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Evaluating agricultural information dissemination in western Kenya

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Summary

Staple crop farming is one of the main sources of income for the rural poor in Africa. Despite its importance, several studies suggest not only that agricultural productivity in Sub-Saharan Africa has remained far from its potential (AGRA 2013; World Bank 2007 Nin Prat et al. 2011), but also that this region has the largest gaps between potential and realized yields (Mueller et al. 2012). Increasing the adoption and efficient use of profitable agricultural technologies is at the heart of addressing these gaps.

A potential explanation for the slow adoption of profitable agricultural technologies is lack of information. To adopt these, farmers might first need to know that the technology exists, where to access it, how to use it and what to expect from it. How to generate and deliver this information is a key policy question, especially since markets for information are often prone to inefficiencies: information is costly to produce and difficult to sell, making it difficult for private producers to emerge. In addition, relevant agricultural information depends on specific agro-ecological features, increasing the need for investment in the creation of information for different geographical areas. Therefore, the task of generating and disseminating information is often the responsibility of public institutions. Agricultural extension services have traditionally aimed to fill this role. However, despite large investments in extension systems, there is limited rigorous evidence on how best to provide this information to farmers and how effective these efforts are (Aker 2011).

This study contributes to our understanding of the role of agricultural information as a potential constraint to smallholder farmers' adoption of agricultural inputs in Kenya. In collaboration with the Kenya Agricultural and Livestock Research Organization, we present results from a randomized controlled trial that evaluated the effectiveness of two extension approaches. Since the informational content of the interventions differed, the evaluation cannot speak directly to the question of effectiveness of different delivery methods for a given message. However, the results provide evidence on the effects of two extension methods implemented by a public agency. Specifically, we evaluate how farmers' knowledge, beliefs and input choices changed after attending a farmer field day or receiving agricultural messages on their mobile phones. We also provide experimental evidence of farmers' valuation of information about locally recommended inputs.

The results suggest that farmer field days increased awareness and led to a modest, though statistically insignificant, increase in the purchase of agricultural lime, a heavily promoted input in this area. In addition, farmers assigned to the farmer field day treatment arm had higher levels of awareness and changed their reported beliefs about the profitability of a chemical fertilizer that the Kenya Agricultural and Livestock Research Organization recommends but is not widely used in the region. In self-reported data, treated farmers were marginally more likely to state that they used this fertilizer.

Using administrative data from local agricultural supply dealers we partnered with, we do not detect increases in the purchase of that input. Instead, we find that when provided with a discount coupon, relative to the control group, farmer field day attendees chose to purchase a type of chemical fertilizer that was already widely known in the region, even though we did not measure changes in awareness or reported beliefs about that input. This raises new questions about the mechanisms through which that effect operated.

Finally, we do not find consistent evidence that advice delivered through mobile phones was effective in increasing knowledge or use of recommended inputs.

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List of abbreviations and acronyms

AGRA	Alliance for a Green Revolution in Africa
BDM	Becker-DeGroot-Marshack
CAN	Calcium ammonium nitrate
DAP	Diammonium phosphate
FFD	Farmer field day
ICT	Information and communication technology
KALRO	Kenya Agricultural and Livestock Research Organization
NPK	Nitrogen, phosphorous and potassium
RLIS	Random Lottery Incentive System
WTP	Willingness to pay

1. Introduction

Seventy-five per cent of the world's poor live in rural areas and a majority earn at least part of their livelihood from agriculture. While food production has more than doubled in Asia and Latin America since the 1960s, in Sub-Saharan Africa agricultural productivity has remained stagnant (World Bank 2007). Raising agricultural productivity is at the heart of improving the economic well-being of millions of smallholder farmers in the region. The adoption and adequate use of agricultural inputs that enhance productivity is key to achieving this objective.

For many farmers, useful information about optimal practices and inputs for their farms might be hard to obtain. Generating information for one's own farm through self-experimentation might be too costly or difficult. For example, the cost of conducting soil tests or setting up experimental plots can be high. Moreover, individuals may not know along which dimensions to experiment (Hanna et al. 2014) or their perceptions may have limited correspondence with actual soil quality (Marenya et al. 2008; Berazneva et al. 2016). Learning may be further hampered by noise due to exogenous shocks, such as variable rainfall patterns.

Since information is non-rival, decentralized markets might not resolve this issue: information is costly to produce and distribute but is cheap to reproduce, making it hard for any producer of information to recover costs. The need for information creation is intensified by the high diversity of agro climatic conditions and soil characteristics in Africa (Voortman et al. 2000; Tittonell et al. 2005; Vanlauwe et al. 2010). This heterogeneity in local conditions, such as soil characteristics, altitude, microclimates or market environment, can also lead to substantial differences in the profitability and suitability of different inputs across space (Marenya and Barrett 2009; Suri 2011). Therefore, blanket recommendations for large areas might not be appropriate in Sub-Saharan Africa.

Public agricultural extension services have played a key role in creating and disseminating local agricultural knowledge to farmers. However, while many developing country governments spend heavily on agricultural extension, the evidence on the impacts of these services is mixed (Anderson and Feder 2007; Benin et al. 2007; Davis et al. 2012). Narrow farmer reach, weak accountability and persistent funding difficulties can hinder traditional public extension services. In Kenya, where this project takes place, a traditional method of extension – the training and visit model, which consisted of high-intensity contact with a limited number of farmers – was assessed to have limited efficacy and to be financially unsustainable (Gautam 2000). In other contexts, there is limited evidence on the effectiveness of training lead farmers and relying on them to spread agronomic messages to others (Kondylis et al. 2017).

In this project, we evaluate the impacts of two extension approaches used by the Kenya Agriculture and Livestock Research Organization (KALRO) to improve agricultural practices and increase adoption of locally relevant agricultural technologies in western Kenya. We conducted a randomized control trial that assigned a representative group of smallholder maize farmers into three groups. The first group was invited to attend a farmer field day (FFD) organized in their area. FFDs are one-day events to which farmers are invited to observe demonstration plots for promoted inputs, and where they receive information about agricultural practices from extension agents and/or other

actors such as input companies, community-based organizations or non-governmental organizations. A second group of farmers was invited to participate in an e-extension program, through which they received extension text messages on their mobile phones during the entire agricultural season. The third group remained as a comparison group.

We study how these interventions changed farmers' reported knowledge and beliefs about the recommended inputs and whether treated farmers were more likely to report using them. We also collected administrative data from agricultural shops, where all farmers in the sample could redeem a discount coupon to purchase agricultural inputs of their choice.

The FFDs and the e-extension share features that could address some of the limitations of other extension approaches. First, FFDs and e-extension can be implemented at a lower per-farmer cost than individual farm visits by extension agents. This would facilitate their scalability and farmer reach. However, relative to individual extension visits, advice is provided for an area and not for an individual farm. This raises some questions on whether area-level advice is valuable to farmers. To address this question, using data from soil tests we show that soil characteristics are spatially correlated in this region. In addition, we elicited farmers' valuations for local (rather than individual) soil analyses and recommendations. Second, both extension approaches can deliver agronomic messages directly to a large number of farmers and do not need to rely on contact farmers to diffuse messages. (This does not rule out that farmers can also diffuse the information they receive.) Third, the information provided to farmers through these approaches can be sufficiently targeted to match their agro-ecological zones. In other words, although it might be cheaper to deliver information at scale through other methods (e.g. radio, television), messages through FFDs and e-extension services can target relatively small geographical areas.

We find evidence that the FFDs changed farmers' perceptions about the profitability of a type of chemical fertilizer, Mavuno, which was promoted during the intervention. In farmers' self-reported data, we also detect a small increase in the use of this input for two consecutive agricultural seasons after attending the FFD. We find that the intervention had a small effect on the adoption of agricultural lime, one of the key inputs KALRO promoted. However, this effect is statistically insignificant. We do not measure increases in knowledge or self-reported input use as a result of the e-extension intervention.

In contrast, when analyzing the administrative data, we detect an increase in the purchase of diammonium phosphate (DAP), a well-known type of chemical fertilizer (the effect is small and statistically insignificant for the e-extension group). While this input was endorsed in both interventions, almost all farmers in the sample had consistently used it in the past. This might suggest that the interventions affected coupon redemption through a channel other than increasing awareness about this input.

This study contributes to a growing literature on the role of information in technology adoption. Although there is some evidence on the effectiveness of other forms of intensive extension services, such as farmer field schools (Waddington et al. 2014) and contact farmer systems (Kondylis et al. 2017), there is limited rigorous evidence on the effectiveness of other potentially scalable extension services provided by public agencies in developing countries. We are aware of only one other project measuring impacts of FFDs (Emerick et al. 2016). In that study, the authors find that in India, FFDs increased

adoption of improved seeds by 12 percentage points in villages that had been randomly allocated to receive them. However, those FFDs were implemented by a non-governmental organization.

Likewise, although there is a growing literature evaluating the impacts of receiving agricultural information through mobile phones (Aker 2011; Cole and Fernando 2016), there is much less evidence on the impacts of an SMS (text message)-based service with messages delivered by a public institution.

Following our pre-analysis plan, we explore the following hypotheses:

- The interventions may have positive average impacts on farmers' knowledge about the existence and appropriateness of agricultural inputs for their land.
- The interventions may have positive average impacts on farmers' beliefs about the existence and appropriateness of different agricultural inputs for their land.
- The interventions may have positive average effects on the use of recommended inputs and technologies such as soil testing, chemical fertilizers and lime.

This report is structured as follows. In Section 2, we provide a summary of the interventions and the theory of change. In Section 3, we discuss the overall context of this project, and in Section 4 we present a timeline. In Section 5, we describe the details of the experimental design and data collection. Section 6 expands on the details of the interventions. In Section 7, we present results for both impact evaluations and results from the elicitation of willingness to pay (WTP). Section 8 discusses robustness and caveats to the interpretation of results. Section 9 provides a policy discussion and concludes.

2. Interventions and theory of change

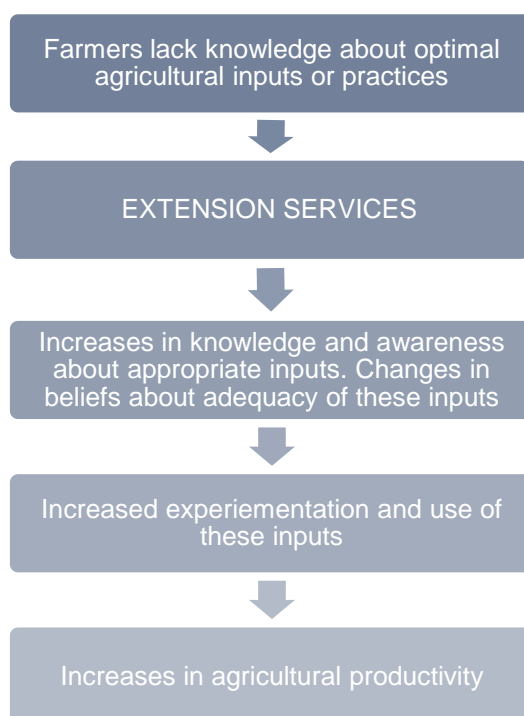
In this section, we discuss the hypothesized role of extension services in changing farmers' agricultural productivity. We first discuss the broad role of information and the key assumptions linking extension services to intended outcomes. In particular, we draw on existing evidence to discuss the relevance of each linkage and explain what additional evidence was gathered to learn about these channels. We then turn our attention to the specific delivery methods that were evaluated and highlight potential channels through which each one might operate.

2.1 A theory of change for agricultural extension

Low rates of adoption in developing countries have been well documented and there is widespread theoretical and empirical literature identifying the determinants of agricultural technology adoption in different contexts (Conley and Udry 2010; Duflo et al. 2011; Feder et al. 1985; Foster and Rosenzweig 1995; Suri 2011).

There is an extensive literature documenting the determinants of agricultural technology adoption in developing country contexts (see, for instance, Jack 2011 and Foster and Rosenzweig 2010). In this study, we explore the role of information in the adoption process, in particular the role that agricultural extension services play in addressing knowledge gaps. Birkhaeuser and others (1991) propose a simple theory of change for the impact of extension services on the adoption of new technologies. Figure 1 builds on their general framework.

Figure 1: Theory of change



Note: Prepared by authors, based on Birkhaeuser and others (1991).

We start by hypothesizing that there are some gaps in farmers' knowledge about agricultural practices or inputs. This assumption is supported by existing work in the region (Gautam 2000) and our own qualitative work conducted with farmers in this area.¹ During focus group discussions, farmers reported lack of information about agricultural inputs and practices as a constraint to ongoing experimentation. Their reported knowledge gaps ranged from queries about how to improve certain aspects of the agricultural production process² to broader questions about how to diagnose what was causing low yields on their farms.

The theory of change predicts that KALRO's extension services will solve underlying needs by providing farmers with information that will close those information gaps. The information provided in both interventions covered a range of topics, which KALRO deemed as optimal agronomic practices for maize management in the area. In particular, KALRO wanted to inform farmers about the use of agricultural lime to address soil acidity, use of locally appropriate chemical fertilizers and intercropping of legumes. We find some evidence of knowledge gaps in these dimensions at baseline. More than half of the sample surveyed had never heard about agricultural lime, and less than 10 per cent had ever heard about Mavuno, a chemical fertilizer that KALRO recommends to reduce soil acidity. However, 70 per cent of farmers were already intercropping legumes at baseline.

The extension services we evaluate provided farmers with agronomic information that was locally relevant but not necessarily specific to individual farms. One question is

¹ We discuss details about the qualitative data collection in Section 5.

² For instance, what types of seed varieties to use, the correct time to start planting, which type of fertilizers to use on their soils and how to handle specific weeds and pests.

whether farmers would value local rather than individual information. We explore this issue by eliciting farmers' WTP for results from local (not individual) soil tests.

Since we wanted to learn about the role of information in increasing adoption, we attempted to rule out situations in which farmers would not receive KALRO's messages (e.g. by not attending FFDs or being unable to read the SMS). Therefore, as part of this evaluation, we incentivized farmers assigned to the FFD group to attend the meetings by providing them with a small gift. Although we cannot know what the take-up for this intervention would have been in the absence of incentives, we can be confident that farmers attended the FFDs and received the information provided by KALRO.

In addition, two of the criteria for inclusion in the sample were to be literate and to own a phone. This is common in this population (94 per cent of farmers included in the census qualified). These criteria were meant to increase the likelihood that farmers who were assigned to the e-extension intervention could receive and understand the messages. We also collected data on farmers reported engagement with the e-extension messages at endline.

Although other work has found instances in which input adoption can increase without corresponding increases in knowledge (e.g. Kondylis et al. 2017; Cole and Fernando 2016), we hypothesize that one mechanism through which extension messages work is by changing awareness about the existence of inputs, increasing knowledge about their use and/or by changing farmers' beliefs about their effectiveness or profitability. Therefore, we collected measures on these intermediate outcomes during the endline survey.

The theory of change predicts that increases in relevant knowledge could lead to increased experimentation, adoption and, ultimately, agricultural productivity. We do not have measures of long-term adoption or agricultural productivity. Therefore, our primary outcome measure is whether farmers report using the recommended inputs. To measure this, we collected two types of data.³ First, we collected self-reported data on input use during the endline survey. We asked farmers about their use of agricultural practices and whether they had intercropped legumes, used agricultural lime and/or other types of chemical fertilizers.

Second, to address concerns about social desirability bias in self-reporting, we collected a direct measure of input choice. All research subjects received two discount coupons (one for their choice of chemical fertilizer and one for agricultural lime) that could be used to acquire inputs at a 50 per cent discount at a local shop. We used coupon redemption as an additional measure to assess whether information made farmers more likely to choose the inputs recommended by KALRO.

Finally, the theory of change assumes that farmers can acquire these inputs if they choose to do so. In this context, this was not necessarily the case. For instance, farmers might be financially constrained or there might be problems in input supply chains. We attempted to deal with this issue in two ways. First, the discount was likely to help with liquidity constraints. Second, to ensure that farmers could purchase the inputs, the implementing agency ensured that participating agricultural supply dealers were stocked

³ We did not have sufficient statistical power to conduct soil tests at endline to obtain an objective measure against which to assess changes in soil characteristics (e.g. acidity).

with all the inputs for which the coupons were redeemable. This last feature helped us evaluate the impacts of the information interventions on input demand, ruling out other types of supply constraints.

2.2 KALRO's extension services and potential mechanisms for impact

We now discuss specific channels through which each of the interventions might work. Although both interventions aimed to increase smallholder farmer productivity by scaling up the uptake of agricultural lime and chemical fertilizers, each extension mode highlighted different agricultural inputs and practices. Therefore, treatment effects for each intervention conflate the impacts of the delivery method and differences in the information conveyed.

2.2.1 Farmer field days

FFDs were one-day meetings where 100-300 farmers were invited to learn more about different agricultural technologies. The information provided to farmers during these meetings varied, but in all cases the intervention emphasized the use of soil tests to determine correct use of inputs, use of various locally relevant fertilizers and use of agricultural lime.

During the FFDs, farmers received information about different inputs through listening to presentations, observing experimental plots and walking through specially set up booths. Upon their arrival at the site, farmers were invited to walk through a field where experimental test plots had been set up and different agricultural inputs were showcased. Demonstration plots were set up early in the season by a host farmer. KALRO provided inputs and technical support for the experimental plots. FFDs were organized just before harvest, when farmers could observe and compare the effects of different inputs on mature crops. One of KALRO's key messages to farmers during these meetings focused on soil acidity: how to test for it (through soil analysis) and how to solve it (primarily by the application of agricultural lime and use of fertilizers containing lime, such as Mavuno).

Beyond providing farmers with agricultural messages, any impact from FFDs could work through other channels. First, observing demonstration plots can reinforce knowledge, give more credibility to the messages or help farmers quantify and compare the impacts of different agricultural technologies. For instance, Kondylis and others (2017) found in Mozambique that adding a centralized training component to traditional extension methods led to large increases in the adoption of sustainable land management practices. The authors venture a potential explanation: that the additional training made farmers think the information was of higher quality or more credible.

Second, since farmers can observe and obtain information about the different inputs during an FFD, it might help them notice relevant dimensions that they might have not noticed before (Hanna et al. 2014). Third, because farmers can ask specific questions of extension staff or other farmers at the FFD, they might find answers or learn directly from the experience of other adopters (Emerick et al. 2016). Finally, FFDs could make farmers more likely to adopt because of 'herd behavior', not because of increased knowledge (Banerjee et al. 1992).

2.2.2 E-extension

The e-extension program was designed to be a low-cost way to reach farmers during the agricultural season with simple agricultural messages that could help them use optimal

inputs and practices. This was a push-only intervention, in the sense that farmers could read the messages but not reply to them. Therefore, in contrast to the FFDs, the amount of information they received was limited to what was contained in each SMS. The messages contained broad recommendations about what KALRO considered to be agronomically optimal (e.g. 'If soil is acidic (pH less than 5.5), apply recommended rate of agricultural lime at least 30 days before planting' or 'Topdress one bottle top of Fanta soda with CAN [calcium ammonium nitrate] or Mavuno on every maize plant 3 weeks or 4 after planting').

In addition to providing information, the messages could have served as ongoing reminders to acquire or use inputs. In Bolivia, Laroche and others (2016) evaluated the effect of SMS reminders about agricultural practices and found a positive effect from that intervention. Messages might also have served as ongoing motivation or acted as soft commitment devices. There is evidence from other contexts that SMS messages can be effective for behavior change; for instance, to adhere to certain drugs, quit smoking or lose weight (Hall et al. 2015).

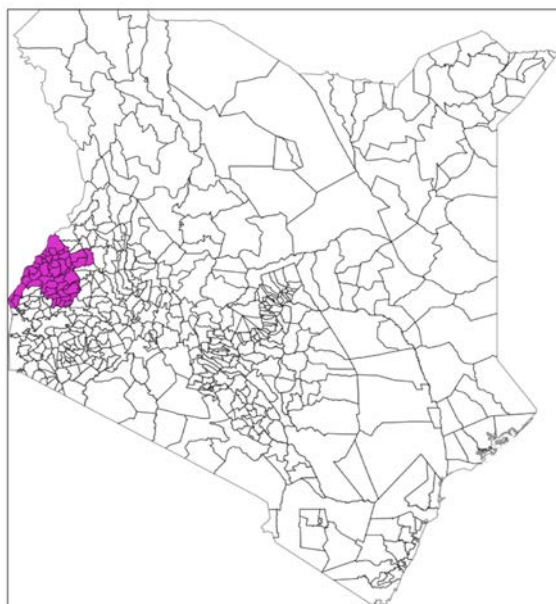
Since this intervention was designed to deliver information to farmers throughout the season, to correspond with the cycle of maize growing, the endline survey measures effects that took place during the season in which farmers received the messages, with coupon redemption measured for the following season. In contrast, for FFDs we measure impacts for the two subsequent agricultural seasons after the intervention.

3. Program context

3.1 Agro-ecological conditions in western Kenya

The study took place in Kenya's Western Province, as shown in the map in Figure 2. This region is home to about 4.3 million people, for whom farming is the main economic activity (KNBS 2009). We worked in three counties: Kakamega, Busia and Vihiga. The primary staple crop in these areas is maize. All the farmers in our sample were primarily maize growers. There are two agricultural seasons for maize growing. The Short Rain season, which starts with planting in late August and ends with harvesting in December or January, and the Long Rain season, which starts in March and ends in late July or August. The latter is the main agricultural season.

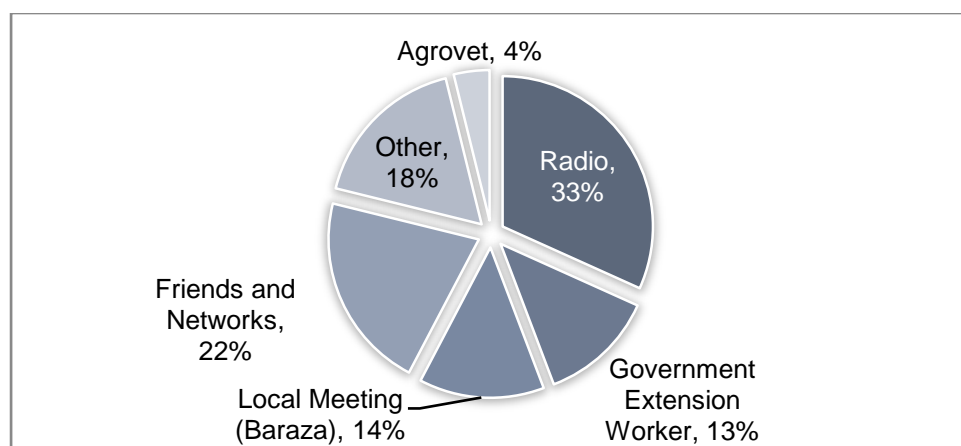
Figure 2: Map of Kenya



Note: Compiled by authors.

Figure 3 shows the main agricultural information source reported by farmers during the baseline survey. Friends and Networks and Radio appear to be their main sources of information. The majority of farmers (86 percent) had never received a visit from an extension worker. This is perhaps not surprising given the high ratio of farmers to extension workers in this area (one extension worker to serve 1,500- 2,500 farmers, according to KALRO).

Figure 3: Main source of agricultural information



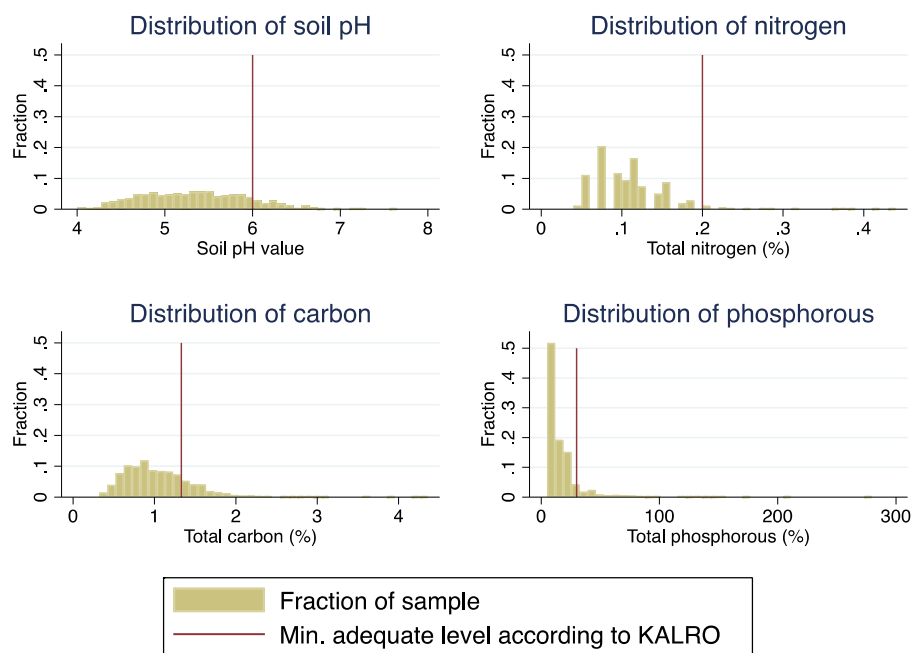
Note: Data collected during baseline survey as part of this project.

In Kenya, women represent 80 percent of all labor in food production; however, they have been reported to be much less likely to receive extension services (AfDB 2007). In our sample, more than two-thirds of respondents were women. At baseline, we found that women were also less likely to be aware of certain inputs, such as agricultural lime. Since women might experience larger knowledge gaps, we explore heterogeneous treatment effects by gender in Section 7.

Widespread soil fertility depletion undermines the ability of many households in the region to produce sufficient food to ensure subsistence (Marenja and Barrett 2007).

Figure 4 shows histograms for different soil characteristics, constructed based on a random sample of soil samples taken by the research team and analyzed at the soil laboratories at KALRO. The charts show the distribution of soil pH, nitrogen, carbon and phosphorous. The solid line reflects the minimum adequate level as recommended by KALRO. For all of these soil characteristics, most of the mass is to the left of the minimum adequate level.

Figure 4: Distribution of pH, nitrogen, carbon and phosphorous

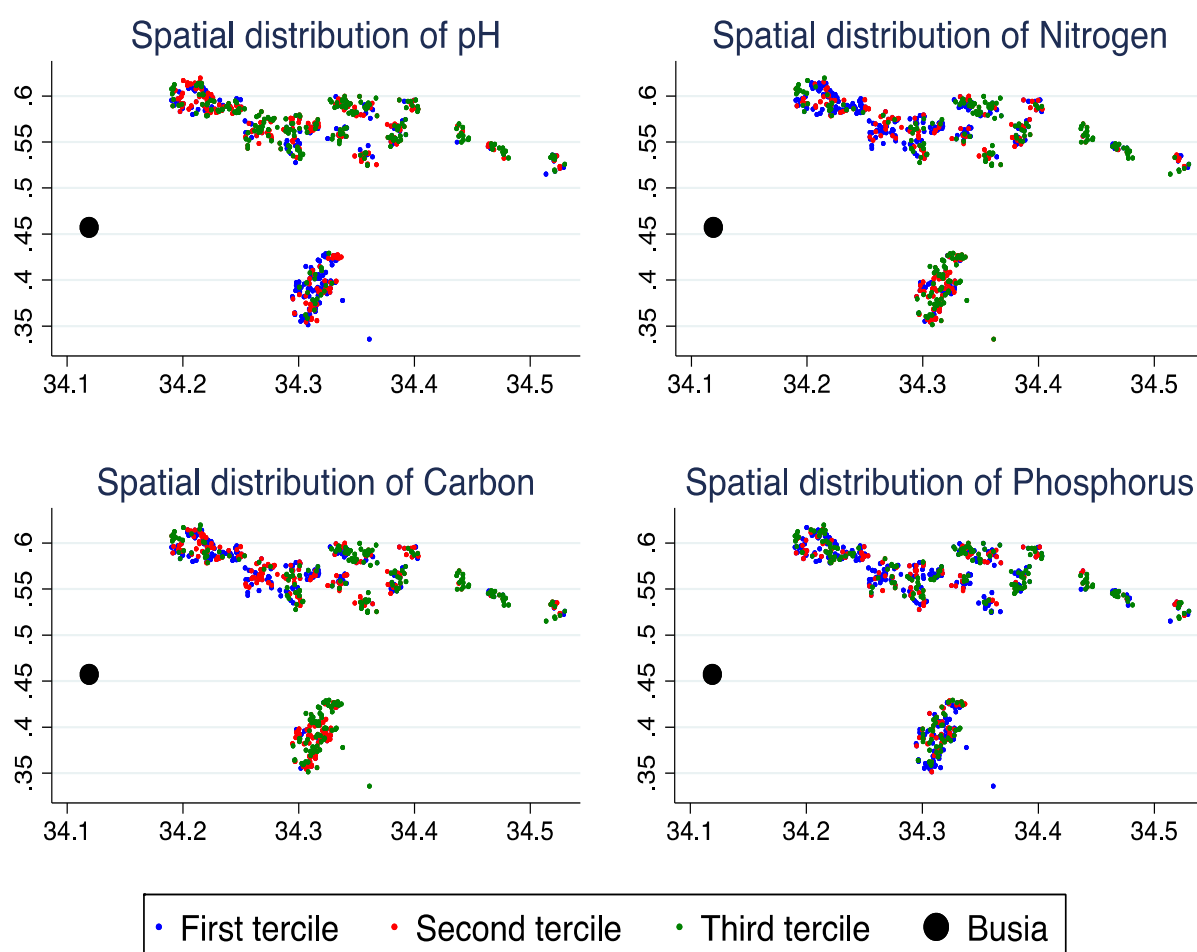


Note: Based on authors' calculations using soil data collected as part of this project.

Using the results from these soil analyses, we also uncover heterogeneity and spatial correlation in soil characteristics in this region. We provide a visual representation in Figure 5, which plots the measured values of different soil characteristics by tercile. Visual inspection of these maps suggests spatial correlation. Additionally, local means appear to be predictive in this sample of soil tests. For instance, using local means instead of global means reduces the mean square error of the prediction by 12% for pH and by 15% for nitrogen.

The role of heterogeneity and spatial correlation is important for this intervention. On the one hand, if there were no heterogeneity, extension agents could deliver a single message across the entire country. On the other hand, if there were no spatial correlation in soil characteristics, local information would not be informative to farmers, and only information generated on their own farms would be useful to them.

Figure 5: Spatial heterogeneity and correlation in soil characteristics



Note: Based on authors' calculations using soil data collected as part of this project.

3.2 Input use in western Kenya

By comparing yields from on-farm demonstrations against average yields in the region, KALRO estimates that the potential for yield increases would be 3–5 times higher under better agronomic management conditions. KALRO hypothesizes that the low productivity is mainly driven by small landholdings that are continuously cultivated without adequate nutrient replenishment and with prevalent weeds, high soil acidity and low adoption of productivity-enhancing technologies, especially fertilizers and improved crop varieties (KALRO 2014).

The information provided as part of this intervention focuses on two technologies that are recommended to address issues of soil acidity and nutrient deficiency: the use of chemical fertilizers and application of agricultural lime to reduce soil acidity.

3.2.1 Chemical fertilizers

There is a large body of work suggesting that chemical fertilizers can substantially raise agricultural yields and that it can be profitable to apply them (Evenson and Gollin 2003; Duflo et al. 2011). In this region, fertilizers such as DAP and CAN are widely known. Others chemical fertilizers – nitrogen phosphorus and potassium (NPK 23:23:0, 17:17:17) and urea – are not as widely known and used by a smaller fraction of farmers,

mostly for sugar cane. Mavuno fertilizers were particularly recommended during FFDs because of their effectiveness in acidic conditions (Omenyo et al. 2010). Despite all these options, many farmers do not seem to have much information about the adequacy of different types of fertilizers. In the baseline survey, more than 50 per cent of farmers said that they had chosen the fertilizer they were using either because they guessed that it was the correct one or because it was the only one they knew.

3.2.2 Agricultural lime

Soils are considered acidic when pH is lower than 5.5 (Sumner 1999). Acidity is associated with aluminum toxicity and other deficiencies that limit plant growth. Acidic soils are not unique to Kenya. Large parts of Ethiopia, Uganda, Zambia and Rwanda are also affected by high acidity. Kenya's Ministry of Agriculture recommends applying agricultural lime as one of the most practical ways to manage soil acidity. In addition, KALRO reports a cost-benefit ratio of between 2.5 and 3 for the use of lime (KALRO 2014). Others have reported high rates of return for agricultural lime in this area (One Acre Fund 2015; Omenyo et al. 2010).

However, agricultural lime is not a widely known input in this area; despite its being relatively cheap, usage and knowledge about it are relatively low. Agricultural lime is not typically commercially available, but was made so as part of KALRO's program.

4. Timeline

We show the project timeline in Table 1. During the summer of 2014, Ugenya and Mumias sub-counties were selected as target areas to evaluate KALRO's interventions. In July 2014, a team of enumerators conducted a census to select participants. Subsequently, farmers who met the inclusion criteria (described in the next section) were invited to complete the baseline survey. FFDs took place around the end of the Short Rain season, in November and December 2014.

E-extension services were planned to start in early 2015. However, because of technical issues in deploying the system, the e-extension information delivery system was implemented in mid-2015. Endline survey data was collected at the end of the 2015 Short Rain season. During the endline survey, farmers in all treatment groups received coupons redeemable for fertilizer and lime for the subsequent season (the deadline to redeem was set for the beginning of the next Long Rain planting season in March 2016).

In addition, in 2015 we elicited WTP for local soil test results for a sample of farmers in this region, but not in the same counties.

Table 1: Project timeline

Date	Event	Farmer sample
<i>July/August 2014</i>	<i>Harvest Long Rain Season 2014</i>	-
August 2014	Farmer Census	KALRO
<i>September 2014</i>	<i>Planting for Short Rain Season 2014</i>	-
September/October 2014	Baseline survey	KALRO
November/December 2014	FFDs take place	KALRO
<i>December 2014/January 2015</i>	<i>Harvest Short Rain Season 2014</i>	-
January 2015	WTP Elicitation (First Visit)	WTP
March/April 2015	WTP Elicitation (Second visit)	WTP
<i>March/April 2015</i>	<i>Planting for Long Rain Season 2015</i>	-
July/August 2015	Focus Groups Discussions	QUAL
<i>July/August 2015</i>	<i>Harvest for Long Rain Season 2015</i>	-
July/August 2015	KALRO's SMS intervention starts	KALRO
<i>December 2015/January 2016</i>	<i>Harvest for Short Rain Season 2015</i>	-
December 2015/January 2016	Endline Survey, farmers get coupons	KALRO
March 2016	Coupon Redemption for KALRO ends	KALRO
<i>March/April 2016</i>	<i>Planting for Long Rain Season 2016</i>	-

Note: The project timeline spanned from August 2014 until the last round of data collection in March 2016. The Farmer sample column indicates separate samples of farmers: KALRO denotes farmers in KALRO's evaluation, QUAL denotes the qualitative sample and WTP denotes farmers who participated in WTP surveys.

5. Evaluation design, methods and implementation

The data used in this study was collected through fieldwork led by Innovations for Poverty Action. All activities described were subject to Internal Review Board reviews from Maseno University, Harvard University and the University of California at Santa Cruz. All key study staff members completed relevant ethical training. Informed consent was obtained from all individuals enrolled in research activities, and participation was strictly voluntary.

Our data collection started in August 2014 and ended in March 2016, spanning two full agricultural seasons. We collected two rounds of surveys: a baseline survey in September 2014 and an endline survey in December 2015 and January 2016. The endline survey took place two agricultural seasons after the FFDs were organized and coincided with the end of the season in which the e-extension took place.

In addition to the sample of farmers that participated in the experimental evaluation of KALRO's extension services, we elicited WTP for different types of soil analysis information from a separate sample of almost 400 farmers. We describe all data collection activities in the following subsections.

5.1 KALRO's extension services

We conducted a randomized controlled trial to evaluate whether KALRO's FFDs and e-extension services were effective in increasing farmers' knowledge and adoption of recommended agricultural inputs. We sought to answer the following questions:

- Does receiving information increase farmers' knowledge about the existence and adequate use of agricultural inputs and technologies?
- Does receiving information improve individuals' beliefs about profitability and effectiveness of agricultural practices and inputs?
- Does receiving information increase individuals' adoption of these inputs?

A sample of 1,249 eligible farmers was randomly assigned in equal proportions to one of three groups: (i) those invited to participate in FFDs, (ii) those invited to participate in e-extension services and (iii) those assigned to a comparison group. Below we describe details of the sample selection, evaluation design and identification strategy.

5.1.1 Sample selection

At the onset of the 2014 Short Rain season, the research team and KALRO jointly selected the subcounties of Ugenya and Mumias (out of five potential locations) to recruit farmers for the evaluation. KALRO had already selected these areas to implement its program and set up demonstration plots, and they were deemed representative of the agroclimatic conditions of other regions.

To recruit a representative sample of participants, the research team first identified key landmarks in these areas. Starting from these, enumerators used specific walking rules to visit a random sample of households and invite them to participate in a census questionnaire. Enumerators completed 1,330 surveys following these protocols.

A subsample of these farmers were invited to participate in the research study and complete a baseline survey. There were three criteria for inclusion in the research sample:

- The individual or another household member owned a mobile phone;
- The individual had grown maize or legumes during the previous year; and
- The individual was in charge of farming activities for the household.

These criteria were used to ensure that the sample was representative of the farmers who are usually targeted by KALRO. Approximately 94 per cent of individuals who completed the census survey were eligible for inclusion in the baseline survey. At the time, our power calculations suggested minimum detectable effects of 0.19–0.23 standard deviations for our coupon redemption measure, with a sample of 400 farmers per treatment arm. We discuss power calculation assumptions in Appendix B.

5.1.2 Data collection and randomization

The research team conducted a baseline survey in September 2014 with 1,249 consenting farmers. The questionnaire asked for information about individuals' demographics, literacy and numeracy, input use during the previous two seasons (Short Rain season 2013 and Long Rain season 2014), their beliefs about input effectiveness and profitability, their sources of agricultural information, and their perceptions about the members of their community.

Once the baseline survey was completed, participants were randomized into treatment arms by the research team, using Stata (a statistical software). Randomization was stratified by subcounty, recruitment area, gender, knowledge about lime, land size, legume farming, scores on the cognitive test and an index for agricultural input use.

Farmers who were assigned to the e-extension or the FFD received a phone call to invite them to participate in the activity. In the final sample of farmers, 92 per cent of respondents reported being the primary owners of their mobile phones.

The FFDs took place in November and December 2014, a couple of weeks before the end of the 2014 Short Rain season. Four FFDs were organized in the experimental areas. FFDs are open to all members of the public. To reduce the likelihood of contamination, it was agreed that Innovations for Poverty Action would actively invite and reach out to farmers assigned to the FFD treatment group. Invitations to the event were made through a phone call and a letter that stated the location and event time.⁴

Since we were interested in evaluating the causal effects of attending the events and wanted to ensure that we had enough power to detect them, the team encouraged attendance by providing a small gift and facilitating transport to farmers who lived more than 5 kilometers away from the closest FFD site. KALRO and the research team both kept attendance records for all farmers who attended the events. Overall, 87% of invited farmers attended the FFD, relative to 4% of farmers in the e-extension group and 4% of farmers in the control group. We consistently show intent-to-treat estimates in the results section, unless otherwise specified.

The e-extension program was scheduled to be implemented starting in the Long Rain agricultural season (March 2015). However, technical difficulties experienced by the project implementation team delayed implementation of this treatment arm until the following Short Rain season (July 2015). Before the intervention started, farmers were called and invited to receive the messages on their mobile phones. All farmers agreed to participate in this treatment arm. Participants received extension messages until early November 2015.

To measure impacts, the research team collected information through an endline survey, conducted in late November and December 2015. Face to face interviews were conducted with farmers in the two treatment groups and the control group. The survey collected information on farmers' knowledge, beliefs, input use, community relationships and experience with the interventions.

In addition, at the end of the endline survey, all farmers received two discount coupons redeemable at specific agricultural supply dealers in their nearest market center. The first coupon was redeemable for a 50 per cent discount (up to 1,000 KES) on any chemical fertilizer of their choice (NPK, DAP, CAN, urea or Mavuno). The second coupon was redeemable for a 50 per cent discount for agricultural lime. Coupon redemption was open until March 2016, which corresponded with the start of the 2016 Long Rain agricultural season. Participating agricultural supply dealers were stocked with inputs as part of KALRO's overall program.

The coupons were devised as a way to collect information on participants' actual agricultural input choices. The use of coupons may reduce concerns about social desirability biases, since farmers make purchase decisions at a later time when they are not observed by the enumerator. In addition, once a person's resources are on the line, they are likely to better reflect their true preferences (Glennester and Takavarasha

⁴ Farmers were asked to bring the letter to the meeting to receive the token of appreciation for attending, which increased the likelihood that assigned farmers would show up.

2013). Each coupon was marked with an individual respondent ID. Agricultural supply dealers were instructed (and incentivized through a small payment) to keep clear records on input choices and quantities purchased. The research team linked this administrative data on coupon redemption with the survey records.

One limitation in the interpretation of the results is that we measure only self-reported input use during the season in which the e-extension was implemented, and we do not collect additional survey data for subsequent seasons. However, since all farmers received coupons during the endline survey, and redemption for all groups lasted until the beginning of the following season, this measure could be used to detect changes in input choices for the season following the e-extension intervention.

To ensure data quality, approximately 10 per cent of surveys were back-checked. In addition, random audio audits were performed on enumerators. (Enumerators were aware that they could be audited.)

5.1.3 Empirical strategy

We obtain intent-to-treat estimates through following equation,

$$y_{i,t=endline} = \beta_0 + \beta_1 e_extension_i + \beta_2 FFD_i + \beta_2 y_{i,t=baseline} + \delta X_{i,t=baseline} + \varepsilon_i$$

where $y_{i,t=endline}$ indicates the post-treatment outcomes of interest (knowledge, beliefs and input use) and $e_extension$ represents a dummy variable that takes value 1 to indicate assignment to e-extension. FFD is a dummy variable that takes value 1 to indicate assignment to the farmer field days. Their coefficients (β_1 and β_2) provide the intent-to-treat estimates for each treatment. To improve precision, we control for baseline outcomes for all cases in which we collected information for these variables at baseline. To identify heterogeneous impacts, we interact each treatment variable with selected baseline characteristics (as described in the heterogeneity subsection). To adjust standard errors for constraints we imposed during the stratified randomization, we include dummies for the different strata used in the randomization (X). All regressions use robust standard errors.

Since some invited farmers did not attend the FFDs, we also estimate an instrumented specification (instrumental variable), in which we will instrument participation with the treatment assignment:

$$y_{i,t=endline} = \beta_0 + \beta_1 Participation_i + \beta_2 y_{i,t=baseline} + \delta X_{i,t=baseline} + \beta_3 e_extension_i + \varepsilon_i$$

To assess the validity of the random assignment, we tested for differences between the control group and the treatment groups for several baseline variables. We also tested for differences among attriters and non-attriters in the endline survey and find no significant differences (see Appendix D Table D-4).

5.1.4 Focus group discussions

In addition to the data collection described above, the field team was trained by a qualitative researcher to conduct focus group discussions with different groups of farmers to understand their interest in the use of information and communication technology (ICT) and gather their thoughts about their experiences with extension services and FFDs. The focus group discussions took place during the Long Rain season of 2015. These discussions were conducted with a separate sample of farmers, who were not part of the experimental evaluation. Sampling for the focus group discussions was purposive, whereby participants were selected based on their area of

residence and gender. Farmers had sociodemographic characteristics similar to farmers who participated in the experimental evaluation.

Ten focus group discussions were organized, with 8 to 12 participants in each. We had five general groups of mixed gender, three groups of female-only farmers, one mixed-gender group of FFD attendees (but not part of the experimental sample) and one women-only group of FFD attendees. The discussions centered on perceptions about farming needs (especially information needs), use of current information channels, perceptions about agricultural extension workers, use of ICT for receiving information, experiences in FFDs and dissemination of information in communities.

We share a summary of the final report from the focus group discussions in Appendix G.

5.2 Willingness to pay

In addition to KALRO’s evaluation, the research team collected measures of WTP for results of soil analyses that KALRO had conducted in this region during the Long Rain season of 2014. This exercise was carried out to obtain measures of farmers’ valuation for local agricultural information.

5.2.1 Sample selection

As part of a different experimental evaluation focused on the impacts of receiving soil samples, we had worked with a subset of farmers in Busia County to provide them with results from soil analyses from samples collected at their farms (another subset had been assigned to a control group). The soil samples were sent for analysis at the KALRO soil laboratories in the summer of 2014.⁵ In addition, at baseline the research team had collected information on the peers of all the farmers who had participated in that evaluation.

Table 2: Willingness to pay elicitation samples

	Description	Sample size	Sample description
Group 1 WTP	WTP elicited for local soil test result	207	Individuals sampled through random walk method in Busia County
Group 2 WTP (Networks)	WTP elicited for first soil test result from networks	185	Networks of other farmers who had received individual soil information

We use the information generated through these soil analyses to elicit WTP from a representative sample of neighboring farmers in those areas (e.g. farmers who were not part of that evaluation, but who lived in the same area). Therefore, the WTP elicitation was for ‘local’ but not individual soil test results.

In addition, the field team tracked down the peers of farmers who had originally received individual soil test results and elicited the peers’ WTP for the soil analysis results. The rationale for eliciting WTP from this group was to explore whether there was information-selling among farmers (which could be a potential explanation for a positive WTP) and

⁵ The figures presented in the program context section (Section 3) were constructed with the results from this data. Also, since the results from the individual soil analyses were promised to be delivered to farmers, we could not credibly elicit WTP for these results from this sample of farmers.

explore the extent of information diffusion among farmers. (Under perfect information diffusion among peers, it is unlikely that the peers would have wanted to pay for the results, since they could have asked their friends for the results.) Therefore, we can compare the WTP for local soil information of the peers of those who were randomly assigned to receive soil tests to the average WTP of the peers of farmers who had not received soil test information.

5.2.2 Data collection

We elicited WTP through two methods, both of which are widely used in the experimental economics literature. Some of the strengths and weaknesses of each method are discussed below. The methods were randomly assigned to understand whether they led to differences in measured WTP.

The first method was a variant of the Random Lottery Incentive System (RLIS) in which farmers were offered a series of choices between different monetary amounts and the information from soil tests. Participants were informed that one of those choices would be randomly selected for implementation, to ensure that they had an incentive to truthfully reveal their willingness to pay. The choices were offered in descending or ascending order (randomly assigned) and ranged from 0 KES to 900 KES.

The second method was to elicit WTP using a Becker-DeGroot-Marshack (BDM) elicitation method in which farmers used their own money (Becker et al. 1964). During this process, respondents stated their WTP for the information before a random price, p , was drawn. If the stated WTP was greater than p , the respondent committed to purchasing the good at price p . However, if WTP was less than p , the respondent was not allowed to purchase the good. Therefore, farmers were incentivized to reveal their true WTP. The random price, p , was distributed from 0 KES to 900 KES. Other studies (e.g. Hoffmann et al. 2009; Berry et al. 2012) have implemented this method successfully in developing-country contexts.

There are some important differences with elicitation using these methods. In the RLIS elicitation, farmers did not use their own money. Rather, they were offered a choice between an amount of money or the information. A potential concern with this method is that WTP was high due to social desirability bias. On the other hand, the BDM elicitation was done through surprise home visits, and respondents could bid only whatever cash they had on hand (there was no opportunity to gather additional funds). To the extent that this population of farmers is cash constrained, this method might undervalue their true valuation for the information sheets.

We elicited WTP for information sheets by summarizing input recommendations from soil analyses performed by KALRO. These analyses included chemical measurement of soil characteristics and contained recommendations on the types and quantities of agricultural inputs that, according to KALRO's soil scientists, were most appropriate given measured soil deficiencies. In particular, the results highlighted types and quantities of chemical fertilizers and additives, such as lime.

In all cases, we elicited WTP for information based on the results of neighboring farms. To explain this concept to farmers, we told participants how far (in walking distance) from a well-known landmark (primary schools) the soil sample had been taken from. We measured farmers' distance to the landmarks to determine which was closest to them.

To understand how valuation changes with the characteristics of the information and, more specifically, to infer how demand changes with improved precision, we offered different versions of the information sheets to each farmer. We used two sets of modules: one that elicited WTP for soil test results within different distances from the landmark (0–5 kilometers, 0–10 kilometers and 10–20 kilometers) and another that elicited WTP for different numbers of local soil test results (1, 2 or 3).

Finally, to address potential social desirability bias or enumerator effects, farmers were also offered an information sheet to purchase that had little information content. This sheet listed only the total maize yields, in kilograms, of an unknown test plot. The idea was to use this sheet to benchmark how much farmers would pay for something that presumably contained very little information of value to them. We elicited farmers' WTP to pay for this information, but the actual probability of this option being implemented was minimal. In Section 7, we present preliminary results from this exercise. A detailed discussion of the results can be found in Fabregas et al. (2017).

6. Program design, methods and implementation

6.1 KALRO's extension services

In 2014, KALRO launched the 'Scaling up integrated soil fertility management in western Kenya through an innovative public-private partnership' program. The program was financially supported by the Alliance for a Green Revolution in Africa (AGRA) and its objective was to increase agricultural productivity in the region. The program had multiple components, including linking farmers to productive value chains, training extension workers and agricultural supply dealers, and marketing (sourcing inputs and disposing outputs). It also had a component that delivered information to farmers; this evaluation focuses on that aspect of the program.⁶

The information component sought to increase farmer productivity by scaling the uptake of locally relevant inputs and management practices. Two information delivery methods were tested. Originally, the evaluation was envisioned as a way to disentangle the impacts of different delivery methods, holding core messages constant. However, there were departures from this protocol and, as explained below, the informational content of each intervention ended up highlighting different aspects of maize management. Therefore, the impacts of these interventions are not necessarily comparable, as the results do not uniquely reflect the appropriateness of the delivery method. However, the estimated effects from each intervention are still useful for policy purposes.

6.1.1 Farmer field days

One of KALRO's main strategies for providing farmers with information about locally relevant agricultural practices is to organize large events around farming demonstration sites, where they showcase appropriate agricultural technologies for the area's agro-ecologies. These meetings are a learning platform for farmers, who can observe the results from demonstration plots and learn about different technologies and practices from other farmer groups and from extension workers. As part of the overall program, KALRO organized several FFDs in western Kenya. For the purposes of this evaluation,

⁶ The recruitment of farmers for this experiment was independent from other interventions. The other treatments occurred in different geographic areas, such that concurrent treatment by another KALRO intervention is less of a concern for this evaluation.

farmers assigned to the FFD group were invited to one of the FFDs organized in the evaluation subcounties. Four FFDs were organized in these areas.

KALRO set up the demonstration plots at the onset of the Short Rain season 2014. Host farmers were selected by KALRO, and they received all the inputs and technical support to set up the plots. To promote ownership of the demonstrations, KALRO and the host farmers agreed that the farmers would provide most of the labor. A key criterion for selecting farmers was to choose someone with sufficient land to host test plots and who could host an FFD. All demonstration plots showcased different types of fertilizers (e.g. DAP, Mavuno, NPK and CAN, legumes and agricultural lime). FFDs were held on pre-specified days and generally lasted the entire morning.

A typical FFD worked as follows: once farmers arrived, they were registered and organized into smaller groups by a member of the KALRO team. They then toured the demonstration plots, guided by an extension worker. After the tour, farmers could independently visit information booths that had been set up by fertilizer companies, self-help groups and/or community organizations. The content of the booths differed by FFD. At the end of the day, special guests (e.g. local leaders, successful farmers or extension workers) gave speeches. Although farmers could leave at any point, the majority stayed throughout the event. Each FFD had approximately 100–300 attendees (including, in our case, farmers who participated in the experiment and others in the area who did not).

One of the key messages highlighted by extension workers during the FFDs was the recommendation to conduct soil analyses and apply lime if the soil was acidic (pH less than 5.5), intercrop their maize with legumes and use chemical fertilizers, particularly CAN, DAP and Mavuno. Mavuno was highlighted as a good option because it already contains some lime. Although we do not have experimental measures of the profitability of each of the technologies that were showcased during the FFDs, others have documented positive rates of return for agricultural lime and CAN, and large impacts in yields from Mavuno use in these areas (as discussed in Section 3).

6.1.2 E-extension

This intervention consisted of farmers receiving 15 SMS messages on their mobile phones. To the extent possible, message delivery corresponded with the agricultural cycle. For instance, farmers were reminded to prepare their land early at the beginning of the planting season and to weed their fields about halfway through the season. An example of messages sent to farmers (translated to English from Swahili) can be found in Appendix E. One of the messages recommended that farmers test their soils to determine acidity levels and use agricultural lime in acidic soils (but did not explicitly mention how much lime to apply). Other messages also provided direct recommendations on types and quantities of chemical fertilizers to apply (DAP for planting and CAN and Mavuno for topdressing). Messages did not provide information on the benefits of different types of inputs; they simply stated a recommendation.

In contrast to the FFDs, in which we evaluated take-up of recommended inputs and practices on subsequent seasons, for the e-extension program we evaluated impact during the season when the program took place (although coupon redemption was evaluated for use in the subsequent season).

The message content was chosen and developed by the Ministry of Agriculture. KALRO partnered with them to implement this intervention. Since 2014, the ministry has

announced plans to roll out an e-extension system to reach more than 7 million farmers (Onyango 2013; Daily Nation 2014). The main plan is to provide this service to extension workers, who would then advise farmers. The version of the program that we evaluated was a pilot to deliver information directly to farmers.

The first set of messages, sent at the beginning of the Short Rain planting season 2015 (August 2015), were in English. After discussions with implementers about the appropriateness of language, the messages were translated into Swahili. Although 75 per cent of farmers reported speaking English at baseline, there is a risk that some farmers might have not understood the initial messages. We look for evidence of heterogeneous treatment effects by language spoken in Section 7.

7. Results

We describe the results from the willingness to pay surveys in Subsection 7.1. In Subsection 7.2, we show results for KALRO's impact evaluation on the research questions proposed in the pre-analysis plan. In Subsection 7.3 we discuss heterogeneous treatment effects and in Subsection 7.4 we discuss potential breaks in the theory of change.

7.1 Willingness to pay for local soil information

In Appendix D, we show summary statistics for farmers in this sample and balance checks for farmers assigned to the RLIS versus the BDM group.

The average WTP elicited for this soil analysis through RLIS was KES487 (about US\$4.80). Average WTP elicited through BDM was KES20.5 (about US\$0.20). These differences are statistically significant.⁷ For comparison, the approximate price of a single soil test (not including costs of sampling and transport) was KES1,100 (about US\$11).⁸ Both estimates are higher (by 56% and 85%, respectively) than the WTP we obtained from offering farmers the product with low information content. This is consistent with the idea that farmers find these local soil test results valuable.

Although there are large differences in WTP depending on the elicitation method, we can use these estimates to benchmark a valuation range for farmers. From an economic standpoint, if the aggregate valuation in an area is higher than the costs of generating the information (since it can be shared by many), it would be socially beneficial to invest in creating this information. We discuss these issues in detail in the academic paper that makes use of this data (Fabregas et al. 2017). In Appendix D Table D-2 we show how different farmer characteristics correlate with WTP.

Figure 6 shows farmers' WTP for different types of information offered to them. For a given farmer, the research team elicited WTP through RLIS or BDM for different distances to the landmark and different numbers of soil test results. In previous work, we had found that farmers were more likely to bid higher amounts for more precise information than for other types of agricultural information (Fabregas et al. 2017). That pattern seems to hold true for variation in distance to landmark but not for the number of

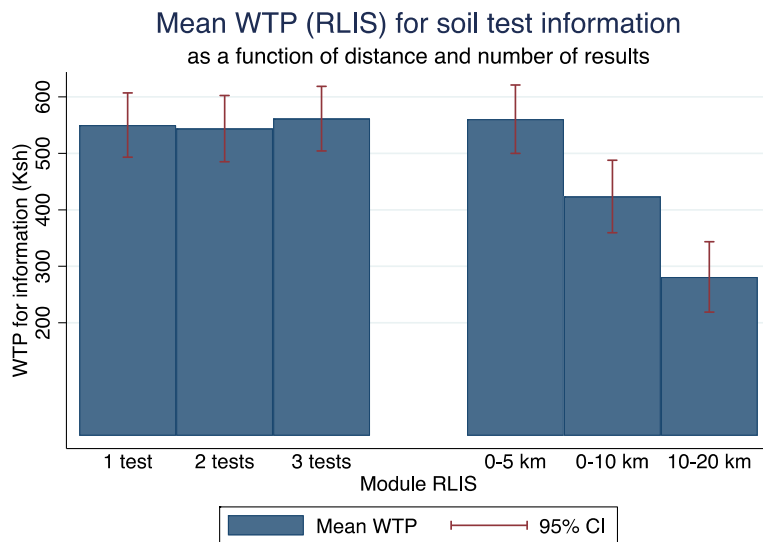
⁷ They remain significant when we control for land size, which is slightly unbalanced across groups, as shown in Appendix D Table D-1.

⁸ If farmers paid for a soil test, this was for information about their own farm. However, we elicited information for a local result.

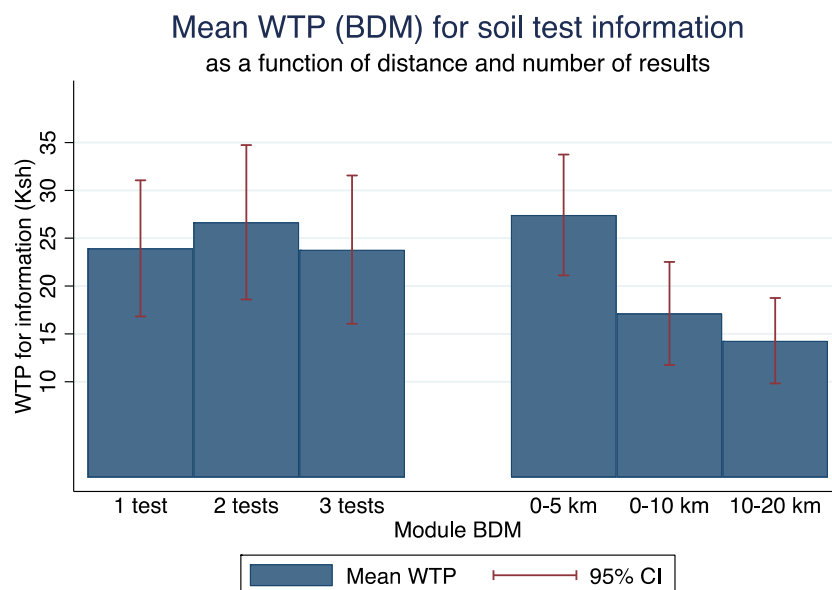
soil test results offered. This could reflect the fact that farmers do not perceive much improvement in information precision as they receive more soil test results. However, farmers appear to exhibit higher WTP for results that are closer to their farms.

Figure 6: Average WTP by module

(a) RLIS



(b) BDM



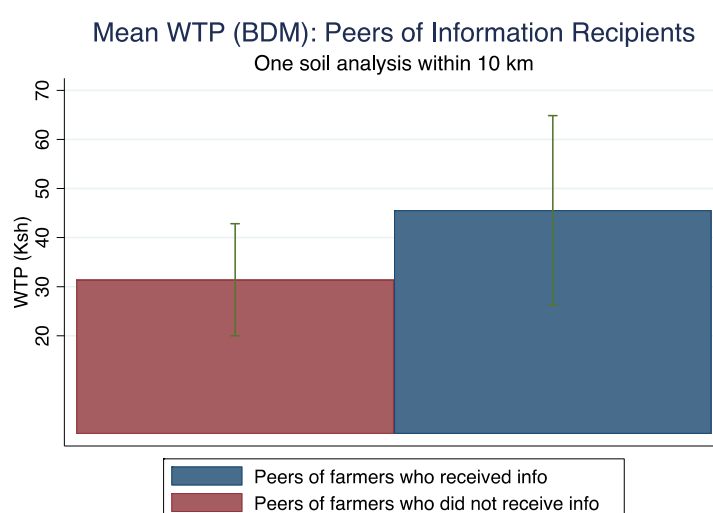
Note: This figure shows WTP for the results of a different number of soil analyses within a 10-kilometer radius (1, 2 or 3 tests) and the WTP for one soil analysis within 5, 10 or 10–20 kilometers from a landmark close to the respondent. The first figure (a) shows results as elicited by the RLIS method and the second figure (b) as elicited by the BDM method.

When soil samples were collected from a different sample of farmers (for a different research project), we asked those farmers to provide the name of a neighboring farmer with whom they discussed agricultural issues (this question was also asked of those in a corresponding control group). Once the research team had returned results to the original farmers from whom we had taken soil samples, we allowed a period of 2–3

months for information to diffuse. At that point, the field team tracked the reported network farmers to elicit their WTP for the same information that the original farmer had received.

Figure 7 shows WTP results for these networks by treatment status of original farmer. The first bar shows WTP for peers of those who did not receive soil tests in the past and the second bar shows WTP for peers of those who did receive information in the past. Point estimates for WTP for those with peers who were randomly allocated to receive information are higher than for those with peers who did not receive information. Although these raw differences are not statistically significant (note that the sample size is small), it is interesting to note that this does not support the idea that farmers who had received soil test information sold or diffused the information to their networks.

Figure 7: Average WTP by network type



Note: This figure shows WTP for the peers of farmers of two groups. The first group was randomly assigned to receive information. The second group remained as control. The WTP was elicited through the BDM method and respondents could only bid with cash on hand.

7.2 Impact evaluation of KALRO’s extension services

We now turn to the results of KALRO’s impact evaluation. In particular, we discuss the questions related to this intervention as noted in the pre-analysis plan: does receiving information improve an individual’s knowledge and beliefs about the appropriateness of agricultural inputs and does this translate to actual adoption of these inputs?

7.2.1 Balance and sample characteristics

Table 3 shows balance checks for key variables in the analysis. We show means for each treatment group in the first three columns, overall means in column (4) and p-values of different comparisons in columns (5), (6) and (7). Overall, individuals assigned to different treatments appear to be very similar at baseline. We note that the control group was slightly more likely to have experimented with Mavuno. We control for this variable in the specifications we run, but the estimates are robust to the exclusion of this variable.

We have a sample of farmers composed of a majority of females (65 per cent), with an average age of 40 years. Although participation was conditioned on self-reporting of owning a mobile phone and being literate during the census survey, in the baseline data

we see that only 90 per cent of respondents reported that they could read a letter in Swahili and owned a phone. This is balanced across groups, so it should not affect the internal validity of our estimates.

Only 10 per cent of farmers reported ever having done a soil test on their land. Although everyone in sample had heard about DAP, other fertilizers such as CAN, Mavuno and NPK were not universally known. Less than half the sample had ever heard about lime and only 7 per cent reported ever having used it.

Table 3: KALRO summary statistics and balance checks

	FFD	SMS	Control	Overall	(1) vs. (2), p- value	(1) vs. (3), p- value	(2) vs. (3), p- value
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Female	0.65 (0.02)	0.65 (0.02)	0.65 (0.02)	0.65 (0.01)	0.87	1.00	0.87
Mumias	0.56 (0.02)	0.57 (0.02)	0.56 (0.02)	0.56 (0.01)	0.94	0.89	0.83
Age	40.25 (0.66)	39.79 (0.65)	41.29 (0.66)	40.44 (0.38)	0.62	0.27	0.10
Primary school complete	0.54 (0.02)	0.54 (0.02)	0.53 (0.02)	0.54 (0.01)	0.89	0.78	0.67
Can read letter in Swahili	0.90 (0.01)	0.91 (0.01)	0.91 (0.01)	0.91 (0.01)	0.74	0.91	0.83
Respondent owns phone	0.93 (0.01)	0.91 (0.01)	0.92 (0.01)	0.92 (0.01)	0.24	0.59	0.52
Log expenditure	8.27 (0.07)	8.38 (0.07)	8.32 (0.07)	8.33 (0.04)	0.28	0.67	0.50
Wears footwear	0.57 (0.02)	0.56 (0.02)	0.61 (0.02)	0.58 (0.01)	0.79	0.26	0.16
Acres owned	1.64 (0.11)	1.54 (0.09)	1.88 (0.26)	1.69 (0.10)	0.47	0.40	0.21
Ever done a soil test	0.10 (0.01)	0.10 (0.01)	0.12 (0.02)	0.11 (0.01)	0.89	0.23	0.28
Heard about DAP	0.99 (0.01)	0.99 (0.01)	0.99 (0.01)	0.99 (0.00)	0.99	0.76	0.77
Heard about NPK	0.51 (0.02)	0.47 (0.02)	0.50 (0.02)	0.49 (0.01)	0.33	0.94	0.37
Heard about CAN	0.89 (0.02)	0.89 (0.02)	0.90 (0.01)	0.89 (0.01)	0.93	0.66	0.72
Heard about lime	0.40 (0.02)	0.40 (0.02)	0.40 (0.02)	0.40 (0.01)	0.93	0.89	0.96
Heard about Mavuno	0.08 (0.01)	0.08 (0.01)	0.06 (0.01)	0.08 (0.01)	0.88	0.22	0.17
Have ever used DAP	0.92 (0.01)	0.94 (0.01)	0.94 (0.01)	0.93 (0.00)	0.35	0.41	0.90
Have ever used NPK	0.14 (0.02)	0.14 (0.02)	0.12 (0.02)	0.14 (0.01)	0.90	0.36	0.29
Have ever used CAN	0.64 (0.02)	0.63 (0.02)	0.61 (0.02)	0.63 (0.01)	0.79	0.32	0.46
Have ever used lime	0.06 (0.01)	0.07 (0.01)	0.06 (0.01)	0.07 (0.01)	0.57	1.00	0.57
Have ever used Mavuno	0.01 (0.01)	0.01 (0.00)	0.03 (0.01)	0.02 (0.00)	0.74	0.13	0.07*
Ag. knowledge score	9.41 (0.10)	9.27 (0.10)	9.39 (0.09)	9.36 (0.06)	0.34	0.89	0.39

	FFD	SMS	Control	Overall	(1) vs. (2), p- value	(1) vs. (3), p- value	(2) vs. (3), p- value
Ag. input use score	7.13 (0.10)	7.09 (0.10)	7.08 (0.10)	7.10 (0.06)	0.77	0.76	0.98
N	417	415	417	1,249			

Note: The table shows summary statistics and balance tests using covariate variables from a baseline survey of 1,249 farmers. Columns (1)–(3) display the mean and standard error of each characteristic for each treatment group. Column (4) displays the mean across the sample. Columns (5)–(7) show the p-value of the test of difference across treatment groups. ‘0 Ag. knowledge score’ is an index that can take value 0–12, constructed from the agricultural knowledge question. ‘Ag. knowledge score’ is an index that can take value 0–12, constructed from questions on agricultural input use. ‘Log expenditure’ refers to log per capita household expenditure. Statistical significance is indicated at the 1% (***) , 5% (**) and 10% (*) levels.

Attrition is a first-order concern for any evaluation, since it can seriously bias estimates. The primary approach to limit this problem was to intensively track and re-survey all baseline respondents. To check whether there was selective attrition, we regressed an indicator of attrition (either not found or declined to complete survey) on treatment status. The results are displayed in Appendix D Table D-4. We do not find any evidence of differential attrition across treatment arms.

7.2.2 Awareness and knowledge

The first set of outcomes relate to whether the interventions changed awareness about the existence of inputs and individuals’ knowledge about them. Table 4 shows estimates from regressing a dummy for awareness of different inputs and practices on treatment status (the omitted category is the control group). The first column shows that farmers who participated in the FFDs were more likely to report knowing about the existence of lime and how to test for acidity. Compared with 40% in control group, 65% in the FFD group reported knowing about the existence of lime. We do not find differential increases in awareness about Mavuno, NPK, CAN or DAP, though a large fraction of farmers in the comparison group already knew that these inputs existed.

Since the information provided in the FFD and through SMS was wide-ranging, we also collected information about several other practices that KALRO believed were important: composting, manure, intercropping, crop rotation, use of rhizobia, use of improved maize and legume seeds, how to control diseases, how to control striga (a parasitic weed of cereals), methods to store grain and how to test for acidity. In column (6), we standardize treatment effects following the construction of indices, as Kling and others (2007). This index aggregates information over multiple outcomes for which a unidirectional treatment effects is expected. It consists of the average of the z-scores for each component of the index, with the control group mean and standard deviation as reference. The effects are positive and significant, though mostly driven by the effect of lime and knowledge about acidity.

Table 4: Have you heard about the following inputs/practices?

	Lime (1)	Test acidity (2)	DAP (3)	CAN (4)	Mavuno (5)	Input index (6)
FFD	0.247*** (0.030)	0.131*** (0.031)	0.002 (0.002)	-0.008 (0.014)	0.032 (0.021)	0.282*** (0.097)
E-extension	-0.004 (0.032)	0.054* (0.033)	0.002 (0.002)	-0.019 (0.014)	0.005 (0.022)	0.169* (0.102)
Controls	Y	Y	Y	Y	Y	Y
R-squared	0.225	0.054	0.090	0.176	0.172	0.087
Observations	1,166	1,166	1,166	1,166	1,166	1,166
Y-mean	0.40	0.67	1.00	0.96	0.70	0.56

Note: The table shows a regression of farmers' knowledge regarding different inputs on treatment status dummies and controls. Each test includes demographic characteristics and baseline input use that were used as randomization strata. The standard errors in each regression are robust. The dependent variable mean is displayed for the control group. Statistical significance is indicated at the 1% (***), 5% (**) and 10% (*) levels.

For the e-extension intervention, we find a marginally statistically significant impact on knowledge about testing for soil acidity, but not an increase in reporting having knowledge about less widely known inputs (agricultural lime and Mavuno) about which farmers also received SMS messages.

During the endline, farmers were asked what they thought was the best way to control soil acidity on their farms. This was an open-ended question; respondents could provide any answer they chose. We coded answers on whether they correctly identified a technique that decreases acidity (e.g. applying lime or ash) versus mentioning a technique that was not commonly or directly associated with the reduction of soil acidity (e.g. intercropping, using chemical fertilizers or testing the soil).

In Table 5, the dependent variable in column (1) takes a value of 1 if the farmer reported at least one correct method to control acidity (according to KALRO's soil scientists). The dependent variable in column (2) takes the value of 1 if the farmer reported at least one other method. Farmers who participated in FFDs were more likely to correctly identify a technique that was promoted to reduce soil acidity and marginally less likely to identify a technique that was not promoted (and could be incorrect). This could suggest that new information acts as a substitute for previous beliefs. The dependent variable in column (3) takes the value 1 if farmers mentioned 'agricultural lime' as one of their answers.

Table 5: Knowledge gaps between farmers and KALRO information

	Promoted acidity (1)	Unpromoted acidity (2)	Mentions lime (3)	Correct test frequency (4)	Correct fertilizer quantity (5)
FFD	0.243*** (0.032)	-0.070** (0.036)	0.249*** (0.030)	0.010 (0.007)	-0.040* (0.022)
E-extension	-0.007 (0.030)	-0.006 (0.036)	-0.008 (0.025)	0.020** (0.009)	-0.019 (0.024)
R-squared	0.142	0.031	0.151	0.035	0.043
Observations	1,166	1,166	1,166	1,166	1,166
Y mean	0.24	0.57	0.16	0.01	0.13

Note: The table shows a regression of dummy dependent variables on treatment status dummies and controls. Column (1) is a dummy for mentioning at least one correct way to address soil acidity. Column (2) a dummy for at least one incorrect way to deal with acidity. Column (3) is a dummy for mentioning lime as a solution for acidity. Columns (4) and (5) test for gaps in the information that farmers reported and the one provided by KALRO. Each test includes demographic characteristics and baseline input use that were used as randomization strata and Mavuno use. The dependent variable mean is displayed for the control group. The standard errors in each regression are robust. Statistical significance is indicated at the 1% (***), 5% (**) and 10% (*) levels.

Farmers were also asked other knowledge questions about soil testing frequency and fertilizer quantities that KALRO recommended. We code as ‘correct’ any answer that matches KALRO’s information. Receiving information through their phones helped farmers remember recommended frequency for soil testing, but did not help them remember the correct quantities of fertilizer to apply per planting hole.

7.2.3 Self-reported beliefs about yields and profitability

A second set of intermediate outcome measures we explore is whether the interventions changed farmers’ beliefs about the potential yield gains and profitability of different types of fertilizers. It is important to highlight that we are measuring changes in farmers’ beliefs, and do not have experimental evidence on how all these inputs compare in terms of profitability.

The survey asked farmers how many bags they thought they could harvest using 50-kilogram bags of different types fertilizers, relative to not applying any fertilizer on their farms. In Table 6, Panel A, we show coefficients from a regression of those numbers on treatment status. Not all farmers were able to answer these questions. On average, farmers reported that a 50-kilogram bag of CAN would lead to higher yields. This contrasts with the belief shared by most farmers that DAP is the most profitable type of fertilizer for their land. Interestingly, the cost of DAP and CAN are usually in the same range, but it is possible that other costs associated with application of these inputs might differ.⁹

In Panel B, we explore whether the treatments changed respondents’ answer to a hypothetical question about how would they use a voucher for 1,000 KES (approximately US\$10) for fertilizer. There were no restrictions on how they could spend it. The

⁹ If anything, based on average price data collected from a census of agricultural supply dealers, in the region, we find that the price of CAN is slightly lower than the price of DAP.

dependent variable is the amount allocated to different types of fertilizers. On average, farmers appeared to be more likely to want to spend a larger share of the voucher on DAP. However, those who participated in FFDs were more likely to say they would spend more money on Mavuno and less on NPK. There were no changes for those in the e-extension activities.

Table 6: Beliefs about fertilizer yields and profitability

	DAP	CAN	NPK	
Panel A: How many additional bags of maize you could harvest from 50 kg of:				
	(1)	(2)	(3)	
FFD	8.658 (5.997)	3.417 (9.499)	9.812 (9.480)	
E-extension	4.242 (3.061)	-2.607 (5.120)	0.753 (4.020)	
R-squared	0.034	0.062	0.032	
Observations	1,156	1,118	1,032	
Y mean	25.49	36.20	30.99	
Panel B: If you received a fertilizer voucher for KES1,000 how would you spend it?				
	DAP	CAN	NPK	Mavuno
	(1)	(2)	(3)	(4)
FFD	-15.074 (20.039)	-3.631 (13.681)	-38.024** (16.107)	57.506*** (21.188)
E-extension	2.280 (19.389)	17.702 (14.133)	-2.699 (16.342)	-16.400 (19.553)
R-squared	0.115	0.076	0.086	0.032
Observations	1,165	1,165	1,165	1,165
Y mean	390.60	103.79	306.66	198.96
Panel C: What do you think is the most profitable fertilizer for your land?				
	DAP	CAN	NPK	Mavuno
	(1)	(2)	(3)	(4)
FFD	-0.004 (0.033)	-0.036 (0.028)	-0.037* (0.020)	0.010** (0.005)
E-extension	0.022 (0.033)	0.020 (0.029)	-0.036* (0.020)	0.010** (0.005)
R-squared	0.130	0.117	0.058	0.030
Observations	1,165	1,165	1,165	1,165
Y mean	0.38	0.22	0.11	0.00

Note: Each test includes demographic characteristics and baseline input use that were used as randomization strata. Panel A does not include Mavuno as that information was not collected for that input. The standard errors in each regression are robust. The dependent variable mean (Y mean) is displayed for the control group. Statistical significance is indicated at the 1% (***), 5% (**) and 10% (*) levels.

Finally, we asked farmers what type of fertilizer they thought it would be the most profitable for them to use in their land. Approximately 40 per cent reported DAP as the most profitable type of fertilizer. The FFD intervention appears to have reduced farmers' beliefs about the profitability of NPK. It also increased by 1 percentage point their likelihood to report Mavuno as the most profitable fertilizer. No one in the control group mentioned Mavuno.

7.2.4 Self-reported input use

We now focus on the main outcome variable. Table 7 shows a regression of self-reported input use on treatment dummies.

The first panel shows retrospective results for the Long Rain season in 2015. Since farmers in the e-extension group had not yet received any treatment at that point, we show coefficients only for FFDs (the results are similar whether we pool the SMS group with the control or not). The results suggest that the program had a positive impact on the use of Mavuno of 4 percentage points. However, we do not see any additional impact on any other type of fertilizers.

The effect on Mavuno persists in the self-reported use for the subsequent season, and we do not find changes in reported use for any other type of fertilizer. This seems in line with changes in beliefs about profitability for different types of fertilizers. Columns (9) and (10) show coefficients for asking farmers whether they had used lime and/or planted legumes at any point in previous seasons. We do not find that the interventions modified use of lime or farmers' likelihood to plant legumes.

Table 7: Have you used any of the following inputs?

	DAP	CAN	NPK	Mavuno	Lime	Legumes
Panel A: Long Rain Season 2015 (March–August)						
	(1)	(2)	(3)	(4)		
FFD	−0.021 (0.026)	−0.023 (0.027)	0.014 (0.018)	0.044** (0.022)		
R-squared	0.030	0.276	0.061	0.099		
Observations	1,166	1,166	1,166	1,166		
Y mean	0.81	0.58	0.07	0.15		
Panel B: Short Rain Season 2015 (September–December)						
	(5)	(6)	(7)	(8)	(9)	(10)
FFD	−0.003 (0.033)	−0.019 (0.031)	−0.015 (0.016)	0.041* (0.024)	0.003 (0.020)	0.011 (0.028)
E-extension	−0.022 (0.033)	−0.050 (0.031)	0.001 (0.017)	−0.010 (0.023)	−0.002 (0.020)	0.023 (0.028)
R-squared	0.045	0.266	0.037	0.077	0.130	0.123
Observations	1,166	1,166	1,166	1,166	1,166	1,166
Y mean	0.69	0.47	0.06	0.12	0.10	0.12

Note: Each test includes demographic characteristics and baseline input use that were used as randomization strata. The dependent variable mean is displayed for the control group. The standard errors in each regression are robust. Statistical significance is indicated at the 1% (***) , 5% (**) and 10% (*) levels.

7.2.5 Coupon redemption

We now explore the effects of the intervention on the redemption of discount coupons. The outcome data is taken from administrative shop records of the redemption of the 50 per cent coupons for lime and fertilizer.

Table 8 shows the effects for lime coupon redemption. We do not detect statistically significant effects from either intervention. The coefficient for the FFDs is positive, but insignificant (p-value is 0.11). We note that we are underpowered to detect effect sizes of that size. The point estimates for the quantity of lime purchased and total lime expenditures are positive, but also insignificant, for the FFD group. This lack of detectable impact seems in line with the self-reported data from the survey. We do not

find significant effects for use of the lime coupon for the e-extension group; if anything, point estimates are negative. The e-extension intervention sent only one message about the use of lime, so it was potentially much weaker than the information provided at FFDs.

Table 8: Lime coupon redemption

	Lime coupon (1)	Lime quantity (kg) (2)	Lime expenditures (KES) (3)
FFD	0.036 (0.023)	5.739 (3.867)	34.432 (23.203)
E-extension	-0.011 (0.022)	-2.295 (3.676)	-13.770 (22.057)
R-squared	0.074	0.112	0.112
Observations	1,166	1,166	1,166
Y mean	0.11	16.97	59.79

Note: The dependent variable in column (1) is a dummy variable that takes value 1 if lime was redeemed. Column (2) shows the quantity it was redeemed for. Column (3) shows the total reported expenditures on lime. Each test includes demographic characteristics and baseline input use that were used as randomization strata. The standard errors in each regression are robust. The dependent variable mean is displayed for the control group. Statistical significance is indicated at the 1% (***) , 5% (**) and 10% (*) levels.

Table 9 shows results for coupon redemption for different types of fertilizer. Here, there is a clear impact of the FFD on the redemption of the fertilizer coupon. Columns (1) and (2) show results for redeeming the coupon for any type of chemical fertilizer offered. Columns (3), (4) and (5) show separate increases in quantity purchased for DAP, CAN and Mavuno.¹⁰

Farmers assigned to the FFD group purchased 2 additional kilograms of DAP relative to the 5.6 kilograms purchased in the control group (column (3)). Those assigned to the e-extension purchased an additional 1 kilogram of DAP. We detect no other changes in quantities purchased for other types of fertilizers. Consistent with these results, we see an increase of approximately US\$2 in expenditures for DAP in the FFD group and US\$1 for the SMS-based intervention. However, in contrast to the self-reported data, we do not measure significant increases in the purchase of Mavuno. We cannot say with certainty why this is the case, but it does not necessarily indicate that farmers' reported use of Mavuno in the survey is suspect. First, it is not clear why farmers would misreport using Mavuno but not other inputs that were also heavily recommended during the intervention, such as lime. Second, it is possible that farmers might have access to Mavuno in other shops where we did not collect information or from other sources (e.g. government subsidy programs). Third, the coupon redemption and the self-reported data were for different seasons, so they might have used different inputs in different seasons.

¹⁰ Nobody in the sample redeemed the coupon for NPK.

Table 9: Fertilizer coupon redemption

	Fert. coupon	Fert. quantity (kg)	DAP quantity (kg)	CAN quantity (kg)	Mavuno quantity (kg)	Fert. expenditures (KES)
	(1)	(2)	(3)	(4)	(5)	(6)
FFD	0.126*** (0.035)	2.454*** (0.826)	2.233*** (0.697)	0.158 (0.412)	0.063 (0.064)	196.691*** (58.062)
E-extension	0.029 (0.035)	1.464 (0.913)	1.389* (0.771)	0.059 (0.444)	-0.000 (0.006)	108.376* (61.856)
R-squared	0.079	0.046	0.039	0.059	0.016	0.046
Observations	1,166	1,166	1,166	1,166	1,166	1,166
Y mean	0.41	6.91	5.61	1.30	0.00	513.60

Note: Each test includes demographic characteristics and baseline input use that were used as randomization strata. The dependent variable mean is displayed for the control group. The standard errors in each regression are robust. Statistical significance is indicated at the 1% (***), 5% (**) and 10% (*) levels.

However, one would also need to explain why we find that the interventions increased the purchases of DAP in the administrative data. A large share of farmers in the sample (38 per cent) believed that DAP was the most profitable type of fertilizer for their land, so it is not surprising that a large fraction might have redeemed their coupons for this input. However, the finding that DAP purchases increased as a result of the treatments, even when we do not find that they changed knowledge or beliefs about DAP, suggests that these impacts are working through alternative channels. However, since we do not have sufficient information on what these could be, we refrain from speculating further on this result.

In Table 10, in accordance to the pre-analysis plan, we show results for an instrumental variable specification to deal with imperfect compliance in attendance for the FFDs. The coefficients are roughly similar to the intent-to-treat estimates, which is not surprising since compliance was high. We note, however, that even though we detect a clear increase in the quantity of fertilizer purchased, the amount of fertilizer that farmers acquired with the coupon was relatively small (optimal recommended amounts are around 50 kilograms per acre).

Table 10: Instrumental variable results

	First-stage regression	Lime coupon	Lime quantity (kg)	Lime expenditures (KES)	Fert. coupon
	(1)	(2)	(3)	(4)	(5)
FFD treatment	0.837*** (0.019)				
FFD participation		0.044 (0.027)	6.855 (4.555)	41.133 (27.327)	0.151*** (0.041)
R-squared		0.078	0.116	0.116	0.073
Observation		1,166	1,166	1,166	1,166
Y mean		0.11	16.97	59.79	0.41
	Fert. quantity (kg) (6)	Fert. expenditures (KES) (7)	DAP quantity (kg)	CAN quantity (kg)	Mavuno quantity (kg)
FFD participation	2.932*** (0.973)	234.967*** (68.614)	2.667*** (0.826)	0.189 (0.477)	0.076 (0.075)
R-squared	0.041	0.040	0.034	0.059	0.016
Observation	1,166	1,166	1,166	1,166	1,166
Y mean	6.91	513.60	5.61	5.61	0.00

Note: Each test includes demographic characteristics and baseline input use that were used as randomization strata. The dependent variable mean is displayed for the control group. Column (1) includes the first-stage regression of participation in an FFD on a treatment indicator for assigned to the FFD treatment group. The standard errors in each regression are robust. Statistical significance is indicated at the 1% (***) , 5% (**) and 10% (*) levels.

7.3 Heterogeneous treatment effects

We also explore whether there are heterogeneous treatment effects along a number of dimensions. First, we check whether there are differential effects by gender. As previously discussed, females in this sample were less likely to be aware of different inputs at baseline. On the one hand, the theory of change predicts that the interventions will work by closing knowledge gaps; consequently, one would expect the interventions to be more effective for those with less information about inputs at baseline. On the other hand, females might be more credit constrained. Overall, we do not find differential effects of treatment by gender. We also check whether there are differential treatment effects by other measures of knowledge at baseline and we do not find consistent evidence that the interventions were more effective for those with less knowledge.

Other authors (e.g. Gautam 2000) have discussed idea that extension staff might target wealthy farmers, hoping for increased adoption of new technologies that would later spread to others. To explore the differential role of wealth, we check whether the interventions were more effective for wealthier farmers (which we proxy by plot size). There is a marginally significant effect for the interaction of FFD with our measure of acreage or lime redemption, but not for fertilizer (and the magnitude is small).

In Appendix D Table D-3, we show results for all specifications of heterogeneity that were listed in the pre-analysis plan. In addition, given that the e-extension program

switched from English to Swahili mid-intervention, we check whether its impacts differ by self-reported knowledge of English at baseline. We do not find that they do.

7.4 Potential breaks in the theory of change

7.4.1 Farmer field days

Although we find increases in the self-reported use of Mavuno following the FFDs, we do not detect increases in the use of lime (but we are underpowered to detect small increases in adoption). The FFDs appear to have been successful in changing farmers' knowledge about issues of soil acidity in the area and the appropriateness of lime to address this problem, so the break in the theory of change might have to do with other linkages. We can only speculate on some of these.

We do not think that lack of trust in the information was a main factor, since farmers were able to see the experimental plots that had performed better than control plots. In addition, during focus group discussions most farmers thought that extension workers associated with KALRO and the Ministry of Agriculture were a reliable source of information.

Another issue that could have hindered the adoption of lime is that farmers might have been uncertain about whether their farms had acidic soils. KALRO advises farmers to test their soil for acidity before applying agricultural lime. Although agricultural lime is cheap, individual soil tests are relatively expensive (about US\$11). We do not measure increases in soil testing, so this might have limited farmers' decision to experiment with this particular input.

7.4.2 E-extension

We do not find evidence that the e-extension messages increased the use of agricultural lime or significantly increased the use of chemical fertilizers. One must question whether the information that was provided was sufficiently geared toward increasing uptake of these inputs. The messages focused on providing recommendations for how to manage maize farms and the types and quantities of fertilizers to apply, but did not provide farmers with information on why they should adopt them or how effective or profitable these inputs would be. Therefore, it is perhaps not surprising that beliefs about the adequacy or profitability of these inputs did not change. However, we also do not find that the intervention changed knowledge about management practices that were explicitly discussed in the messages (i.e. types and quantities of fertilizers, use of soil tests to address soil acidity and amount of seeds per planting hole).

Since farmers did not appear to consistently recall information from the messages, an obvious question is whether they received and read the messages. A priori, during focus group discussions farmers were generally supportive of the idea of having agricultural messages delivered to them through their phones, because it would be easy to reach them. Although we took care in ensuring that participants were literate and had mobile phones, it is impossible to know with certainty to what extent farmers were actually 'treated' by the intervention. One of the endline questions asked farmers whether they had received the agricultural messages. Only 55 per cent of the e-extension group reported having received agricultural messages through their mobile phones during the previous year.

We do not detect significant differences between farmers who reported receiving messages and those who did not in terms of gender, previous knowledge of inputs,

acres owned or reporting farming as a primary source of income. However, not using the main mobile phone operator in the area is significantly associated with being less likely to receive messages. This suggests that there were implementation problems in the delivery of messages between the e-extension system and different mobile phone companies. For completeness, we show an instrumental variable specification to account for imperfect compliance in Appendix D Table D-5. However, these estimates suffer from the important limitation that the measure we have for compliance is self-reported. Although this issue seems to be partially accounted for by problems with mobile networks, it is also possible that some respondents may have forgotten whether they received the messages, which would bias those estimates.

Finally, we have the limitation that the endline was collected at the end of the season in which the e-extension intervention took place. Therefore, we cannot know whether farmers might have adopted agricultural lime or fertilizers during subsequent seasons. (The partner organization believes that adoption is likely to have been delayed and that long-term outcomes should have been measured.) However, the evidence on the impact of the coupon redemption measures, which corresponded with the subsequent season, suggests that the increases in use affected only DAP and not lime. This provides partial evidence that lime use did not increase in the season following the message delivery.

8. Discussion

8.1 Cost data

We collected cost data for the FFDs. Based on information reported by KALRO, we calculate that each FFD cost about US\$2,600 to implement. This includes all costs for staff, transport, compensation and materials required to set up the test plots, invite presenters, advertise the FFDs to farmers and carry out the events. Since each FFD hosted between 100 and 300 farmers, this amounts to a per farmer cost of between US\$9 and US\$26 per farmer attending.

An in-depth cost-analysis is beyond the scope of this report, because we do not have detailed information on the gains that result from the adoption of Mavuno or DAP. However, if we take the point estimates from the endline survey as our measure of impact, they reveal an increase in Mavuno use of four percentage points. This implies that each FFD would increase Mavuno adoption for 4–12 farmers. A full cost-benefit analysis is necessary to determine whether social benefits outweigh the costs, but given the limited impact on adoption, it seems highly unlikely that this is a cost-effective way to increase the use of Mavuno.

We cannot rule out other potential impacts from FFDs that the endline survey did not capture.

8.2 Internal validity

We used a field experiment to evaluate the impacts of two information delivery methods commonly used by extension workers in Kenya, finding that farmers who attended the FFDs were more likely to learn about recommended technologies – especially about agricultural lime – and more likely to report that they would spend money on a newly recommended chemical fertilizer, Mavuno. Farmers were only marginally more likely to report that they had adopted Mavuno. We find no effect on the adoption of agricultural lime.

Additionally, we find significant impacts of this intervention on the redemption of a discount voucher for a specific fertilizer that is already widely used by farmers in this region and that was not very actively promoted during the FFDs. We do not find evidence that the intervention changed measured beliefs or knowledge about this input, and although most farmers in the control group report preferring this input, that does not explain why the intervention affected their likelihood to acquire it differentially. We do not have a convincing explanation for this result.

In contrast, we do not find any consistent and significant learning effects for the group of farmers who received messages through their mobile phones, nor were they more likely to adopt the recommended inputs.

The internal validity of these results relies on experimental variation. Since the sample was balanced at baseline and there was very limited attrition, there is a low risk of selection bias in our estimates. To address potential social desirability bias in self-reporting (e.g. farmers reporting that they adopted the new inputs to please enumerators), we collected administrative data from a discount voucher that was provided to all farmers in the sample, enabling us to measure the input choices they would make when they had to use their own money and were not observed by a member of the research team. Since randomization was conducted in private and farmers in the control group were not reminded about their status, John Henry effects (i.e. the comparison group works harder to compete with treatment group) are likely to be less problematic in this context.

A potential threat to these results is whether farmers who participated in the interventions diffused the information to farmers in the control group, ultimately leading to an underestimation of impacts. In qualitative work we find that a potential issue in this context is low (not high) diffusion of information. In addition, we do not find evidence of high diffusion of soil information among farmers, nor significant changes in knowledge about the new inputs between baseline and endline for those in the control group.

Another issue is whether the outcome measures that were chosen for this project (which were delineated with KALRO's pre-implementation stated objectives in mind) fully captured the gains from these interventions. It is possible that farmers gained other knowledge and/or changed other practices that were not measured as part of this evaluation.

8.3 External validity

The agricultural issues (e.g. low input use, low productivity, high soil acidity) that farmers experience in western Kenya are representative of other regions in Sub-Saharan Africa. Additionally, the extension techniques described in this project are also commonly used in other contexts by public and private entities. The sample of farmers with whom we worked is also likely to be representative of the average farmer that KALRO targets. However, it is difficult to know whether other types of messages would have been more successful in changing the types of indicators that we collected information for.

We are aware of only one other experimental evaluation of an FFD (Emerick et al. 2016). Though the context and the promoted technology were different, the authors find positive (and much larger) effects on adoption of the recommended inputs. The authors' back-of-envelope calculations suggest that theirs was a cost-effective intervention (it generated

one-year revenue gains of about US\$410 for farmers in a 69-person village, and each of their FFDs cost about \$200 to execute).

So far, there has been mixed evidence on the role of ICT interventions on the adoption of agricultural technologies (Nakasone et al. 2014). If effective, the use of ICT in delivering extension services to farmers holds great promise, since costs are likely to be much lower than providing the same information through other methods (Aker 2011). In this case, however, we do not find any consistent evidence that KALRO's e-extension intervention was effective. At the very least, this suggests that additional piloting and evaluation are required before deciding whether a countrywide scale-up of SMS messages is warranted.

9. Policy recommendations

9.1 Policymakers

Local agricultural information appears to be informative and there is evidence of positive demand for it.

Using data from soil analyses, we find that soil characteristics, particularly measures of soil acidity, are spatially correlated in this area of western Kenya. This suggests that farmers could learn from information generated at the local level. We also find that there is a positive valuation in receiving information about these local (not individual) results.

We find a positive WTP for agricultural advice based on a neighbor's soil test results. Given that conducting individual soil tests for each farmer could be prohibitively expensive (beyond the means of most farmers), this suggests that generating local soil information and recommendations that many farmers could share could be a promising policy avenue.

In addition, all farmers invited to the e-extension program agreed to enroll in it, suggesting that they thought that receiving advice would be valuable. During qualitative work in the area, many farmers expressed a desire to receive more information about new technologies and how to improve management practices on their farms.

FFDs increased knowledge and had a small but positive effect on input use.

However, as currently formulated, they are unlikely to be a cost-effective way to increase adoption of Mavuno and agricultural lime in the region. A full cost-benefit analysis of this approach is recommended. We find increases of 4 percentage points on the adoption of Mavuno. The point estimates for lime adoption are positive (increases of 4 percentage points) but statistically insignificant. Although we cannot rule out that this intervention increased farming profitability through other channels – for instance, through better management practices in the farm or adoption of other crops – if the primary objective was to increase the adoption of Mavuno and agricultural lime, the overall benefits for adopters would need to be extremely large to compensate for the costs of arranging the FFDs. We note, however, that in qualitative discussions, farmers expressed positive views about their learning experiences through FFDs. Many reported that seeing the demonstration plots made them more confident about the results. For example:

[We] saw a difference in their crop and were happy with their results...Yes because we saw that through the demonstration plots, we also have a chance of

improving our yields...I learnt that when you use fertilizer you can get good yields
— FFD focus group discussion participant, Anyiko

A potentially fruitful next step would be to identify which features of the FFDs were most effective and to try to strengthen or replicate them at lower costs. It would be useful to know whether farmers learned because of the delivery method (e.g. observing test plots, talking to others) or because of the informational content (which could be delivered in other ways).

E-extension services did not increase knowledge or take-up of the promoted inputs.

However, given the low cost of SMS message delivery, it is probably worthwhile to continue fine-tuning, improving and investigating the impacts of these types of interventions. Farmers showed a positive reception to the idea of receiving messages through their phones. First, all farmers invited to receive messages agreed to participate in this intervention. Second, most farmers in focus group discussions reported that this would be a convenient way to receive extension advice, since it would be more likely to reach them quickly.

However, this intervention was not effective in changing awareness or knowledge about or increasing the use of fertilizers and lime. We cannot say whether it was effective in other dimensions, such as changing farm management practices (although we do not detect consistent changes in knowledge for some of those dimensions). Beyond problems with message reception (at endline, only 55 per cent of farmers stated that they had received them), from a policy perspective it would be important to disentangle whether the break in the theory of change had to do with the informational content or the delivery method.

We note that the messages mostly focused on providing general information about maize management practices. Only a few messages explicitly mentioned the use of lime or fertilizers. This might have limited their impact on input take-up. Moreover, the messages contained recommendations that might have been hard to follow without additional clarification from extension workers (who could recommend optimal dosages) or without individual soil analysis (to determine farmers' soil acidity). This might have limited how much farmers were able to react to the advice.

In ongoing work in this region, but with different farmer populations, we study the impact of other SMS-based agricultural extension interventions. Preliminary results suggest that actionable messages, which informed farmers about local soil acidity and suggested quantities of lime to apply, had modest positive effects on lime purchases. This might suggest that the nature of the messages is quite important and that additional optimization in that regard is needed.

One limitation to our results is that we measured only self-reported use of these inputs during the season in which farmers received the messages. The implementing partner's view is that this was not a sufficiently long period of time to detect impacts. We agree that evidence on subsequent-season input use would be informative about the overall effectiveness of the program. However, we remain skeptical that input use would have increased in the long run following this intervention. First, we did not find changes on coupon redemption for fertilizer or agricultural lime for this group, even though the redemption period corresponded with the subsequent planting season. Second, we did

not find changes in awareness or knowledge about these inputs following the intervention.

Since ICT holds promise for reaching farmers at scale at low costs, it is a worthwhile exercise to continue investigating in which circumstances this approach could be effective. We also note that any future randomized controlled trial in this area would benefit from larger sample sizes to detect smaller effects.

9.2 Implementers

Decide on key objectives of interventions and continue to use those as benchmarks of effectiveness.

This evaluation can shed light only on the effectiveness of the interventions in the dimensions that were determined before implementation. It does not capture delayed adoption and/or changes in other management practices that farmers might have adopted. While evaluating all potential effects of the interventions would require further investigation, we recommend that before any program and evaluation take place, all parties involved clearly define a clear list of objectives for the intervention and the timeline to achieve those objectives, and commit to use those to assess effectiveness.

There were some implementation problems with the e-extension interventions, but those are likely to be easily solved.

If e-extension approaches continue to be piloted, implementers should be careful with technical issues around the compatibility of the e-extension service with different mobile phone operators. In addition, we recommend messages be thoroughly tested for framing, language and other contextual factors before rollout.

When designing messages, weight economic considerations in addition to agronomic ones.

Farmers were advised to test their own soil to determine levels of acidity *before* applying agricultural lime. Since there is heterogeneity in soil conditions across farmers, individual soil testing was considered the first best recommendation from an agronomic point of view. However, individual soil tests are prohibitively expensive for many of the targeted farmers in this region. We did not find any evidence that the treatments increased the likelihood of conducting individual soil tests, and this might have hindered the adoption of lime. This suggests that economic and agronomic considerations might need to be balanced to create future agricultural recommendations.

Online appendixes

Note to the reader: Online appendixes are provided as received from the authors. They have not been copy-edited or formatted by 3ie.

Appendix A: Pre-analysis plan and sample design

http://www.3ieimpact.org/media/filer_public/2017/09/15/appendix_a-tw41011-pre-analysis-plan.pdf

Appendix B: Power calculations

http://www.3ieimpact.org/media/filer_public/2017/09/15/appendix_b-tw41011.pdf

Appendix C: Instruments

http://www.3ieimpact.org/media/filer_public/2017/09/15/appendix_c-tw41011-wtp_survey_piloted.pdf

Appendix D: Additional results and descriptive statistics

http://www.3ieimpact.org/media/filer_public/2017/09/15/appendix_d-tw41011.pdf

Appendix E: Messages sent by KALRO

http://www.3ieimpact.org/media/filer_public/2017/09/15/appendix_e-tw41011.pdf

Appendix F: Cost data

http://www.3ieimpact.org/media/filer_public/2017/09/15/appendix_f-tw41011.pdf

Appendix G: Summary from the qualitative report

http://www.3ieimpact.org/media/filer_public/2017/09/15/appendix_g-tw41011.pdf

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This impact evaluation by Fabregas and colleagues examines the role of information in addressing the constraints smallholder farmers in Kenya face in adopting agricultural inputs. The study provides evidence on the effectiveness of two types of information-delivery methods in influencing farmers' knowledge and choice of agricultural inputs. The study finds that participation in farmer field days increased farmers' awareness about testing soil acidity and identifying techniques for reducing it. Farmers receiving information over the mobile phone remembered the recommended frequency for soil testing but not the correct quantities of fertiliser to apply. Farmers participating in farmer field day were more likely to change beliefs about the profitability of using recommended fertilisers. However, when provided with a discount coupon, they purchased the fertiliser commonly used in the region.

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