Evaluating agricultural information dissemination in western Kenya

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Note to readers

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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 that agricultural productivity in Sub-Saharan Africa has not only remained far from its potential (AGRA 2013, World Bank 2008, Ninn-Prat et al 2011), but also, that this region has the largest gaps between potential and realized yields (Muller 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 a lack of information about them. In order to adopt, 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 fulfill 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 are these efforts (Aker 2011).

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

The results suggest that FFDs 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 FFD treatment arm had higher level of awareness and changed reported beliefs about the profitability of a chemical fertilizer that is recommended by KALRO but not widely used in the region. In self-reported data, treated farmers are 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 particular input. Instead, we find that when provided with a discount coupon, relative to the control group, FFD attendees choose to purchase a type of chemical fertilizer that is already widely known in the region, even though we do not measure changes in awareness or reported beliefs about that particular input. This raises new questions about the mechanisms through which that effect

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

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List of Abbreviations and Acronyms

AGRA	Alliance for a Green Revolution in Africa
Agrovet/Agrodealer	Agricultural Supply Dealer
ATAI	Agricultural Technology Adoption Initiative
FFD	Farmer Field Day
CAN	Calcium ammonium nitrate
CBO	Community Based Organizations
CF	Contact Farmer Extension
DAP	Diammonium Phosphate
GoK	Government of Kenya
IPA	Innovations for Poverty Action
IPAK	Innovations for Poverty Action – Kenya
KALRO	Kenya Agricultural and Livestock Research Organization
Ksh	Kenyan Shillings
MoA	Ministry of Agriculture
NPK	Nitrogen, Phosphorous, Potassium (Fertilizer type)
PAP	Pre-analysis Plan
RCT	Randomized Control Trial
SSA	Sub-Saharan Africa
T&V	Training and Visit Extension
ToC	Theory of Change
WTP	Willingness to Pay

1. Introduction

Seventy-five percent of the world's poor live in rural areas and a majority earns 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 (SSA) agricultural productivity has remained stagnant (World Bank, 2008). 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 farm might be hard to obtain. Generating information for one's own farm through self-experimentation might be too costly or difficult. For example, the costs 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 agroclimatic conditions and soil characteristics in Africa (Voortman et al. 2000; Tittonel et al. 2005, Vanlauwe et al. 2010). This heterogeneity in local conditions, such as soil characteristics, altitude, microclimates or the 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 SSA.

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 existing evidence on the impacts of these services is mixed (Anderson and Feder, 2007, Benin et al, 2007, Davis et al. 2010). 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 (T&V) 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 rely 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 the adoption of locally relevant agricultural technologies in Western Kenya. We conduct a randomized control trial (RCT) 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, in which farmers are invited to observe demonstration plots for promoted inputs, and where they receive information about agricultural practices from extension agents and/or from other actors such as input companies, community based organizations (CBOs) or Non-Governmental Organizations (NGOs). A second group of farmers was invited to participate in an e-extension program, in which they received extension text messages on their mobile phones through the entire agricultural season. Finally, 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 are more likely to report using them. We also collect administrative data from agricultural shops, where all farmers in the sample could redeem a discount coupon to purchase agricultural inputs of their choice.

Both the FFDs and the e-extension share features that could potentially 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 elicit 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 could also diffuse the information they receive). Third, the information provided to farmers through these approaches could still be sufficiently targeted to match their agro-ecological zones. In other words, while it might be cheaper to deliver information at scale through other methods (radio, television, etc.) 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 self-reported data, we also detect a small increase in the use of this input 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 promoted by KALRO. 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 an statistically insignificant for the e-extension group). While this input was also endorsed in both interventions, almost all farmers in the sample have 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 project contributes to a growing literature on the role of information on technology adoption. While 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 (CF) 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 only aware of one other project measuring impacts of FFDs (Emerick et al., 2016). In that case, 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 an NGO. Likewise, while 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-based service with messages delivered by a public institution.

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

- The interventions may have positive average impacts on farmer's knowledge about 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 the 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 WTP elicitation. Section 8 discusses robustness and caveats to the interpretation of results. Section 9 provides a policy discussion and concludes.

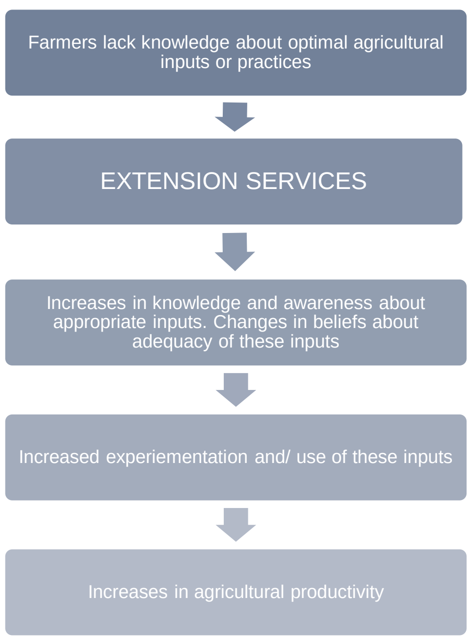
2. Interventions and Theory of Change

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 we 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 (ToC) for Agricultural Extension

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 project, we explore the role of information in the adoption process, and in particular the role that agricultural extension services play in addressing knowledge gaps. Birkhaeuser et al. (1991) propose a simple ToC for the impact of extension services on adoption of new technologies. Figure 1 builds upon their general framework.

Figure 1: Theory of Change



Source: Prepared by authors, based on Birkhaeuser et al (1991).

In our context, 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 from our own qualitative work conducted with farmers in this area.[1] During Focus Groups Discussions (FGDs), farmers reported lack of information about agricultural inputs and practices as a constraint to ongoing experimentation. Their reported knowledge gaps ranged from concrete queries on how to improve certain aspects of the agricultural production

[1] We discuss details about the qualitative data collection in section 5.

process[2] to broader questions on how to diagnose what was causing low yields in their farms.

The ToC predicts that KALRO's extension services will solve underlying needs by providing farmers with information that will close those informational gaps. The information provided in both interventions covered a range of topics, deemed by KALRO 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, the use of locally appropriate chemical fertilizers and the intercropping of legumes. We find some evidence of knowledge gaps in these dimensions at baseline. Over half of the sample surveyed had never heard about agricultural lime. Fewer than 10% had ever heard about Mavuno, a chemical fertilizer that KALRO recommends for acidity. However, 70% of farmers were already intercropping legumes at baseline. The extension services that we evaluate provide farmers with agronomic information that is locally relevant but not necessarily specific to their individual farms. One question is whether farmers' would value local (rather than individual) information. We explore this issue by eliciting farmers' Willingness to Pay (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 these meetings by providing them with a small gift. While 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 FFD and received the information provided by KALRO. In addition, two of the criteria for inclusion in the sample were to be literate and own a phone. In this population this is common (94% of censed farmers 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 collect 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 collect measures on these intermediate outcomes during the endline survey.

The ToC predicts that increases in relevant knowledge could lead to increase experimentation, adoption and ultimately to increases in agricultural productivity. We do not have measures of long-term adoption nor agricultural productivity. Therefore our primary outcome measure is whether farmers report using the recommended inputs. We collect two types of data to measure this.[3] First, we collect self-reported data on input use during an 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, in order to address

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

[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).

concerns about social desirability bias in self-reporting, we collect a direct measure of input choice. All research subjects were provided with 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% discount at a local shop. We use coupon redemption as an additional measure to assess whether information made farmers more likely to choose the inputs recommended by KALRO.

Finally, the ToC assumes that farmers can acquire these inputs if they choose to do so. In this context, this is 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 theis issue in two ways. First, the discount is likely to help with liquidity constraints. Second, in order to ensure that farmers could purchase these inputs, the implementing agency ensured that participating agrodealers were stocked with all the inputs that the coupons were redeemable for. This last feature will help 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 one of the two interventions might work. While 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 will conflate the impacts of the delivery method and differences in the information conveyed.

- Farmer Field Days

FFDs were half-day meetings where 100 to 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 input use, the use of various locally relevant fertilizers and the use of agricultural lime.

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

Aside from simply providing farmers with agricultural messages, any impact from FFDs could work through other channels. First, observing the 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, in Mozambique, Kondylis et al. 2017, find 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 that a potential explanation might be that the additional trainings made farmers think that the information was of higher quality or more credible. Second, since farmers can observe and obtain information about the different inputs, it might help them notice relevant dimensions that they might have not noticed before (Hanna et al., 2014). Third, during FFDs farmers were able to ask specific questions to extension staff or to other farmers. Therefore, they might have found answers to specific questions they might have had or directly learned from the experience of other adopters (Emerick et al 2016). Finally, they could be more likely to adopt because of herd behavior and not because of increased in knowledge (Banerjee et al. 1992).

- 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 make use of optimal inputs and practices. This was a push-only intervention, in the sense that farmers could read the messages but could not reply to them. Therefore, in contrast to the FFDs the amount of information that 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", "Top dress one bottle top of FANTA soda with CAN or Mavuno on every maize plant three weeks or four after planting").

In addition to the information, the messages could have served as ongoing reminder to acquire or use inputs. In Bolivia, Larochelle et al. (2016) evaluate the effect of SMS reminders about agricultural practices and find a positive effect from that intervention. Messages might have also served as ongoing motivation or act as soft commitment devices. There is evidence in 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 different cycles of maize growing, the endline survey measures effects that took place during the season in which farmers received the messages (coupon redemption was measured for the following season). In contrast, for FFDs we measure impacts for the two subsequent agricultural seasons after the intervention took place.

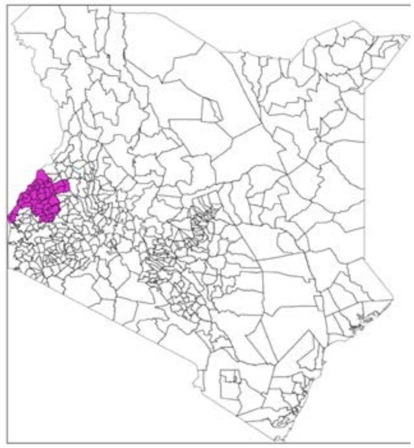
3. Program Context

3.1 Agro-ecological conditions in Western Kenya

Our study takes place in the Western Province of Kenya, 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 (KBNS, 2009). We work in Kakamega, Busia, and Vihiga counties

The primary staple crop in these areas is maize and all of the farmers in our sample are maize growers (though they might also grow other crops). 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.

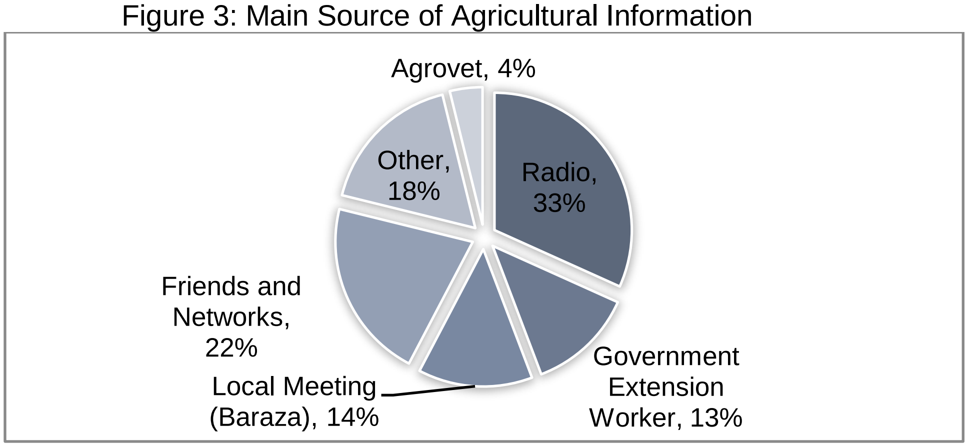
Figure 2: Map of Western Kenya



Source: Compiled by authors.

Figure 3 shows the main agricultural information source reported by farmers during the baseline survey. Networks and the radio appear to be their main sources of information. The majority of farmers (86%) have 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 between 1,500 and 2,500 farmers, according to KARLO).

Figure 3: Main Source of Agricultural Information

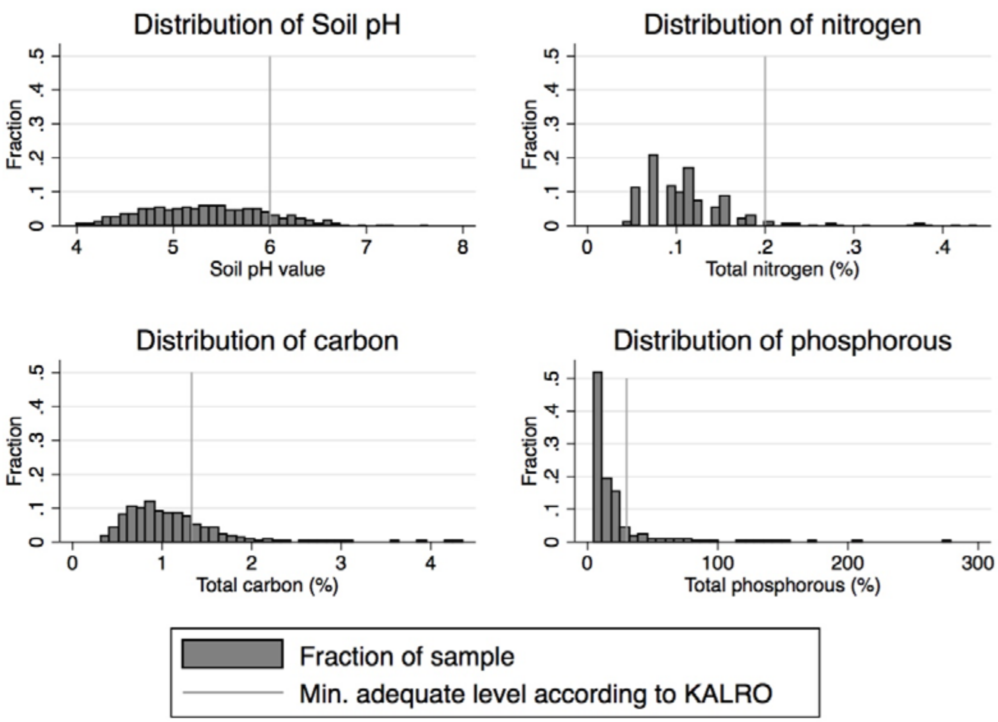


Source: Data collected during baseline survey as part of this project.

In Kenya, women represent 80% of all labor in food production; however, they have been reported to be much less likely to receive extension services (ADB, 2007). In our own sample, over two thirds of respondents are women and we find that at baseline, women are 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 the results section.

Recent agronomic research has shown that widespread soil fertility depletion undermines the ability of many households in the region to produce sufficient food to ensure subsistence (Marenya 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 by the soil laboratories 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 at the left of the minimum adequate level.

Figure 4: Distribution of pH, Nitrogen, Carbon and Phosphorous

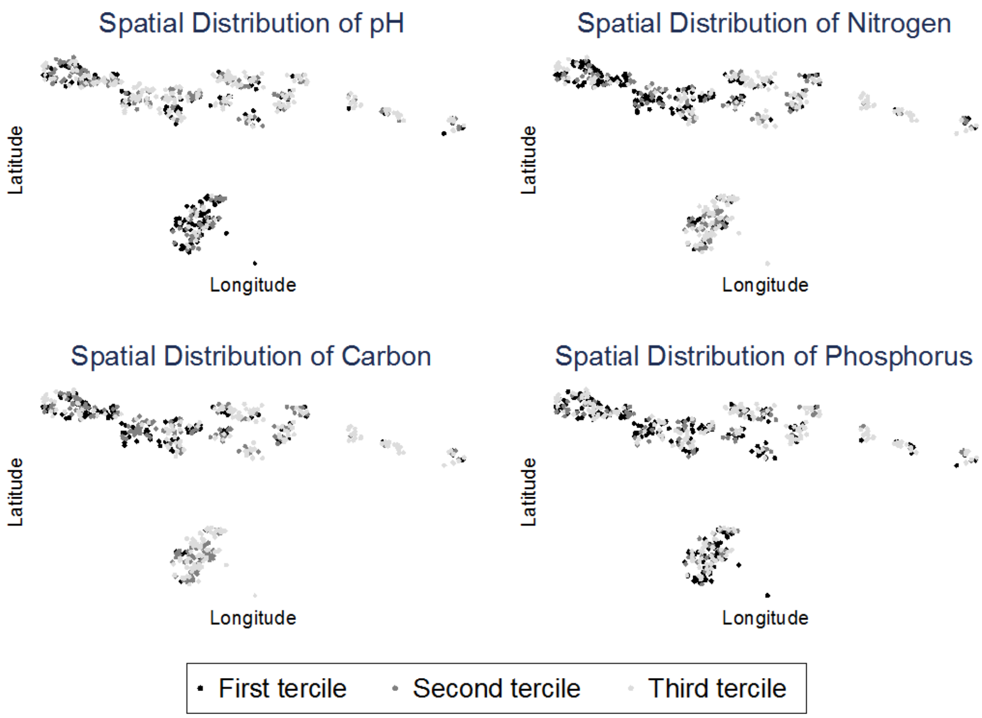


Source: Author's own calculations using soil data collected as part of this project.

Using the results from these soil analyses, we also uncover heterogeneity and spatial correlation in soil characteristics in this region. We provide some 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 the global means reduces the mean square error of the prediction for pH by 12% 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



Source: Author's own calculations using soil data collected as part of this project.

3.2 Input Use in Western Kenya

By comparing the yields from on-farm demonstrations against average yields in the region, KALRO estimates that the potential for yield increases would be 3 to 5 times higher under better agronomic management conditions. They hypothesize that the low productivity is mainly driven by small land holdings that are continuously cultivated without adequate nutrient replenishment, the prevalence of 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. In particular, the use of chemical fertilizers and the application of agricultural lime to reduce soil acidity.

- Chemical Fertilizers

There is already a large body of work suggesting that chemical fertilizer can substantially raise agricultural yields and that it can be profitable to apply them (Evenson and Gollin 2003; Duflo, Kremer, Robinson 2011). In this region, fertilizers like diammonium phosphate (DAP) and calcium ammonium nitrate (CAN) are already widely known. Others chemical fertilizers NPK (Nitrogen Phosphorus and Potassium 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, over 50% of farmers said that they had chosen the fertilizer they were using because they either guessed that it was the correct one or it was the only one they knew.

- Agricultural Lime

Soils are considered acidic when their pH is below 6 (KALRO, 2009). 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. The MoA of Kenya recommends applying agricultural lime as one of the most practical ways to manage soil acidity. In addition, KALRO reports a benefit-cost ratio of between 2.5 and 3 for the use of lime (KALRO 2014). Others have also reported high rates of return for agricultural lime in this area (OAF, 2015, Omenyo et al. 2010).

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

4. Timeline

We show the timeline for this project in Figure 6. During the summer of 2014, both 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 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. The e-extension services were planned to start in early 2015. However, because of technical issues deploying the system, the e-extension information delivery system was only implemented 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 to the beginning of the next Long Rain planting season, 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).

Figure 6: Project Timeline

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

The figure shows a timeline of the project between August 2014 and until the last round of data collection March 2016. The farmer sample columns indicate separate samples of farmers: KALRO to denote farmers in KALRO's evaluation, QUAL, to denote the qualitative sample and WTP to denote farmers who participated in willingness to pay surveys.

5. Evaluation: Design, Methods and Implementation

The data used in this study was collected through fieldwork led by Innovations for Poverty Action (IPA) Kenya. All activities described were subject to IRB reviews from Maseno University, Harvard University and the University of California at Santa Cruz. All key study staff members completed relevant ethical trainings. 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 collect two rounds of surveys: a baseline survey that took place in September 2014 and an endline survey that started in December 2015 and finished in 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 also elicited WTP for different types of soil analysis information for a separate sample of almost 400 farmers. We describe all data collection activities in the next subsections.

5.1 KALRO's Extension Services

We conducted a randomized control trial (RCT) to evaluate whether KALRO's FFDs and e-extension services were effective in increasing farmers' knowledge and adoption of recommended agricultural inputs. In particular, we answer the following questions:

- Does receiving information increase farmer's knowledge about the existence and adequate use of agricultural inputs and technologies?
- Does receiving information improve individual's 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) invited to participate in FFDs, (ii) invited to participate in e-extension services and (iii) assigned to a comparison group. Below we describe details of the sample selection, evaluation design and identification strategy.

(a) Sample Selection

At the onset of the 2014 Short Rains, 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 their program and set-up demonstration plots, and they were deemed representative of the agroclimatic conditions of other regions.

In order 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 to invite them to participate in a census questionnaire. Enumerators completed a total of 1,330 surveys following these protocols.

A subsample of these farmers was invited to participate in the research study and complete a baseline survey. The criteria of inclusion into the research sample were: (i) the individual or another household member owned a mobile phone, (ii) the individual had grown maize or legumes during the previous year and, (iii) the individual was in charge of farming activities for the household. These criteria were used to ensure that the sample was representative of those farmers who are usually targeted by KALRO. Approximately 94% 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 of our coupon redemption measure with a sample of 400 farmers per treatment arm. We discuss power calculations assumptions in Appendix C.

(b) 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 individual's 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, a test of cognitive skills 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, in private, using Stata (a statistical software). Randomization was stratified on the basis of subcounty, recruitment area, gender, knowledge about lime, land size, legume farming, scores in cognitive test, and an index for agricultural input use. Farmers who were either assigned to the e-extension or FFD received a phone call to invite them to participate in each activity respectively. In the final sample of farmers, 92% of respondents report being the primary owner of their cellphone.

The FFDs took place in November and December 2014, a couple of weeks before the end of the 2014 Short Rain season. In total, four different FFDs were organized in the experimental areas. FFDs are public events and entry is open to all members of the public. In order to reduce the likelihood of contamination, it was agreed that IPA would actively invite and reach out to farmers assigned to the FFD treatment group. Invitations to the event were done through a phone call and a letter that stated location and event time.[4] Since we were interested in evaluating the causal effects of attending these events and wanted to ensure that we had enough power to detect them, the team encouraged attendance by providing a small gift and by facilitating transport to those farmers who lived more than 5 km away from their closest FFD site. Both KALRO and the research team kept attendance records from all farmers who attended these events. Overall, 87% of farmers invited to the FFD attended the event, relative to 4% of the 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 the implementation of this treatment arm until the following Short Rain season (July 2015). Before the intervention started, farmers were called and invited to receive these messages in 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 though an endline survey conducted in late November and December 2015. Face-to-face interviews were conducted conducted with farmers in the two treatments and in the control groups. The survey collected information on farmers' knowledge, beliefs and input use, community relationships and experience with the interventions.

In addition, at the end of the endline survey, all farmers received two discount coupons

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

redeemable at a specific agrodealer in their nearest market center. The first discount coupon was redeemable for a 50% discount (up to 1,000 Ksh) for any chemical fertilizer of their choice (NPK, DAP, CAN, Urea or Mavuno). The second discount coupon was redeemable for a 50% discount for agricultural lime. Coupon redemption was open until March 2016, which corresponded with the start of the subsequent 2016 Long Rain agricultural season. Participating agrodealers were stocked with inputs as part of KALRO's overall program.

The coupons were devised as a way to collect information on actual agricultural input choices made by participants. The use of coupons may reduce concerns about social desirability biases; since farmers make purchase decisions at a later time where 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 (Glennerster and Takavarasha, 2013). Each coupon was marked with individual respondent IDs and agrodealers 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 only measure 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% of surveys were back-checked. In addition, random audio audits were performed on enumerators (enumerators were aware that they could be audited).

(c) Empirical Strategy

We obtain intent-to-treat estimate by estimating the 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, input use). $e\_extension$ represents a dummy variable that takes value one to indicate assignment to e-extension. FFD is a dummy variable that takes value one to indicate assignment to the farmer field days. Their coefficients (β_1 and β_2) provide the intent to treat (ITT) estimates for each treatment. To improve precision, we control for baseline outcomes for all cases in which we had 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). In order to adjust standard errors for constraints we imposed during the stratified randomization, we include dummies for the different stratum used in the randomization (X's). All regressions use robust standard errors.

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

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

In order to assess the validity of the random assignment, we test for differences between the control group and the treatment groups for several baseline variables. We also test for differences among attritters and non-attriters in the endline survey and find no significant differences. See Table D in the Appendix D.

(d) Focus Groups Discussions (FGDs)

In addition to the above data collection, the field team was trained by a qualitative researcher to conduct a number of focus group discussions (FGD) with different groups of farmers to understand their interest in the use of ICT and gather their thoughts about their experiences with extension services and FFDs. The FGDs took place during the Long Rain season of 2015. These discussions were conducted with a separate sample of farmers that were not part of the experimental evaluation described above. The sampling for the FGDs was purposive, whereby participants were selected based on their area of residence and gender. Farmers had similar socio-demographic characteristics similar to farmers who participated in this experiment.

A total of 10 FGDs with 8-12 participants in each were organized. We had five general groups of mixed gender, three groups formed by female farmers only, one group of mixed-gender previous FFD attendees (but not part of the experimental sample) and one group of women only FFD attendees. The discussions centered on perceptions about farming needs, and in particular information needs, the use of current information channels, perceptions about agricultural extension workers, the use of ICT for receiving information, experiences in FFDs and the dissemination of information in communities.

We share a summary of the final report from FGDs in Appendix G.

5.2 Willingness to Pay

In addition to KALRO's evaluation, the research team collected measures of willingness to pay (WTP) for results of soil analyses that had been conducted by KALRO in this region during the Long Rains of 2014. This exercise was carried out in order to obtain measures of farmers' valuation for local agricultural information.

(a) 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). These soil samples were sent for analysis at the KALRO soil laboratories in 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 1. WTP 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 particular 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 also tracked down the peers of the farmers who had originally received the individual soil test results, and elicited the peers' WTP for the soil analyses 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 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 these results since they could have just asked for them to their friends). 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.

(b) Data Collection

We elicited willingness to pay through two different 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.

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

The first method was a variant of the Random Lottery Incentive System (RLIS) in which farmers are 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 chosen at the end to be implemented, 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 Ksh to 900 Ksh.

The second method was to elicit WTP using a Becker-DeGroot-Marshack (BDM) elicitation method in which farmers use 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 purchase the good at price p. However, if WTP was less than p, the respondent was not allowed to purchase the good. Therefore, farmers are incentivized to reveal their true WTP. The random price p was distributed from 0 Ksh to 900 Ksh. Other studies have successfully implemented this method in developing-country contexts (e.g. Hoffmann et al. (2009) and Berry et al. (2012)).

There are some important differences with elicitation using these methods. In the RLIS elicitation, farmers' did not use own money. Rather they were offered to choose 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 only bid 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 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. In order 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 landmark to determine which landmark was closest to them.

In order 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: a module that elicited WTP for soil test results located within different distances from the specific landmark (0-5km, 0-10km and 10-20km) and a module that elicited WTP for different numbers of local soil test results (1, 2 or 3).

Finally, in order to address potential social desirability bias or enumerator effects, farmers were also offered for purchase an information sheet that had little information content. This information sheet only listed the total maize yields in kg of an (unknown) test plot. The idea was to use this sheet as a way 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 these 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 a program entitled "Scaling up integrated soil fertility management in Western Kenya through an innovative public-private partnership". The project was financially supported by the Alliance for the 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 an information delivery component to farmers, and this evaluation focuses on that aspect of KALRO's overall program.[6]

The information component sought to increase farmer productivity by scaling the uptake of locally relevant inputs and management practices. Two informational and 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 reader should be aware that 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.

- Farmer Field Days

One of KALRO's main strategies to provide information to farmers about locally relevant agricultural practices is to organize large events around farming demonstration sites, where they demonstrate appropriate agricultural technologies for the respective area agro-ecologies. These meetings serve as learning platform for farmers, where they can observe the results from demonstration plots and learn about various technologies and practices from other farmer groups and from extension workers. As part of their overall program, KALRO organized several FFDs in Western Kenya. For purposes of this evaluation, farmers assigned to the FFD group were invited to one of the field days organized in the evaluation subcounties (a total of four FFDs were organized in these areas).

KALRO had 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, labor and technical support

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

to set up these plots. To promote ownership of the demonstrations, KALRO and the host farmers agreed that the farmer would provide most of the labor. One of the key criteria to select farmers was to choose someone who has sufficient land to host test plots and who could host a FFD. All demonstration plots showcased different types of fertilizers (including DAP, Mavuno, NPK and CAN), legumes and agricultural lime. FFDs were held on pre-specified days and they generally lasted the entire morning.

A typical FFD would work as follows: once farmers arrived, they were registered and organized into smaller groups by a member of the KALRO team. They would then tour the demonstration plots with guidance from 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 these booths differed by FFD. At the end of the day, special guests (e.g. local leaders, successful farmers, extension workers, etc) would give speeches. While farmers could leave at any point, the majority would stay throughout the event. Each FFD had approximately 100-300 attendees (which in our case, included farmers who participated in the experiment and other farmers within the area who did not).

One of the key messages highlighted by extension workers during 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, in particular CAN, DAP and Mavuno. Mavuno was highlighted as a good option because it already contains some lime. While we don't 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).

- E-Extension

This intervention consisted on farmers' receiving 15 different text messages on their mobile phones. To the extent possible messages were delivered to correspond 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 half way 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 farmers to test their soils to determine acidity levels, and to use agricultural lime in acidic soils (but did not explicitly mentioned how much lime to apply). The 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 evaluate take-up of recommended inputs and practices on subsequent seasons, for the e-extension program we evaluate impact during the season in which the program took place (though coupon redemption is evaluated for use in the subsequent season).

The content of the messages was chosen and developed by the MoA. KALRO partnered with them to implement this intervention. Since 2014 the MoA has announced plans to roll out an e-extension system to reach over 7 million farmers.[7] Their main plan is to provide this service to extension workers who would then advice farmers. The version of the program that was evaluated as part of this project was a pilot to deliver information directly to farmers.

The first set of messages that were sent at the beginning of the Short Rain planting season 2015 (August 2015) were written in English. However, after discussions with implementers about the appropriateness of language, the messages were translated to Swahili. Although 75% of farmers report 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 first 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 ToC.

7.1 Willingness to Pay for Local Soil Information

In Appendix D we show summary statistics for farmers in this sample as well as balance checks for farmers assigned to the RLIS vs. the BDM group.

The average WTP elicited for this soil analysis through RLIS was 487 Ksh (~$4.8 US) and through BDM 20.5 Ksh (~$0.2 US). These differences are statistically significant.[8] For comparison, the approximate price of a single soil test (not including costs of sampling and transport) is approximately Ksh 1,100 (~$11 US).[9] 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.

While 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 this 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 Table B in Appendix B we show how different farmer characteristics correlate with WTP.

Figure 7 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

[7] See for instance: http://www.nafis.go.ke/2013/04/digital-system-to-improve-service-delivery-to-farmers/ , http://www.nation.co.ke/business/Extension-services-to-farmers-now-go-digital/996-2274680-jrp6lh/index.html

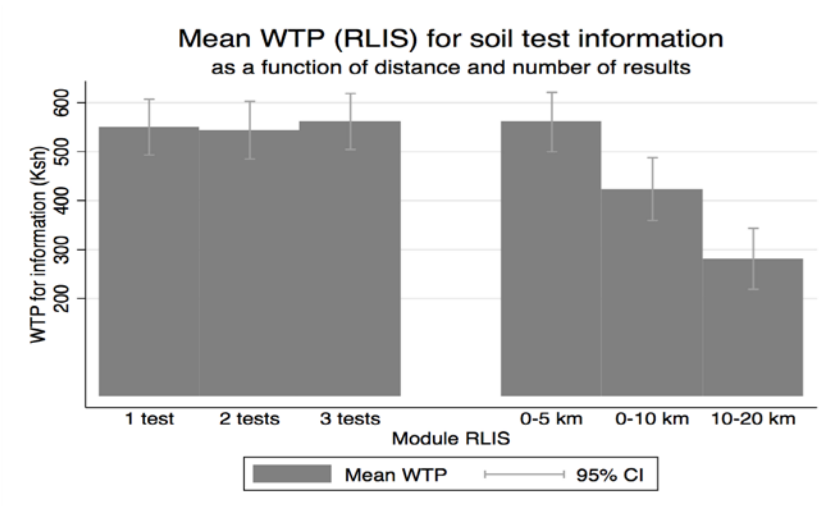
[8] They remain significant when we control for land size which is unbalanced across groups, as shown in the appendix Table A.

[9] Note that if a farmer paid for a soil test, this would be information for their own farm. We, however, elicited information for a local result.

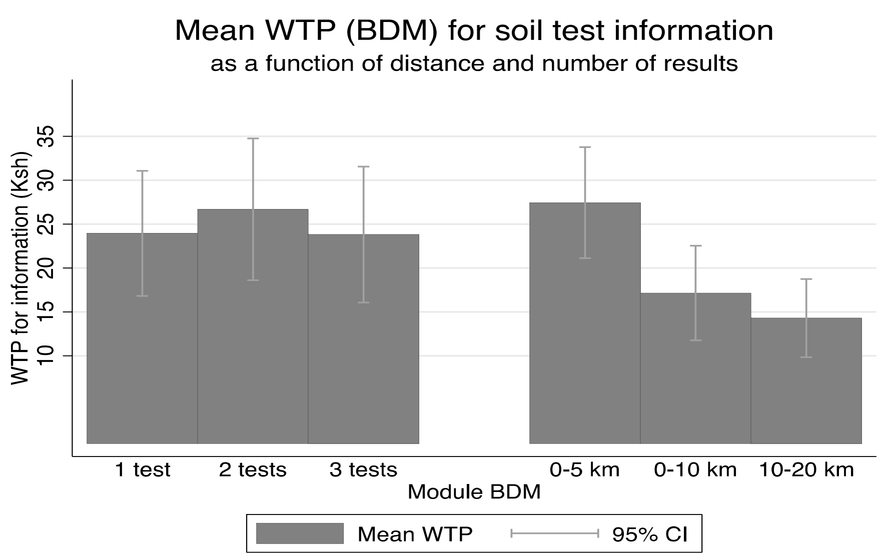
landmark and different number of soil test results. In previous work, we had found that farmers were more likely to bid higher amounts for more precise information for other types of agricultural information (Fabregas et al., 2017). That pattern seems to hold true for variation in distance to landmark but not for the number of soil test results offered. This could potentially 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 willingness to pay for results that are closer to their farms.

Figure 7: Average WTP by Module

(a) RLIS



(b) BDM

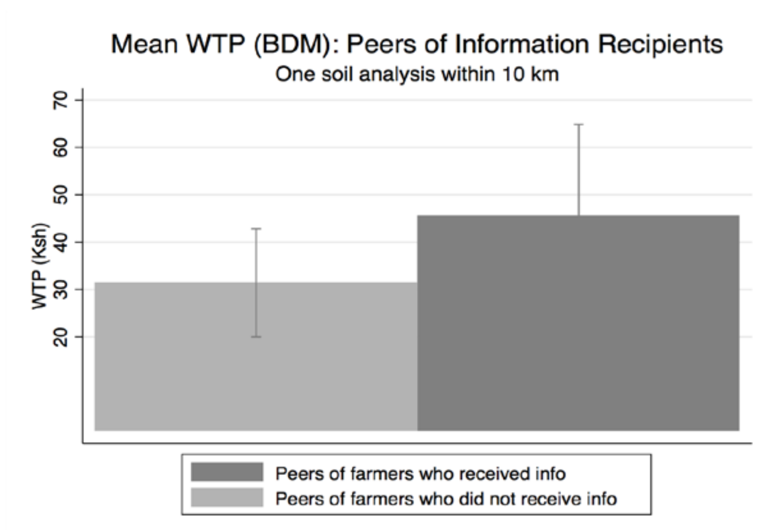


Note: This figure shows WTP for the results of a different number of soil analyses within a 10 km radius (1, 2 or 3 tests) and the WTP for one soil analysis within 5km, 10 km or 10-20km from a landmark close to the respondent. The first figure shows results as elicited by the RLIS method and the second figure 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 report the name of a neighboring farmer with whom they discussed agricultural issues (this question was also asked to those in a corresponding control group). Once the research team had returned results to the original farmers from whom we had taken the soil samples, we allowed for a period of 2 to 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 8 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. While these raw differences are not statistically significant (note that the sample size is small), it's 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. First group was randomly assigned to receive information. Second group remained as control. The WTP is elicited through 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 and noted in the PAP. 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?

(a) 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 3 columns, overall means in column 4 and p-values of different comparisons in column (5) to (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 (65%) of females and the average age is 40 years. While participation was conditioned on self-reporting owning a phone and being literate during the census survey, in the baseline data we see that only 90% of respondents reported that they could read a letter in Swahili and owned a phone. This is all balanced across groups, so it should not affect the internal validity of our estimates.

In terms of existing information, only 10% of farmers report ever having done a soil test on their own land, and while 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% report ever having used it.

Attrition is a first-order concern for any evaluation since it can seriously bias the estimates. The primary approach to limit this problem was to intensively track and re-survey all baseline respondents. In order 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. We don't find any evidence of differential attrition across treatment arms.

(b) Awareness and Knowledge

The first set of outcomes relate to whether the interventions changed awareness about the existence of inputs and individual's 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 to 40% in control group, 65% in the FFD report knowing about the existence of lime. We do not find differential increases in awareness about Mavuno, NPK, CAN, DAP though a large fraction of farmers in the comparison group already knew about the existence of these inputs.

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	0.65	0.65	0.65	0.87	1.00	0.87
	(0.02)	(0.02)	(0.02)	(0.01)			
Mumias	0.56	0.57	0.56	0.56	0.94	0.89	0.83
	(0.02)	(0.02)	(0.02)	(0.01)			
Age	40.25	39.79	41.29	40.44	0.62	0.27	0.10
	(0.66)	(0.65)	(0.66)	(0.38)			
Primary school complete	0.54	0.54	0.53	0.54	0.89	0.78	0.67
	(0.02)	(0.02)	(0.02)	(0.01)			
Can read letter in Swahili	0.90	0.91	0.91	0.91	0.74	0.91	0.83
	(0.01)	(0.01)	(0.01)	(0.01)			
Respondent owns phone	0.93	0.91	0.92	0.92	0.24	0.59	0.52
	(0.01)	(0.01)	(0.01)	(0.01)			
Log expenditure	8.27	8.38	8.32	8.33	0.28	0.67	0.50
	(0.07)	(0.07)	(0.07)	(0.04)			
Wears footwear	0.57	0.56	0.61	0.58	0.79	0.26	0.16
	(0.02)	(0.02)	(0.02)	(0.01)			
Acres owned	1.64	1.54	1.88	1.69	0.47	0.40	0.21
	(0.11)	(0.09)	(0.26)	(0.10)			
Ever done a soil test	0.10	0.10	0.12	0.11	0.89	0.23	0.28
	(0.01)	(0.01)	(0.02)	(0.01)			
Heard about DAP	0.99	0.99	0.99	0.99	0.99	0.76	0.77
	(0.01)	(0.01)	(0.01)	(0.00)			
Heard about NPK	0.51	0.47	0.50	0.49	0.33	0.94	0.37
	(0.02)	(0.02)	(0.02)	(0.01)			
Heard about CAN	0.89	0.89	0.90	0.89	0.93	0.66	0.72
	(0.02)	(0.02)	(0.01)	(0.01)			
Heard about lime	0.40	0.40	0.40	0.40	0.93	0.89	0.96
	(0.02)	(0.02)	(0.02)	(0.01)			
Heard about mavuno	0.08	0.08	0.06	0.08	0.88	0.22	0.17
	(0.01)	(0.01)	(0.01)	(0.01)			
Have ever used DAP	0.92	0.94	0.94	0.93	0.35	0.41	0.90
	(0.01)	(0.01)	(0.01)	(0.00)			
Have ever used NPK	0.14	0.14	0.12	0.14	0.90	0.36	0.29
	(0.02)	(0.02)	(0.02)	(0.01)			
Have ever used CAN	0.64	0.63	0.61	0.63	0.79	0.32	0.46
	(0.02)	(0.02)	(0.02)	(0.01)			
Have ever used lime	0.06	0.07	0.06	0.07	0.57	1.00	0.57
	(0.01)	(0.01)	(0.01)	(0.01)			
Have ever used mavuno	0.01	0.01	0.03	0.02	0.74	0.13	0.07*
	(0.01)	(0.00)	(0.01)	(0.00)			
Ag. knowledge score	9.41	9.27	9.39	9.36	0.34	0.89	0.39
	(0.10)	(0.10)	(0.09)	(0.06)			
Ag. input use score	7.13	7.09	7.08	7.10	0.77	0.76	0.98
	(0.10)	(0.10)	(0.10)	(0.06)			
N	417	415	417	1249			

The table shows summary statistics and balance tests using the covariate variables from a baseline survey of 1249 farmers. Columns 1-3 display the mean and s.e. of each characteristic for each treatment group and column 4 displays the mean across the sample. Columns 5-7 show the p-value of the test of difference across treatment groups. Ag knowledge score is an index that can take value 0-12 constructed from 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.

Since the information provided in the FFD and through SMS was wide-ranged, 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 grain storage and how to test for acidity. In column (6) we standardize treatment effects following the construction of indices as per Kling, Katz and Liebman (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	**Test Acidity**	**DAP**	**CAN**	**Mavuno**	**Input Index**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
FFD	0.247***	0.131***	0.002	-0.008	0.032	0.282***
	(0.030)	(0.031)	(0.002)	(0.014)	(0.021)	(0.097)
E-extension	-0.004	0.054*	0.002	-0.019	0.005	0.169*
	(0.032)	(0.033)	(0.002)	(0.014)	(0.022)	(0.102)
Controls	Y	Y	Y	Y	Y	Y
R-squared	0.225	0.054	0.090	0.176	0.172	0.087
Observations	1166	1166	1166	1166	1166	1166
Y-mean	0.40	0.67	1.00	0.96	0.70	0.56

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) which farmers' also received SMS messages for.

During the endline, farmers were also asked what did they think was the best way to control soil acidity in their farm. This was an open-ended question and respondents were allowed to provide any answer of their choice. We code answers on whether they correctly identify a technique that decreases acidity (e.g. applying lime, ash, etc.) vs. mentioning a technique that is not commonly or directly associated with the reduction of soil acidity (e.g. intercropping, using chemical fertilizers, testing the soil, etc.). The dependent variable in column (1) in Table 5 takes a value of one if the farmer reports at least one correct method to control acidity (according to KALRO's soil scientists). The dependent variable in column (2) takes the value of one if farmers report at least one other method. Farmers who participated in FFDs are 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 potentially be incorrect). This could suggest that the new information acts as a substitute for previous beliefs. The dependent variable in column (3) takes the value one if farmers mentioned "agricultural lime" as one of their answers.

Table 5: Knowledge Gaps between farmers and KALRO Information

	Promoted acidity	**Unpromoted acidity**	**Mentions Lime**	**Correct test frequency**	**Correct fertilizer quantity**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**
FFD	0.243***	-0.070**	0.249***	0.010	-0.040*
	(0.032)	(0.036)	(0.030)	(0.007)	(0.022)
E-extension	-0.007	-0.006	-0.008	0.020**	-0.019
	(0.030)	(0.036)	(0.025)	(0.009)	(0.024)
R-squared	0.142	0.031	0.151	0.035	0.043
Observations	1166	1166	1166	1166	1166
Y mean	0.24	0.57	0.16	0.01	0.13

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. Column 4 and 5 test for gaps in the information that farmers report 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 the frequency to test their soil and the fertilizer quantities that KALRO recommended. We code as "correct" any answer that matches KALRO's information. Receiving information through phone helps farmers remember recommended frequency for soil testing but not the correct quantities of fertilizer to apply per planting hole.

(c) 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 about different types of fertilizers. It is important to highlight that we are just measuring changes in farmers' beliefs but we 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 kg bags of different types fertilizers relative to not applying any fertilizer on their farm. In panel A, in Table 6 we show coefficients from a regression of those numbers on treatment status. Not all farmers were able to answer these questions. On average, farmers report that a 50kg bag of CAN would lead to higher yields. This is in contrast to the belief shared by a majority of farmers that DAP is the most profitable type of fertilizer for their land. Interestingly, the cost of DAP and CAN are usually within the same price range (but its possible that other associated costs with application of these inputs might differ).[10]

[10] If anything, from average price data collected from a census of agrodealers, in the region, we document find that the price of CAN is slightly lower that the price of DAP.

In panel B, we explore whether the treatments changed respondents' answer to a hypothetical question about how would they allocate a voucher for 1,000 Ksh (approximately $10 US) for fertilizer. There were no restrictions in how they could spend it. The dependent variable is the amount allocated to different types of fertilizers. On average, farmers appear to be more likely to want to spend a larger share of this voucher on DAP. However, those who participated in FFD are more likely to say that they would spend more money in Mavuno and less in NPK. There are no changes for those in the e-extension activities.

Table 6: Beliefs about Fertilizer Yields and Profitability

Panel A: How many additional bags of maize you could harvest from 50 kg of:				
	DAP	**CAN**	**NPK**	
	(1)	**(2)**	**(3)**	
FFD	8.658	3.417	9.812	
	(5.997)	(9.499)	(9.480)	
E-extension	4.242	-2.607	0.753	
	(3.061)	(5.120)	(4.020)	
R-squared	0.034	0.062	0.032	
Observations	1156	1118	1032	
Y mean	25.49	36.20	30.99	
Panel B: If you received a fertilizer voucher for Ksh 1000 how would you spend it?				
	DAP	**CAN**	**NPK**	**Mavuno**
	(1)	**(2)**	**(3)**	**(4)**
FFD	-15.074	-3.631	-38.024**	57.506***
	(20.039)	(13.681)	(16.107)	(21.188)
E-extension	2.280	17.702	-2.699	-16.400
	(19.389)	(14.133)	(16.342)	(19.553)
R-squared	0.115	0.076	0.086	0.032
Observations	1165	1165	1165	1165
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	-0.036	-0.037*	0.010**
	(0.033)	(0.028)	(0.020)	(0.005)
E-extension	0.022	0.020	-0.036*	0.010**
	(0.033)	(0.029)	(0.020)	(0.005)
R-squared	0.130	0.117	0.058	0.030
Observations	1165	1165	1165	1165
Y mean	0.38	0.22	0.11	0.00

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 particular 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% though DAP was the most profitable type of fertilizer. The FFD intervention appears to have reduced farmer 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.

(d) 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 at that point farmers in the e-extension group had not yet received any treatment 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 four percentage points. However, we do not see any additional impact on any other types of fertilizers.

In the self-reported use for the subsequent season, the effect on Mavuno persists, 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 the previous seasons. We do not find that the interventions modified use of lime nor farmers' likelihood to plant legumes.

Table 7: Have you used any of the following inputs, during:

	DAP	**CAN**	**NPK**	**Mavuno**	**Lime**	**Legumes**
Panel A: Long Rain Season 2015 (March - August)						
	(1)	**(2)**	**(3)**	**(4)**		
FFD	-0.021	-0.023	0.014	0.044**		
	(0.026)	(0.027)	(0.018)	(0.022)		
R-squared	0.030	0.276	0.061	0.099		
Observations	1166	1166	1166	1166		
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	-0.019	-0.015	0.041*	0.003	0.011
	(0.033)	(0.031)	(0.016)	(0.024)	(0.020)	(0.028)
E-extension	-0.022	-0.050	0.001	-0.010	-0.002	0.023
	(0.033)	(0.031)	(0.017)	(0.023)	(0.020)	(0.028)
R-squared	0.045	0.266	0.037	0.077	0.130	0.123
Observations	1166	1166	1166	1166	1166	1166
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.

(e) Coupon Redemption

We now explore the effects of the intervention on the redemption of the discount coupons. The outcome data is taken from administrative shop records from the redemption of the 50% 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 only sent 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	**Lime Quantity (Kg)**	**Lime Expenditures (Ksh)**
	(1)	**(2)**	**(3)**
FFD	0.036	5.739	34.432
	(0.023)	(3.867)	(23.203)
E-extension	-0.011	-2.295	-13.770
	(0.022)	(3.676)	(22.057)
R-squared	0.074	0.112	0.112
Observations	1166	1166	1166
Y mean	0.11	16.97	59.79

The dependent variable in the first column is a dummy variable that takes value one if lime was redeemed. The second column shows the quantity it was redeemed for. The third column shows 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. Column (1) and (2) show results redeeming for any type of chemical fertilizer offered. Column (3) to (5) shows increase in quantity purchased for DAP, CAN, and Mavuno separately.[11]

We see an increase of 2 Kg in purchase of DAP and 1 kg for SMS but no change in other types of fertilizers. Consistent with these results we see an increase of approximately $2 US in expenditures for DAP for the FFD group and $1 US for the SMS based intervention. However in contrast to the self-reported data, we do not measure significant increases in the purchase of

[11] No one in the sample redeemed the coupon for NPK.

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, its possible that farmers might have Mavuno in other shops for which we did not collect information or if they received fertilizer from other sources (e.g. from government subsidy programs). Third, the coupon redemption and the self-reported data are for different seasons, so they might have used different inputs over different seasons.

Table 9: Fertilizer Coupon Redemption

	Fert Coupon	**Fert Quantity (Kg)**	**DAP Quantity (Kg)**	**CAN Quantity (Kg)**	**Mavuno Quantity (Kg)**	**Fert. Expenditures (Ksh)**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
FFD	0.126***	2.454***	2.233***	0.158	0.063	196.691***
	(0.035)	(0.826)	(0.697)	(0.412)	(0.064)	(58.062)
E-extension	0.029	1.464	1.389*	0.059	-0.000	108.376*
	(0.035)	(0.913)	(0.771)	(0.444)	(0.006)	(61.856)
R-squared	0.079	0.046	0.039	0.059	0.016	0.046
Observations	1166	1166	1166	1166	1166	1166
Y mean	0.41	6.91	5.61	1.30	0.00	513.60

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%) 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 for this input. However, the question is why DAP purchases increased as a result of the treatments, even when we do not find that they changed knowledge or beliefs about DAP. This suggests that these impacts are working through alternative channels. However, since we do not have sufficient information on what these could be we refrain to speculate on this result.

In Table 10, in accordance to the PAP, we show results for an IV specification to deal with imperfect compliance in attendance for the FFDs. The coefficients are roughly similar to the ITT 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 acquire with the coupon is relatively small (optimal recommended amounts are around 50kg/acre).

Table 10: IV results

	First Stage Regression	Lime Coupon	Lime Quantity (Kg)	Lime Expenditures (Ksh)	Fert. Coupon
	(1)	(2)	(3)	(4)	(5)
FFD Treatment	0.837***				
	(0.019)				
FFD Participation		0.044	6.855	41.133	0.151***
		(0.027)	(4.555)	(27.327)	(0.041)
R-squared		0.078	0.116	0.116	0.073
Observation		1166	1166	1166	1166
Y mean		0.11	16.97	59.79	0.41
	Fert Quantity (Kg)	Fert Expenditures (Ksh)	DAP Quantity (Kg)	CAN Quantity (Kg)	Mavuno Quantity (Kg)
	(6)	(7)			
FFD Participation	2.932***	234.967***	2.667***	0.189	0.076
	(0.973)	(68.614)	(0.826)	(0.477)	(0.075)
R-squared	0.041	0.040	0.034	0.059	0.016
Observation	1166	1166	1166	1166	1166
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 about different inputs at baseline. On the one hand, the ToC predicts that the interventions work by closing knowledge gaps, and 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 (for instance see 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 land size). There is a marginally significant effect for the interaction of FFD with our measure of acreage size for lime redemption but not for fertilizer (and the magnitude is small).

In Appendix D, We show results for all specifications of heterogeneity that were listed in the PAP. 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 ToC

(a) Farmer Field Days

While we measure increases in the 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 ToC 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 (which had performed better than control plots). In addition, during FGDs 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 on whether their own farm had acidic soils. KALRO's advises farmers' to test their soil for acidity before applying agricultural lime. While agricultural lime is very cheap, individual soil tests are relatively expensive (~ $11 US dollars). We do not measure increases in soil testing, so this might have limited farmers' decision to experiment with this particular input.

(b) E-extension

We do not find evidence that the e-extension messages increased the use of agricultural lime nor it significantly increased the use of chemical fertilizers. One must question whether the information that was provided was sufficiently geared towards increasing the take up of these inputs. The messages focused on providing recommendations on 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 are. Therefore, it is perhaps not surprising that beliefs about adequacy or profitability of these inputs did not change. However, we do not find that the intervention changed knowledge for management practices that were explicitly discussed in the messages (i.e. types and quantities of fertilizers, the use of soil tests to address soil acidity, amount of seeds per planting hole, etc.).

Since farmers do not appear to consistently recall this information from the messages an obvious question is whether farmers actually received and read the messages. A priori, during FGDs farmers were generally supportive of the idea of having agricultural messages delivered to them through phones because it would be easy to reach them. While 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 message. Only 67% of the e-extension group reports having received agricultural messages through their mobile phone over the previous year. We do not detect significant differences between farmers that report receiving messages vs. those who do 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 IV specification to account for imperfect compliance in the appendix. However, these estimates suffer from the important limitation that the measure we have for compliance is self-reported. While this issue seems to be partially accounted by problems with mobile networks, it is also possible that some respondents may also have forgotten whether they actually received the messages, which would bias those estimates.

Finally, we also 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 be delayed and one should have measured long term outcomes). However, the evidence on the impact of the coupon redemption measures, which corresponded with the subsequent season, suggests that the increases in use only affected DAP and not lime. This provides some partial evidence that lime use did not increase a season following the reception of messages.

8. Discussion

a. Cost Data

We were able to collect cost data for the FFDs. Based on information reported by KALRO, we calculate that each FFD costs about $2,600 U.S dollars to implement. This number 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 $9-$26 US dollars per farmer attended. 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 4 percentage points. This implies that each FFD would increase Mavuno adoption for 4 to 12 farmers. A full cost-benefit analysis is necessary to determine whether social benefits outweigh the costs, but given the limited impacts on adoption it seems highly unlikely that this is a cost-effective way to increase the use of Mavuno. We cannot rule out that there might have been other impacts from FFDs that were not captured in the endline survey.

b. Internal Validity

We used a field experiment to evaluate the impacts of two information delivery methods commonly used by extension workers in Kenya. We document that farmers who attended the FFDs are more likely to learn about recommended technologies, in particular about agricultural lime, and more likely to report that that they would spend money on a newly recommended chemical fertilizer, Mavuno. Farmers are only marginally more likely to report that they adopted Mavuno and 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 particular type of 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 while 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 currently 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. In order 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, that allowed us to measure the input choices that they would make when they have to use their own money and are 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. 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.

An additional 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 capture the gains from these interventions. It is possible that farmers gained other knowledge and/or might have changed other practices that were not measured as part of this evaluation.

c. External Validity

The agricultural issues (low input use, low productivity, high soil acidity, etc.) experienced in Western Kenya are representative of various other regions in SSA. Additionally, the extension techniques described in this project are also commonly used in other contexts by both public and private entities, and the sample of farmers that we worked with is also likely to be representative of the average farmer that KALRO targets. However, it is difficult to know whether other types of messages could have been more successful in changing the types of indicators that we collect information for.

We are only aware of another experimental evaluation of FFDs (Emerick et al. 2016). The context (India), implementing partner (NGO) and promoted technology (improved seeds) are all different from ours but they also find positive (but much larger) effects on the 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 $410 dollars for farmers in a 69-person village, and each of their FFD costs 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). However, in this case, 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 on whether a countrywide scale-up of SMS messages is warranted.

9. Policy Recommendations

a. Policymakers

- **In this context, local agricultural information appears to be informative and there is evidence of positive demand for it.**

Using data from soil analyses we document that soil characteristics, and in particular measures of soil acidity, are spatially correlated in this area. This suggests that farmers could potentially learn from information generated at the local level. We also document 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 might be prohibitively expensive (and beyond the means of most farmers), this could suggest 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 into the program, potentially suggesting that they thought that receiving advice would be valuable. During qualitative work in the area, many farmers express desire to receive more information about new technologies and how to improve management practices in their farms.

- **FFDs increased knowledge and had a small but positive effect on input use. However, as they currently are, 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. While cannot rule out that this intervention increased farming profitability through other channels, for instance though 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 these meetings. We note, however, that in qualitative discussions farmers expressed positive views about their learning experience through FFDs. Many reported that seeing the demonstration plots made them more confident on 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"*
>
> *(Field day FGD participant, Anyiko)*

A potentially fruitful next step would be to identify features of the FFDs were most effective and 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 whether it was because of the informational content delivered (which could be delivered in other ways).

- **We do not find evidence that the e-extension service increased knowledge or take-up of the promoted inputs. However, given the low-cost of text 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 phones. First, all farmers invited to receive messages agreed to participate in this intervention. Second, most farmers in FGD also thought 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, knowledge or increasing the use of fertilizers and lime. We cannot say whether it was effective in other dimensions, like changing farm management practices (but we do not detect consistent changes in knowledge for some of those dimensions). Beyond problems with message reception (only 55% of farmers stated that they had received them at endline), from a policy perspective it would be important to disentangle whether the break in the ToC had to do with the informational content or the delivery method.

We note that the messages that were sent mostly focused on providing general information about maize management practices. A few messages explicitly mentioned the use of lime or fertilizers. This might have limited their impact on input take-up. The messages contained recommendations that might have been hard to follow without additional clarifications from extension workers (who could recommend optimal dosages) or without conducting individual soil analysis (to determine farmers' own 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 (Fabregas et al 2017, On et al. 2017), 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 only measure self-reported use of these inputs during the season that farmers' received messages. The implementing partner's view is that this is 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 don't measure changes on coupon redemption for fertilizer or agricultural lime for this group, even though this redemption period corresponded with the subsequent planting season. Second, we don't measure changes in awareness or knowledge about these inputs following the intervention.

Since ICT holds promise for reaching farmers at scale at a low-cost it is a worthwhile exercise to continue to investigate under what circumstances this approach could be effective. We also note that any future RCT in this area would benefit from larger sample sizes to detect smaller effects.

b. Implementers

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

This evaluation can only shed light on the effectiveness of the interventions on a number of dimensions that were determined pre-implementation. The evaluation 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 requires further investigation, we recommend that before any program and evaluation takes place, all parties involved clearly define: (i) a clear list of objectives to be achieved from the intervention and (ii) the timeline to achieve those objectives, and commit to use those to assess effectiveness.

- **In our context, 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 the messages to be thoroughly tested for framing, language, etc. 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 do 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 in order to create future agricultural recommendations.

Appendix A: Pre-analysis Plan and Sample Design

See separate document contained in the folder for pre-analysis plan. The details of the sample design are discussed in the text.

Appendix B: Power Calculations

For the evaluation of KALRO's interventions our initial power calculations assumed a significance level of 5%, and a statistical power of 80. We expected attrition to be minimal (and this was true) such that minimum detectable effects (MDEs) were largely unaffected by attrition.

We focused our calculations on the impact of information provision on farmers' knowledge and input choices. The relevant comparisons, as proposed in the preliminary project design, were between 400 farmers in each of the treatment groups to 400 farmers in the control group. That is, each of the comparisons will include 800 farmers, of which 400 are in one of the treatment groups, and 400 are in the control group.

We calculated that a sample size of 400 individuals in each of three treatment arms and a control group would allow us to detect an effect of each of the treatments (compared to the control group) of 0.19-0.23 standard deviations of our key outcome measures depending on take-up assumptions (80% and up). Several of the key outcome variables in our project (e.g. coupon redemption, or reported fertilizer or lime use in any given season) are indicator variables such that the variance of the outcome variable is at most 0.25, i.e. (p*(1-p)) in a Bernoulli distribution with p being the probability of the indicator variable taking on the value 1. A conservative estimate of minimum detectable effect (MDE) were 9-11 percentage points in the comparison of treatment and control groups, which were expected to decrease based on additional controls from the baseline surveys.

Appendix C: Instruments

Surveys have been submitted to 3ie as part of reporting requirements.

Appendix D: Additional Results and Descriptive Statistics

Table A: WTP Sample Summary Statistics

	Full sample Mean (Std. Dev)	**BDM** Mean (Std. Dev)	**RLIS** Mean (Std. Dev)	**Networks** Mean (Std. Dev)	**BDM vs RLIS** difference p-value
Maize Land	0.78	0.83	0.71	0.81	0.04**
	(0.57)	(0.65)	(0.47)	(0.56)	
Education (yrs)	6.79	6.82	6.23	7.36	0.13
	(3.94)	(4.14)	(3.79)	(3.79)	
Male	0.41	0.33	0.4	0.52	0.16
	(0.49)	(0.47)	(0.49)	(0.5)	
Age	42.87	42.66	43.33	42.62	0.61
	(13.21)	(13.38)	(13.56)	(12.66)	
Can Read	0.73	0.7	0.7	0.78	0.96
	(0.45)	(0.46)	(0.46)	(0.41)	
Wears shoes	0.52	0.47	0.5	0.59	0.47
	(0.5)	(0.5)	(0.5)	(0.49)	
Knows IPA test plots	0.77	0.72	0.72	0.86	0.95
	(0.42)	(0.45)	(0.45)	(0.34)	
Used fertilizer before	0.72	0.69	0.69	0.8	0.95
	(0.45)	(0.46)	(0.46)	(0.4)	
N	600	210	205	185	

Note: This table shows summary statistics for the sample of farmers from which we elicited WTP. Columns (2) and (3) show farmers in Group 1 by elicitation method. Column (4) shows farmers in the Network group (all WTP elicited was through BDM).Column (5) reports the p-value of the differences between BDM and RLIS sample. The variable Maize Land, is the size of the land in which they plant maize, wears shoes is an indicator if the respondent was wearing shoes (and proxies for income), knows about IPA test plots asks respondents whether they knew about the individual plots IPA helped set up. Statistical significance is indicated at the 1% $***$, 5% $**$, and 10% $*$ levels.

Table B: Correlates of WTP (RLIS)

VARIABLES	(1) WTP	(2) WTP	(3) WTP	(4) WTP	(5) WTP	(6) WTP	(7) WTP	(8) WTP	(9) WTP	(10) WTP
Land devoted to maize last season	-120**									-148***
	(51.7)									(51.18)
Years of education		12.9*								17.2*
		(6.75)								(8.92)
Male			98.2*							142.2**
			(52.40)							(62.90)
Age				0.5						0.2
				(1.94)						(2.06)
Can read					77.9					8.6
					(58.34)					(77.30)
Wears shoes						-4.3				-85.9
						(52.39)				(62.49)
Knows of households with IPA test plots							15.3			-9.6
							(57.31)			(59.54)
Other land different								12.4		6.2
								(52.56)		(55.12)
Used Fertilizer Last Season									-8.5	-79.4
									(57.08)	(62.32)
Observations	185	199	199	199	199	199	199	199	199	185
R-squared	0.024	0.018	0.017	0.000	0.009	0.000	0.000	0.000	0.000	0.086
Mean WTP	150	150	150	150	150	150	150	150	150	150

Note: This table shows regression in which the dependent variable is the willingness to pay (elicited through RLIS) for one soil test result within 10 km of a close landmark. Statistical significance is indicated at the 1% $***$, 5% $**$, and 10% $*$ levels.

Table C: Heterogeneous Treatment Effects: (KALRO)

Panel A: Dependent Variable: Purchased Fertilizer (coupon redeemed)

	Acres Owned	Raven Score	Reading Score	Female	Knowledge input index	Heard about NPK
[X]*Field Day	0.010	-0.182	-0.081**	-0.058	-0.002	0.122*
	(0.010)	(0.152)	(0.038)	(0.074)	(0.017)	(0.071)
[X]*SMS	-0.001	0.121	-0.074**	-0.096	0.006	0.084
	(0.016)	(0.148)	(0.037)	(0.072)	(0.017)	(0.070)
Field Day	0.109***	0.212***	0.122***	0.163***	0.126***	0.064
	(0.039)	(0.080)	(0.038)	(0.059)	(0.035)	(0.050)
SMS	0.023	-0.034	0.024	0.084	0.023	-0.020
	(0.043)	(0.076)	(0.037)	(0.058)	(0.035)	(0.048)
[X]	-0.002	0.060	0.033	0.083	0.004	-0.064
	(0.002)	(0.140)	(0.028)	(0.053)	(0.013)	(0.051)
R-squared	0.106	0.109	0.109	0.107	0.106	0.108
Observations	1138	1138	998	1138	1138	1138

Panel B: Dependent Variable: Purchased Lime (coupon redeemed)

	Acres Owned	Raven Score	Reading Score	Female	Knowledge input index	Heard about lime
[X]*Field Day	0.020*	0.055	0.033	0.044	-0.009	0.046
	(0.011)	(0.098)	(0.027)	(0.051)	(0.011)	(0.047)
[X]*SMS	0.000	0.017	-0.006	0.060	0.003	0.082*
	(0.013)	(0.100)	(0.025)	(0.048)	(0.010)	(0.044)
Field Day	0.001	0.010	0.032	0.008	0.036	0.017
	(0.027)	(0.047)	(0.025)	(0.043)	(0.023)	(0.031)
SMS	-0.009	-0.018	-0.014	-0.048	-0.008	-0.042
	(0.029)	(0.048)	(0.024)	(0.041)	(0.022)	(0.029)
[X]	-0.000	-0.071	0.003	-0.038	0.010	-0.037
	(0.001)	(0.093)	(0.021)	(0.037)	(0.008)	(0.031)
R-squared	0.090	0.086	0.100	0.087	0.089	0.086
Observations	1138	1138	998	1138	1138	1138

Note: The dependent variable in Panel A is redemption of the Fertilizer coupon. Each column shows the coefficient from the interaction between the corresponding treatment (Field Day or SMS) with the variable noted in the column and denoted by [X]. Reading and raven scores are standardized. Knowledge of inputs is an index constructed based on 12 possible variables. Significance indicated at 1% $***$, 5% $**$, and 10% $*$ level.

Table D: Attrition Checks

	Attrition
Field Day	-0.024
	(0.017)
SMS	-0.019
	(0.017)
R-squared	0.002
Observations	1250

This table shows a regression of an attrition indicator on treatment indicators. Statistical significance is indicated at the 1% ∗∗∗, 5% ∗∗, and 10% ∗ levels.

Table E: IV results for SMS

	First Stage Regression (1)	**Lime Coupon (2)**	**Lime Quantity (Kg) (3)**	**Lime Expenditures (Ksh) (4)**	**Fert. Coupon (5)**
SMS Treatment	0.553***				
	(0.029)				
SMS Received (self-reported)		-0.019	-4.150	-24.899	0.053
		(0.039)	(4.576)	(39.457)	(0.062)
R-squared		0.072	0.109	0.109	0.083
Observation		1166	1166	1166	1166
Y mean		0.11	16.97	59.79	0.41
	Fert Quantity (Kg) (6)	**Fert Expenditures (Ksh) (7)**	**DAP Quantity (Kg)**	**CAN Quantity (Kg)**	**Mavuno Quantity (Kg)**
FFD Participation	2.646	195.964***	2.511***	0.136	-0.001
	(1.619)	(109.943)	(1.371)	(0.777)	(0.012)
R-squared	0.048	0.049	0.045	0.059	0.016
Observation	1166	1166	1166	1166	1166
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 reporting receiving SMS messages on an indicator of whether farmers had been assigned to the SMS group. All regressions control for FFD participation. The standard errors in each regression are robust. Statistical significance is indicated at the 1% ∗∗∗, 5% ∗∗, and 10% ∗ levels.

Appendix E: Messages sent by KALRO

Examples of Messages Received by Farmers as part of the E-extension

- Test your soils in the laboratory every 4 years so that you know the right type and amount of fertilizer to apply.
- If soil is acidic (pH less than 5.5), apply recommended rate of agricultural lime at least 30 days before planting. Enquiries: Tel. XXXXXX
- Prepare land early, ready for planting at onset of rains. Buy recommended certified maize and legume seed from approved agrodealers.
- Crops planted in rows are easier to weed & apply fertilizer. Plant seed maize in rows 2.5 feet (75cm) apart and holes 1 foot (30cm) apart along the rows. Plant 1 and 2 seeds in alternate holes -10kg seed/acre.
- Plant legumes seeds 10 cm apart in middle of two maize rows OR rotate maize fields with legumes in the next season to improve soil fertility. Plant sole legume at 40-50cm between rows and 10-15cm between seeds-30-40kg seed/acre, depending on variety.
- Combined use of chemical fertilizers, manure, compost and crop residues increase harvests and improve soils. At planting, apply 1 flat soda bottle-cap DAP or heaped soda bottle-cap mavuno per hole of maize. Cover with little soil to ensure fertilizers DO NOT touch and burn seed.
- If your farm has striga weed (Kayongo), intercrop or rotate striga tolerant maize (KSTP94) with soyabean, groundnuts or desmodium, apply manure and uproot Kayongo before it flowers and burn it.
- Make sure your farm has no weeds by weeding well and in good time. If plants in a hole are many,reduce to one plant in every hole when weeding.
- Put fertilizer (top dress) of CAN or Mavuno topdress size of one bottle top of FANTA soda on every maize plant three weeks or four after planting. Make sure fertilizer does not get in contact with the plant and covered with soil. Put fertilizer when there is moisture in the soil.

Source: Messages created and sent by KALRO in coordination with MoA.

Appendix F: Cost Data

We include a summary of the FFD costs reported by KALRO. KALRO reported costs for all 6 FFDs that they organized in the area (only 4 were part of this study). We approximate with a simple average to provide a reader with a sense of the costs involved in this intervention.

This data should be taken as an approximation as it might have been difficult for the implementation team to separate their operational costs among different parts of their overall programs.

Program Administration	324,000	Includes costs for KALRO staff hours used, costs for partner facilitation, costs of facilities
Farmer and Partner Targeting	631,000	Includes labor used in targeting, costs for materials, partner recruitment, transport
Intervention Costs	386,600	Includes training fees and transport, compensation for employees, materials for FFD
Other Costs	206,600	Additional staff, demonstration plots, etc.
Total (Ksh)	**1,548,200**	
Total (US) 1US=98Ksh	**$ 15,798**	
Approx. Average cost per FFD ($US)	**$ 2,633**	

Source: These calculations are compiled based on a cost spreadsheet that KALRO shared with researchers.

Appendix G: Summary from Qualitative Report

The research project was complemented by a set of Focus Groups Discussions (FGDs) led by Dr. Salome Wawire. The groups were conducted in the Long Rains 2015 (after the FFDs had been implemented and before the e-extension service started). These discussions helped understand farmers' informational needs, current information sources and their perceptions about usefulness of different delivery methods. For completeness, in this section we present a summary of the main findings by theme.

Method and Sampling: Sampling for the FGDs was purposive, whereby participants were selected based on their area of residence, gender, participation in either of the various program activities, non-participation in any of program activities, and belonging in the social network of participants of program activities.

There were a total of 10 FGDs organized, distributed as follows:

FGD	Participants Description	Location/Area	Num. people	Women/Men
FGD1	Farmers	Kotur	11	5/6
FGD2	Farmers (Women Only)	Simba Chai	9	9/0
FGD3	Farmers who had received soil test in past	Lugulu	7	3/4
FGD4	Farmers who had received soil test in past (Women)	Sikura	10	10/0
FGD5	Neighbors of those who received soil tests	Lukolis	9	6/3
FGD6	Neighbors of those who received soil tests (Women)	Lupida	8	8/0
FGD7	FFD attendees	Anyiko	10	5/5
FGD8	Farmers	Gotnanga	11	10/1
FGD9	FFD attendees (Women)	Eluche	9	9/0
FGD10	Farmers	Buhuru	10	5/5

There were 7-12 participants in each FGD, purposely selected to fit the requirement for each of the groups. The FGDs took an average of 1 hour 45 minutes and were facilitated by a moderator, a note-taker, and a translator, whenever the need arose. The discussions were held in the preferred language of the participants, including Kiswahili, Luhya, Luo, and Teso. The discussions were recorded, and later transcribed and translated to English. The transcripts were further cleaned to check for flow, consistency and clarity of the discussions.

Analysis: The main technique for analyzing the data collected through the FDGs is thematic analysis. The final transcripts were thematically coded and analyzed according to the objectives of the study. A preliminary scan through the transcripts revealed the emerging themes, which were coded accordingly. A deeper-dive analysis of the themes was done to get greater knowledge for each identified theme in line with the objectives. The analysis followed the specific questions under each evaluation criterion to get a deeper and more nuanced understanding of community members' perceptions of their farming information needs, existing farming information channels, the possibility of mobile phone as a channel to disseminate farming information, farmers' experiences with extension workers and agrodealers, and experiences with field plots and soil tests, as well as attending field days.

Results:

- **Perceptions about general farming needs**

Some farmers reported that yields had significantly increased in the last ten years because of practicing modern farming methods, which empowered them to use farm inputs such as manure, fertilizer and seeds. Other farmers reported reduced yields in the last ten years and attributed it to reduced farm sizes and not using modern farming methods and inputs. Most discussants said that they did not use as much farm inputs as they would have liked due to lack of financial resources. The limited ability of farmers to understand instructions and advice on modern farming methods from experts was also mentioned as another cause leading to decrease in yields. One of the main concerns experienced by farmers, while farming their principal crops, included a notable increase of weeds on their farms. Adverse weather changes that affect agricultural activities was another concern raised by farmers. These include heavy rains, strong winds, hailstorms, flooding and inadequate rain leading to drought. There are some farmers who indicated that the presence of counterfeited seeds and a lack of finances to farm at the right time delayed farming processes, affecting yields and profitability.

- **Informational Needs**

Farmers reported having several agricultural questions they wished they had answers for. These included questions regarding information about different types of seed varieties available in the market and when planting of crops should be done. Others wanted to know why they harvested less yields of crops than their expectations at the time of planting. While other farmers wanted to know the appropriate type of fertilizer to use (DAP, CAN or NPK) and others were interested in knowing the soil types on their farms and how to get rid of the striga weed that has been a problem for many farmers in the area.

- **Agricultural Information they have received and sources**

Some farmers indicated receiving information on new seed varieties, new crops, prices, importance of testing the soil, soil PH, the type of fertilizer to use, crop rotation, spacing, farm preparation and storage of crops after harvest. The information was received from various sources, including agricultural extension officers, fellow farmers, group meetings, chiefs, assistant chiefs, and other organizations such as IPA, One Acre Farm, KALRO, NALEP, radio, phones and the internet. Most farmers indicated that the agricultural information they received especially on improved/modern farming techniques and practices was useful to them and it has led to increased yields for those who practiced it. Farmers indicated that the agricultural information that would be most useful to them is on land preparation, seed, and planting, use of fertilizers, crop storage and pesticides. Farmers gave varied information on when, during the farming cycle, they found information most useful. Some indicated that information received before planting cycle was useful while others indicated the information was most useful during the harvest cycle.

The majority of farmers interviewed indicated that agricultural information reached them through the following channels: radio, phones, chiefs' barazas, group meetings, agrovets, fellow farmers, agricultural extension workers, field days, friends or word of mouth. Group meetings, radios, chief's barazas and extension officers were listed as the most used and reliable channels for disseminating agricultural information. The least used channels of communicating agricultural information were mentioned as TV and newspapers because majority of people do not have access to them. The interviews indicated that different groups received information through different channels; for instance, while the youth mostly receive their information from seminars, women mostly receive information from groups in which they participate. These channels were said to be effective. Participants reported that the communication channels can be improved by increasing the frequency of the meetings and this should involve the farmers, extension workers and other agricultural organizations. The people who disseminate agricultural information in these forums also need to receive more training. The most preferred communication channel was group meetings and chief barazas.

- **Reliability of Information**

Some farmers indicated that they received advice and recommendations on agriculture from extension workers. The frequency of interaction with the extension workers varied. Some farmers only met with extension officers once a year during the agricultural shows or open field days; others visited their offices with some regularity. A minority received home visits by extension officers. Most farmers appreciated the assistance they received from the extension workers and they indicated that they trusted the information they received from them. Several farmers indicated that they receive agricultural advice and recommendations from agrodealers. Most farmers indicated that they ask the agrodealers for advice on what inputs to buy while some farmers claimed that some agrodealers sell bad inputs. A number of farmers said they did not trust recommendations form agrodealers because they think that their interest is to sell their stock.

- **Farming information on the mobile phone**

A majority of the farmers indicated that they keep their phones in their pockets or hang them around their necks. There are a few who said that they keep their phones in the house. Phone usage varied from once to an average of twenty times a day based on the amount of airtime people had or the motive for calling. This was the case for SMS and MPESA use. Only two participants indicated that they use the internet regularly. Farmers indicated that they received messages on their phones on sports, weather, news and health. There were very few respondents who indicated that they received farming information on their phones. Majority said they received notification for agricultural meetings or events, though not specific information on farming. Although the majority did not receive information on agriculture, they agreed the phone was an effective channel for communicating agricultural information because it is reliable and it would reach many people within a short time.

- **Diffusion of farming information**

A majority of farmers indicated that they do not generally share a lot of information on farming practices with their neighbors. They also indicated that this lack of information sharing was due to a lack of trust and jealousy among themselves, which means few neighbors would share information of seeds that would boost the yields of the farmers if they had this information. Most respondents indicated that some neighbors would not disclose the inputs they have used on their farms and also their last seasons' harvest. They, therefore, reported not to trust the information from their neighbors because it was likely to be inaccurate.

- **Women's Participation in Farming**

A majority of female respondents indicate that they were in charge of agricultural activities in their household and that the husbands played a supplementary role. Most of them indicated that they performed the day to day running of the farm, and their husband only provided advice, labor, inputs, or financial support. A majority of women said they were more knowledgeable on farming practices than their husbands. A majority of women owned phones, and just a few who shared phones with their husbands. Most women carried their phones all the time and they had access to the phone throughout the day.

- **Farmer Field Days**

Two of the 10 FGDs were with participants who had attended open field day activities (but were not part of the quantitative study sample). These participants were asked to share their experiences attending field days, and indicate what they learned from their experiences. The participants indicated that they were invited to the field days through various channels, including chief's baraza, invitation by a KALRO field officer and the owners of demonstration plots, as the quotes below show:

> *"It was advertised.... I was invited by agricultural officers.... I was called by the owner of the shamba where the demonstration plot was set..... Through posters.... Chief Barazas told us." (Field day FGD participants, Anyiko)*

Participants expressed that they were impressed with what they saw at the demonstration plots and were encouraged to adopt the same practices on their own farms. The crops on the demonstration plots were visibly healthier than those on neighboring farms, and this got the participants curious to learn about the practices employed by the plot owners.

All the lessons taught were useful to the participants, but some issues were seen to be most useful. These included farming techniques, seed types, fertilizer selection and application, post harvest storage and market solutions for their harvest.

References

ADB (2007). Kenya Gender Profile. Human Development Department (OSHD). African Development Bank. Available from:https://www.afdb.org/fileadmin/uploads/afdb/Documents/Project-and-Operations/ADB-BD-IF-2008-16-EN-KENYA-GENDER-PROFILE.PDFAfrican Development Bank.

AGRA (2013) The Africa Agriculture Status Report 2013: Focus on Staple Crops. Nairobi, Kenya. Available from: http://agra-alliance.org/our-results/agra-status-reports/

Anderson, J.R. and Feder, G., (2007). Agricultural extension. *Handbook of agricultural economics*, *3*, pp.2343-2378.

Aker, J.C., (2011). Dial "A" for agriculture: a review of information and communication technologies for agricultural extension in developing countries. *Agricultural Economics*, *42*(6), pp.631-647.

Becker, G. M., DeGroot, M. H. & Marschak, J. (1964). Measuring utility by a single-response sequential method. *Behavioral science*, *9*(3), 226-232.

Berry, J., Fischer, G. & Guiteras, R. (2012). Eliciting and utilizing willingness to pay: Evidence from field trials in Northern Ghana. *Unpublished manuscript*.

Benin, S., Nkonya E.,Okecho, G., Pender J., Nahdy S., Mugarura, S., and Kato,E. (2007) Asseding the Impact of the National Agriculture Advisory Services (NAADS) in the Uganda Rural Livelihoods. IFPRI Discussion Paper 00724. Washington DC: International Food Policy Research Institute

Berazneva, J., McBride, L., Sheahan, M. Guerena, D. (2016). “Perceived, measured and estimated soil fertility in East Africa: Implications for farmers and researchers”. Working Paper.

Birkhaeuser, D., Evenson, R. and Feder, G. (1991). The economic impact of agricultural extension: A review. Economic Development and Cultural Change.

Cole, S., & Fernando, A. (2016). The Value of Advice: Evidence from Mobile Phone-Based Agricultural Extension. *Working Paper.*

Davis, K, Nkonya, E, Kato, E, Mekonnen, DA, Odendo, M,Miiro, R, Nkuba, J and Okoth, J, 2012. Impact of farmer field schools on agricultural productivity and poverty in East Africa. *World Development*, 40 (2), pp.402–413.

Duflo, Esther, Michael Kremer, and Jonathan Robinson (2008). How High Are Rates of Return to Fertilizer? Evidence from Field Experiments in Kenya. *American Economic Review* P&P 98, no. 2: 482-488.

Emerick, K., de Janvry, A., Sadoulet, E. and Dar, M.H., 2016. *Identifying early adopters, enhancing learning, and the diffusion of agricultural technology*. Working paper, Economics Department, Tufts University.

Evenson, R. E. & Gollin, D. (2003). Assessing the impact of the Green Revolution, 1960 to 2000. *Science*, *300*(5620), 758-762.

Fabregas, R., Kremer K., Robinson J, and Schilbach F. (2017). The Market for Local Agricultural Information.

Foster, Andrew D., and Mark R. Rosenzweig. "Microeconomics of technology adoption." *Annu. Rev. Econ.* 2.1 (2010): 395-424.

Hall, A.K., Cole-Lewis, H., Bernhardt, J.M., 2015. Mobile text messaging for health: A systematic review of reviews. Ann. Rev. Public Health 18(36), 393–415.

Hanna, R., Mullainathan, S., & Schwartzstein, J. (2014). *Learning through noticing: theory and experimental evidence in farming*. The Quarterly Journal of Economics.

Hoffmann, V., Barrett, C. B., & Just, D. R. (2009). Do free goods stick to poor households? Experimental evidence on insecticide treated bednets. *World Development*, *37*(3), 607-617.

Jack, B.K. (2011) “Market inefficiencies and the adoption of agricultural technologies in developing countries” White paper prepared for the Agricultural Technology Adoption Initiative, JPAL (MIT) / CEGA (Berkeley).

KALRO (2014) “Scaling up integrated soil fertility management in Western Kenya through an innovative public-private partnership”. Grant Proposal.

Kenya National Bureau of Statistics. Population and Housing Census 2009. Accessed from: http://www.knbs.or.ke/index.php?option=com_phocadownload&view=category&id=109:population-and-housing-census-2009&Itemid=599

Kremer, M., Duflo E., and Robinson J.(2011). Nudging Farmers to Use Fertilizer: Theory and Experimental Evidence from Kenya. *American Economic Review*, 101(6), 2350-90

Kondylis, Florence, Valerie Mueller, and Jessica Zhu. "Seeing is believing? evidence from an extension network experiment." Journal of Development Economics 125 (2017): 1-20.

Kling, J.R., Liebman, J.B. and Katz, L.F., 2007. Experimental analysis of neighborhood effects. *Econometrica*, *75*(1), pp.83-119.

Larochelle, Catherine, Jeffrey Alwang, and Elli Travis. "Did you really get the message? Using text reminders to stimulate adoption of agricultural technologies." Agricultural & Applied Economics Association Annual Meeting. Boston, MA. 2016.

Lee, D.S., 2009. Training, wages, and sample selection: Estimating sharp bounds on treatment effects. *The Review of Economic Studies*, *76*(3), pp.1071-1102.

Marenya, P., and Barrett C. (2009). "State-conditional fertilizer yield response on western Kenyan farms." American Journal of Agricultural Economics 91.4: 991-1006.

Marenya, P., Barrett C., and Gulick T.(2008). “Farmers Perceptions of Soil Fertility and Fertilizer Yield Response in Kenya.” SSRN Scholarly Paper ID 1845546, Social Science Research Network, Rochester, NY.

Mueller, N.D., Gerber, J.S., Johnston, M., Ray, D.K., Ramankutty, N. and Foley, J.A., 2012. Closing yield gaps through nutrient and water management. *Nature*, *490*(7419), pp.254-257.

Nin-Pratt, A., Johnson, M., Magalhaes, E, & You, Liangzhi & Diao, Xinshen & Chamberlin, Jordan (2011) Yield gaps and potential agricultural growth in West and Central Africa. Research reports, International Food Policy Research Institute (IFPRI)

One Acre Fund (2015). Managing Soil Acidity with Lime. 2015 Trial Report. Available from: https://www.oneacrefund.org/uploads/all-files/Managing_Soil_Acidity_with_Lime_.pdf’

Omenyo, V. S., J. R. Okalebo, and C. O. Othieno. "Effects of lime and phosphorus fertilizers on maize performance in acid soils of western Kenya." *Research Application Summaries of the Second RUFORUM Biennale Meeting*. 2010.

World Bank (2008) World Development Report 2008: Agriculture for Development (World Bank, Washington, DC)

Suri, T. (2011). Selection and comparative advantage in technology adoption.Econometrica 79.1: 159-209.

Tittonnell P. et al. (2005) Exploring diversity in soil fertility management of smallholder farms in western Kenya II. Heterogeneity at region and farm scale. Agriculture, Ecosystems and Environment, 110, 149-165

Tjernstrom, E., Carter M., and Travis J. Lybbert (2015). The Dirt on Dirt: Soil Characteristics and Variable Fertilizer Returns in Kenyan Maize Systems. Working Paper

Vanlauwe, Bernard, et al. (2010) "Integrated soil fertility management operational definition and consequences for implementation and dissemination." Outlook on agriculture 39.1: 17-24.

Voortman, R., B. Sonneveld, and M. Keyzer (2000). “African Land Ecology: Opportunities and Constraints for Development.” Center for International Development Working Paper No. 37. Boston: Harvard University

Waddington, Hugh, Howard White, and J. Anderson. "Farmer field schools: From agricultural extension to adult education." *Systematic review summary* 1 (2014).