sample (see table 6). While in the FREG sample, both extension-only and the combined intervention significantly increase the overall knowledge score, in the non-FREG sample only the combined intervention is highly significant. Again, the overall knowledge score is split into principles and how-to knowledge.

The results for principles knowledge look very similar to those from the full sample. Only the combined intervention significantly increases principles knowledge in the non-FREG sample (see columns (5) and (6) of table 6). In the FREG sample, both T1 and T2 have positive and significant effects on principles knowledge, with some indication of a statistically stronger effect of the extension-plus-video treatment (see columns (7) and (8)).

Regarding knowledge on how to implement ISFM, treatment effects are positive and significant in both subsamples. In the case of FREG members, differences in the effect sizes of T1 and T2 are not significant (see columns (11) and (12)). For non-FREG farmers, the effect of the combined treatment seems to increase how-to knowledge significantly stronger than extension-only (see columns (9) and (10)). Further analyses reveal that this effect mainly stems from improved knowledge on how to produce compost among this group of farmers. This is fairly surprising, since the video did not convey any information on *how* to implement any of the practices. Yet it may be that increased awareness and understanding of why ISFM is beneficial induced further knowledge-seeking processes on the mode of compost production among non-FREG farmers.

5. Discussion

The present results show that the farmer-to-farmer extension approach under study has significantly increased ISFM knowledge and adoption of individual components and the full package in the treated communities. Moreover, the study finds that ISFM knowledge and adoption—at least of individual practices—also increases among farmers who are not actively participating in extension activities. This points towards the existence of information spillovers from FREG farmers to their peers, which occur either through active information sharing or through observation and imitation. These results provide support for the rationale of farmer-to-farmer extension models and contradict previous research finding weak evidence for diffusion effects (Rola, Jamias, and Quizon 2002; Feder, Murgai, and Quizon 2004; Kondylis, Mueller, and Zhu 2017).

The study finds robust significant treatment effects on the adoption of the more knowledge-intensive ISFM components compost, line seeding and lime, but not on blended fertilizer and improved seeds. The

Table 6. ITT Effects on Different Knowledge Outcomes, FREG- and Non-FREG Samples Separately

	Overall knowledge				Principles knowledge				How-to knowledge			
	Non-FREG sample		FREG sample		Non-FREG sample		FREG sample		Non-FREG sample		FREG sample	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
T1 (extension)	0.013	0.014	0.129***	0.124***	−0.004	0.001	0.089***	0.079***	0.027**	0.027**	0.178***	0.177***
	(0.014)	(0.013)	(0.025)	(0.021)	(0.017)	(0.016)	(0.029)	(0.026)	(0.013)	(0.012)	(0.027)	(0.024)
p-value	0.351	0.284	0.000	0.000	0.803	0.974	0.003	0.002	0.049	0.025	0.000	0.000
T2 (extension + video)	0.049***	0.049***	0.149***	0.152***	0.035**	0.042***	0.129***	0.126***	0.052***	0.052***	0.160***	0.166***
	(0.013)	(0.012)	(0.021)	(0.020)	(0.016)	(0.014)	(0.027)	(0.024)	(0.014)	(0.013)	(0.020)	(0.019)
p-value	0.000	0.000	0.000	0.000	0.030	0.004	0.000	0.000	0.000	0.000	0.000	0.000
Test T1 > = T2 (*p*-value)	0.006	0.005	0.201	0.099	0.014	0.006	0.095	0.049	0.048	0.046	0.750	0.689
Endline control mean	0.464		0.510		0.541		0.578		0.397		0.440	
Additional controls	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
R-squared	0.013	0.136	0.148	0.252	0.005	0.102	0.071	0.178	0.017	0.134	0.203	0.307
Observations	1,540	1,540	390	390	1,540	1,540	390	390	1,540	1,540	390	390

Source: Authors' analyses based on baseline and endline survey data.

Note: OLS regressions of household heads' knowledge scores, ranging from 0 to 1, and calculated based on the number of correct answers relative to the total number of questions in a respective domain. FREG stands for "Farmer research and extension group." FREG- and non-FREG samples consist of actual FREG respectively non-FREG farmers in treatment mws, and their matched controls. Additional control variables identical to those listed in notes of table 5. One-sided equality tests of T1 and T2 are F-tests. Robust standard errors in parentheses, clustered at the mws level. Significance levels indicated as following: ***p<0.01, **p<0.05, *p<0.1.

latter is likely due to the fact that blended fertilizers and improved seeds have been heavily promoted by the public extension system in Ethiopia. As a result, adoption rates of these two practices are rather high in the research area, and also in control mws. Further increasing these already high adoption rates may then hinge on relaxing capital constraints (Ambler, de Brauw, and Godlonton 2020), rather than knowledge constraints. Results indicate that overall, the extension approach is particularly effective in the case of unfamiliar (like lime in the research area) or knowledge-intensive technologies (like the production of good-quality compost or the benefits of line seeding). Additional analyses show that the extension treatment has a significantly positive impact on the quality of the compost farmers produce (see table A1.1 in the Supplementary Online Appendix), suggesting that farmers not only gather more knowledge via the interventions, but are also able to put this knowledge into practice.[21] The causal mediation analysis showed that how-to and—albeit to a smaller extent—principles knowledge are significant underlying drivers of adoption, suggesting that enhancing both types of knowledge—*how* and *why* practices work—can foster more widespread adoption of complex system technologies.

While there is evidence of information spillovers from FREG farmers to other farmers in the community, the study also finds that increases in ISFM knowledge and adoption are substantially lower for non-FREG farmers compared to FREG farmers. When it comes to the *integrated* adoption of all practices on the same plot in particular, the extension-only treatment seems to do little for non-FREG farmers. Furthermore, for non-FREG farmers, knowledge increases through extension-only are modest and mostly limited to gains in *how-to* knowledge (as opposed to *principles* knowledge). This suggests that some information loss occurs in the knowledge transmission process from actively participating farmers to other farmers in the community, so that only some pieces of knowledge are passed on or picked up, likely leading to incomplete adoption.

One possible explanation for these findings is based on selective attention theory (Schwarzstein 2014). ISFM is a complex system technology that requires learning about several individual practices—as well as about the importance of applying them jointly. A resource-constrained farmer might not have the time or mental capacity to learn about all aspects, and hence, pay attention in a selective manner (Hanna, Mullainathan, and Schwartzstein 2014; Niu and Ragasa 2018). Consciously or unconsciously, farmers may base their decisions about which components to focus on, depending on their beliefs about the yield effects of a certain practice, on their complexity, but also on how feasible they consider the adoption of a technology to be in their particular context (Maertens, Michelson, and Nourani 2020).

The video that was shown to farmers in T2 could potentially help to reduce information losses. Findings suggest that for the full sample, there is no strong additional effect of the video on adoption. Yet, for non-FREG farmers, the video has a significant complementary effect on knowledge as well as on adoption, which is particularly pronounced for the *integrated* adoption of ISFM practices, compared to extension-only. One possible explanation is that the video intervention indeed contributed to counterbalance incomplete information transmission by drawing farmers' attention to dimensions of the ISFM technology package they did not notice before, or that were not transmitted via farmer-to-farmer extension at all. The data show, for instance, that for the group of non-FREG farmers, the additional video intervention triggered gains in knowledge about the process of compost production, even though the video conveyed no explicit how-to messages. A possible explanation is that the video increased awareness of the benefits associated with this complex practice and thereby spurred how-to knowledge seeking processes (see Maertens, Michelson, and Nourani 2020). This interpretation is in line with selective attention theory; additional information is especially important for more complex practices, which farmers may disregard if not sufficiently convinced of their benefits.

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[21] This is assessed with a compost quality index ranging from 0 to 9, based on farmers' self-reported information. The index is composed of six questions on the compost production process and three questions on the compost end product (see S2 in the Supplementary Online Appendix for details)

Another possible explanation is that the video intervention increases knowledge and adoption among non-FREGs by providing a platform for exchange and communication, rather than through the video content itself. If this is the case, one would expect higher adoption rates among non-FREG farmers, not only with respect to the five quickwin practices promoted in the video, but also more generally with respect to other ISFM-related practices. Analyzing adoption of four individual practices, that is, urea, green manure, intercropping, and planting of forage crops—which are promoted by the ISFM+ project, but not featured in the video—indicates some evidence for such a "gathering effect."[22] This suggests that non-FREG farmers in T2 mws may not only have learned about the video *content*, but also about other ISFM-related practices from discussions with FREG members and extension agents present during the screening event.[23]

These results point towards the existence of information spillovers from FREG farmers to their peers, and thus provide support for the rationale of farmer-to-farmer extension models to promote even complex agricultural technologies. Yet, to judge the cost-effectiveness of the approach, studies on the actual benefits derived from technology diffusion are needed in order to weigh the project's costs against its benefits. Arguably, in the present study area it may be too early to conduct such an assessment, given that the endline data only cover short-term effects measured during the second season of project interventions. An analysis of treatment effects conditional on adoption of the *integrated* ISFM package shows that adopters in treatment mws have significantly higher yields than their closest matches in control mws.[24] Results on net crop income are not as strong, but they point in the same direction. These results are robust when excluding model farmers from the analysis, who benefited from free input provision (see table A1.2 in the Supplementary Online Appendix), and are also supported by previous survey-based studies that have documented positive productivity and welfare effects of ISFM adoption (Adolwa, Schwarze, and Buerkert 2019; Hörner and Wollni 2021). However, the effectiveness of the extension approach hinges on a combination of both welfare impacts and adoption rates. Analyzing the current data does not reveal significant intent-to-treat effects of the extension interventions on net crop incomes or yields (see table A1.3 in the Supplementary Online Appendix), implying that on average, the project has not (yet) made farmers in treatment mws better off. This is in line with previous research, which has reported treatment effects of extension on adoption, but not on yields or profits (Cole and Fernando 2020). One important observation in this context is that currently adopters of the integrated ISFM package in the research area apply it to only 30 percent of their agricultural land planted with main cereal crops, on average. Accordingly, further increasing the intensity of adoption, preferably on the basis of successful experimentation, remains an important goal.

6. Conclusion

The study shows positive effects of a farmer-to-farmer extension intervention on the adoption of a complex agricultural technology. The effects are stronger for direct beneficiaries of the intervention, but they also trickle down to other community members, suggesting the existence of spillover effects. While this is promising, more research is needed that evaluates the longer-term impacts on adoption intensity, yields, and welfare outcomes to assess the cost-effectiveness of the extension approach.

[22] We find that (1) treatment effects of T1 and T2 are positive and significant indicating that adoption of these ISFM-related practices is higher in treatment than in control mws; (2) the same applies to FREG farmers, but (3) among non-FREG farmers, only T2 has robust significant effects on adoption for two of the four practices (see tables S4.14 to S4.16 in the Supplementary Online Appendix).

[23] The authors thank an anonymous reviewer for suggesting this alternative interpretation and the respective tests.

[24] Given that adoption is a choice variable and therefore subject to selection bias, the same matching approach as above is used to match farmers in treatment mws who adopted the integrated ISFM package with their closest matches from control mws.

In this context, it is important to gain a better understanding of how to further strengthen information exchange between the direct beneficiaries of extension and other farmers in the community. A growing body of literature is dedicated to the investigation of mechanisms that counteract incomplete diffusion. This study has shown that more complex information, such as on the importance of applying practices jointly and on the process of compost production, was only transmitted to the wider community if they were additionally exposed to a video intervention. On the one hand, the video provides an opportunity to highlight the more complex aspects of the technology package that might otherwise be ignored or get lost along the information chain. On the other hand, the video could potentially also reach a larger share of the population in the community and provide them with a platform for information exchange with direct beneficiaries. While previous studies have mostly looked at mechanisms that incentivize model farmers to increase knowledge dissemination, the findings of this study suggest that interventions that activate knowledge-seeking processes among nonmodel farmers can be effective and represent a promising avenue for further research.

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