Preliminary and Incomplete

Information, Market Access and Risk:

Addressing Constraints to Agricultural Transformation in Northern Ghana

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I. **Introduction**

What are the most effective means for improving the agricultural productivity of small-scale farmers in Africa? There is a dramatic contrast between the yields achieved by farmers in Africa and those realized by farmers in other geographical regions or those that crop models generate (e.g., FAO GAEZ). Much of the difference across regions reflects the large differences in the opportunity costs of different factors of production. The goal of a farmer is not simply to maximize yield (as is implicitly assumed by comparing farmer yields to those predicted by models of maximum potential yield); farmers also take into account the costs of production. However, there is a great deal of evidence that most small-scale farmers in Africa are not achieving profit maximizing levels of output given current technology and current levels of prices of inputs and outputs (Dillon and Barrett, 2017). Farmers face a wide array of constraints that reduce their productivity, agricultural income, and living standards. These constraints include imperfect financial markets, uncertain land tenure rights, asymmetric information in input quality, imperfectly competitive output markets, thin and unreliable labor markets and many others. We examine a set of important constraints that previous research has indicated may be of particular importance in the study area of northern Ghana.

Previous research conducted in the region points to the presence of three constraints that bind small farms' productivity: uninsured risk stemming from irregular rainfall; difficulty in accessing high-quality inputs and reliable output markets; and a shortage of information on best practices tailored to local geo-climatic conditions. The present study aims to gain insights on how best to circumvent these constraints to increase yields, boost profits, and improve living standards for millions in the region who depend on smallholder farming.

II. **Research Design and Treatments**

The design of this project rests in particular on findings from two rigorous studies. Karlan et al (2014) found rainfall-based index insurance to have been highly effective in promoting investment among small farmers. But increased investment within the sample did not result in higher profits. Meanwhile, the Soil Health Project (led by the Alliance for a Green Revolution in Africa, 2010-2014) demonstrated the potential for intensified commercial fertilizer use to substantially increase yields when applied according to agronomic best practices.

Integrating these findings, we hypothesized that the increased investment generated by insurance will augment productivity and profit if accompanied by access to inputs and information. We thus implemented three treatments designed respectively to provide each of these three enabling conditions: access to rainfall index insurance (insurance treatment), convenient input purchasing opportunities (inputs treatment), agricultural extension services (extension treatment). In addition, we took advantage of the data collection associated with this project implement two additional interventions: improved access to information about output prices and geographically dispersed markets (MPI treatment), and improved access to information about short-term weather forecasts (forecasts treatment). In the remainder of this section, we explain the study's experimental design and then describe the interventions and data collection procedures.

II.A: Experimental Structure, Sampling Frame and Randomization

We conducted a field experiment designed to estimate the impacts of improved input supply, community-based extension, market price information, and forecast information —alone and in combination—on the cultivation practices of smallholder farmers with access to rainfall index insurance. We also test the effects of these interventions on farmer profits, welfare, finances, and household organization. In addition to overall impact analysis, the design allows us to test operational variations in order to more precisely inform policy recommendations through a set of overlaid experimental components. The interventions were implemented over the course of three farming seasons, 2014-2016.

To construct the study's sampling frame, we carried out censuses in 187 communities from across nine districts of Ghana's Northern Region in 2013. In determining which communities to include in the study itself, we consulted with partner organizations to select inclusion criteria aimed at ensuring feasibility for implementing the interventions as well as the representativeness of sample communities. These criteria included having fewer than 500 compounds located within the community, since the treatments are more difficult to implement within communities larger than this; being connected to at least one telecommunications network, since the extension treatment depends on use of mobile Android devices; never having worked with the partner organizations involved in the project, to allow for an estimate of the treatment itself without the potentially biasing effects of preexisting relationships; and being located at least a kilometer away from any other project community, in order to avoid cross-community spillover effects. From the communities in which we conducted censuses, we selected the 162 communities meeting these criteria to form our sample.[1]

Once our sample of communities had been selected, we implemented a two-step randomization process to assign first year treatments at the community and household levels. The first of the two steps consisted of community-level randomization. The 162 study communities were randomly assigned to four treatment groups, all of which received the insurance treatment:

- Control—Insurance Only (50 communities)
- Extension (52 communities)
- Inputs (31 communities)
- Extension + Inputs (29 communities)

This community-level randomization process was stratified by number of compounds in the community, household size, and distance to the nearest town with a population of at least 250,000.

Within each of the 162 communities, we selected 20 households for our sample. This yielded a total of 3,240 households in our sample, which was reduced to 3,178 households by the

[1] Only 156 of the original 187 communities in which a census was administered met all four criteria, since the distance criteria was added later. We thus conducted an additional six censuses following an identical protocol in order to increase our community sample to the desired number of 162 communities.

end of the study as a result of deaths, permanent migrations, and withdrawals. The random selection of the 20 households within each community was balanced on three variables: household size, total acreage owned, and a dummy variable indicating whether the household head was also the head of the compound. Within each household, two individuals served as respondents: first, the household head and, second, a female spouse who cultivates. If a cultivating female spouse was not available, any other female adult who cultivates was asked to be the respondent. If no cultivating female adults were available, a cultivating male adult other than the household head was selected.

Participating households in communities assigned to each of the four experimental groups—including the control group—were randomized into the insurance treatment. In all study villages, ten respondent households were randomly selected to receive a grant of free insurance. All community residents, including all 20 of our sample households, were given the option to purchase the same product at market price.

Within-community allocation of the remaining treatments worked as follows. In Extension communities, 10 of the 20 study households were randomly assigned to receive the extension treatment. In Inputs communities, all 20 study households along with all other community members received access to the inputs marketing treatment. The 20 study households in each Extension + Inputs community, along with all other community members all received access to the inputs marketing treatment, and 10 were randomly assigned to receive the extension treatment.

Randomization was stratified so as to balance overlap between treatments. Next, we explain the components of each of these three treatments. A description of the two mobile phone treatments – market price information and rainfall forecasting – and their randomization follows.

II.B Insurance Treatment

The insurance treatment consisted of offering rainfall index insurance to farmers residing in study communities. Because farmers within the program's target population depend on rain for a successful harvest, these farmers may be reluctant to increase investment in inputs without assurance that these investments will not be in vain. No matter how high the quality of the inputs, nor how skillfully they are applied, investments will have been rendered useless and money and effort will have been wasted if the rain fails.

The insurance product marketed to project participants was designed by the Ghana Agricultural Insurance Programme (GAIP)—the only agency that was selling rainfall index insurance in Ghana at the time of the study's inception—in collaboration with IPA. In designing the product, GAIP and IPA worked to customize its specifications (i.e., the premium cost, the number of dry days required to trigger a payout to the farmer, and the payout rate) to maximize the benefits for maize farmers in the region while still remaining commercially viable. The resulting product was named Faarigu. The word Faarigu means "savior" in Dagbani, the most widely-spoken language in the study area. The DIRTS project covered the costs of marketing and distribution for Faarigu.

The treatment process worked as follows. At the beginning of each marketing season, all communities were visited by IPA and GAIP staff members. These representatives visited study communities to market the insurance product to the farmers and also to train Community Based Marketers (CBMs). CBMs were individuals residing within their respective study communities, hired and trained to process Faarigu sales and address farmers' questions on the products. CBMs received a flat commission rate for each policy sold. Employing CBMs instead of professional salespeople or agency officers for these tasks was expected to bring two benefits. First, the costs of employing CBMs are lower than those of hiring professional sales agents. Second, trust is a key ingredient within well-functioning insurance markets, and farmers are more likely to trust people they know and live near.

In addition to testing the overall impact of the intervention with CBMs processing the orders, we were interested in learning what types of CBMs would be most effective at selling insurance. Three categories of CBMs were hired across the study communities: village headmen, women's leaders, and people selected on merit following a set of criteria established by IPA. A single CBM belonging to one of these three categories was assigned to each study community. This allowed for a test of the efficacy of different approaches to CBM recruitment relative to one another. Each of the 162 study communities were randomly assigned to CBM groups of equal size, so that each category of CBM was hired in a total of 54 communities. This randomization process was balanced on number of compounds, average household size, and distance from the nearest town with a population of at least 250,000.

For roughly three months following the visit by IPA and GAIP staff members, farmers were given the opportunity to purchase the Faarigu insurance policy through the CBMs. Premiums and payout rates were kept uniform in order to avoid perceptions of inequity. All study households had the opportunity to purchase Faarigu at a flat rate of 12 GHS per policy, with each policy designed to insure roughly one acre's worth of investment. Additionally, ten households within each community were given a grant of three acres of Faarigu, which translated to a maximum payout of 300 GHS (100 GHS per acre) per farming season.

The product as designed at the outset of the DIRTS project was structured as follows. The farming season was divided into three stages: germination, crop growth, and flowering. The germination stage would begin after three rains with two greater than or equal to 8 mm and one greater than or equal to 2.5mm had been recorded within 10 days from 21st of May to June 19th. If these conditions were not met within the window, the germination stage would begin on June 20. Each farmer who received an insurance grant or who purchased insurance would be sent a voice message in their preferred local language during this period to remind them that it was the planting window marking the start of the insurance overage period.

The germination period would last for 25 days and would trigger a flat payout of GHS 25 if 13 or more consecutive dry days were to occur during the period. The second phase, crop growth, would begin on the 26th day of Faarigu coverage and continue through the 120th. Payout would be triggered by 13 or more consecutive dry days within this period. The payout amount would increase as the number of dry days increases beyond 13, to a maximum of GHS 75. For the rest of the coverage period—the flowering stage—a cumulative total of less than 125 millimeters would trigger a payout of the full GHS 100 per acre (or raise the payout to the full GHS 100 if a lesser payout had already been triggered during earlier stages).

To determine payout, the treatment area was divided into pixels covering 10 square kilometer areas. Rainfall data for each pixel would be collected from the National Oceanic Atmospheric Administration of the United States government, and this data would then determine payouts for all communities located within that pixel as calculated by GAIP and confirmed by IPA. Insurance holders would then be notified as to whether they would be receiving a payout for that season and, if so, the payout value.

II.C Insurance Treatment: Implementation, Take-up, and Modifications

2014 Farming Season

To launch the insurance treatment, 162 CBMs—one per community—were recruited in December, 2013. In February, 2014, the insurance marketing script was piloted in three communities, and CBMs received training on the script and other steps in the marketing process. Between March 3 and April 30, the product was marketed within each community by a team consisting of one IPA marketer and the community's CBM. During the first half of May, 2014, premiums were collected from the communities, the CBMs were paid their commissions, the free policies were awarded and insurance certificates were distributed.

For the 2014 season, 437 individuals (including 38 women) across 90 out of the 162 DIRTS communities purchased a total of 601 acres of insurance (i.e., covering GHS 60,100 in investment). With the premium per acre costing GHS 12, this totaled to GHS 7,212 in premium payments. GHS 601 of this was paid to CBMs as a commission (GHS 1 per acre of insurance sold). 4,860 acres worth of free policies were awarded and distributed during the first half of May, 2014 (three acres each for ten farmer each across 162 study communities).This totaled to 5,461 policies: 4,860 from grants and 601 that had been purchased. 2,031 farmers were thus covered by insurance, between the 437 who purchased it and the 1,620 who received grants, (minus the overlap).

Similar to the 2013 pilot sales patterns, policyholders in 2014 insured an average of 1.33 acres (the equivalent figure for the pilot had been 1.36) and 3.7 acres per community with at least one farmer that purchased a policy. The minimum number of acres insured among buyers was one, and the maximum was 10. Average uptake per community was 1.58 percent, considering that the average size of the 162 DIRTS communities is 67 households, 39 compounds, and 203 adults.

Monitoring data suggests that, consistent with findings from the qualitative FGDs that followed the insurance pilot, trust constituted an important constraint on insurance demand. Prior exposure to insurance seems to have been a key factor in uptake. The 41 DIRTS communities that had participated in the insurance pilot exhibited an uptake 1.67 times larger than the communities that were not part of the pilot. This effect is even more evident in communities that actually purchased insurance during the pilot--these communities had an uptake 3.2 times larger than non-pilot communities. This association may have been especially strong because all farmers who had purchased insurance during the pilot had ended up receiving a payout.

Wrap-up questionnaires were administered to 313 of these policyholders at the time of collecting premiums from the communities, with the objective of capturing information on the attributes of insurance buyers, as well as their level of understanding of the product. The majority of farmers who purchased insurance were between the ages of 25 and 45, with most being around 30 years of age. This differs from the distribution of ages that was collected from the community DIRTS baseline survey, where the majority of residents were between the ages of 15 and 30, with a peak at 20.

Women comprised 38 percent of buyers, and on average, they purchased 1.27 acres of coverage in comparison to the men who purchased 1.43 acres of coverage. However, men cultivated an average of 11.13 acres of land, which is significantly more than the average woman who cultivated 4.9 acres of land. Consequently, men only insured 13 percent of the land they cultivated, whereas women insured 26 percent of their land.

The majority of farmers who purchased insurance cultivated between three and four crops. A negative correlation exists between the number of crops that a farmer cultivates and the number of acres of insurance that he or she purchases. This could be an indication that by planting various kinds of crops, farmers feel they face less risk from poor weather and, hence, would not benefit as greatly from insurance.

As explained above, communities were randomly assigned to CBMs of three different types: a community headman, a women's organizer, or a person selected through merit. In 2014, the women's organizers sold the most acres of coverage to the greatest number of farmers. They sold an average coverage of 4.3 acres to 3.2 farmers per community. The community headmen followed, selling an average coverage of 2.72 acres to 2.94 farmers. Last were the CBMs selected on merit, who sold an average coverage of 3.16 acres to an average of 2.18 farmers. To ensure that these results were not skewed by the population size of communities to which CBMs were assigned, uptake as a percentage of the population was also tested This confirmed that women organizers had the highest average uptake of the three CBM types. Of all female buyers, 57 percent purchased from a women's organizer, although women bought similar amounts of coverage from each CBM type. Men were most likely to purchase from the community headman and purchased more coverage from each CBM type than women did. However, the differences in overall sales between the CBM types were not statistically significant.

Community members' understanding of the insurance product also seems to have been a major factor in determining their willingness to purchase it. Four questions to test farmers' knowledge of the product were included as part of the questionnaire administered to policyholders. Farmers with a women's organizer as their CBM scored the highest, followed by those with a village headman as their CBM and lastly those with a CBM selected based on merit. However, there was no connection between the number of acres policyholders purchased and their score on the quiz.

Coverage for the 2014 season ended on October 17. The 2014 season had seen adequate rain, and no farmers holding Faarigu policies received payouts. We drew on lessons from the season's insurance treatment implementation to make several adjustments for the following year.

2015 Farming Season

Demand for insurance during the 2014 season had been lower than expected and, because no payouts had been triggered, we expected that demand for Faarigu during the 2015 season would be at least as low. Furthermore, severe price inflation had weakened the value of the insurance grants. We therefore decided to increase the insurance grant from 3 policies to 23. This meant that, for the 2015 season, each insurance grant recipient was entitled to a maximum payment of GHS 2,300.

We additionally sought to stimulate demand for the insurance product through a more ambitious advertising campaign. Beginning in 2015, information on Faarigu and agricultural insurance more generally was circulated through a special episode of a popular radio program called Batoro, aired on Savanna Radio. This was aired four times during March-April of 2015 and twice in May of 2016.The program included a fictional drama about agricultural insurance and a live question and answer session with listeners, broadcast during prime time.

Mobile video vans were also hired to show informational videos within all 162 study communities during evenings. This effort was conducted in partnership with both the Ministry of Food and Agricultural Information Support Unit and District Information Service Department. Posters providing information on Faarigu were also posted in DIRTS communities. Farmers within the sample were thus amply informed about and given sustained opportunities to purchase Faarigu.

CBMs collected premiums for the 2015 farming season between February and mid-May. Perhaps in part as a result of the increased advertising, 2015 saw a near-doubling in value of insurance purchased relative to 2014, with 1,070 acres of insurance sold (worth GHS 107,000 in payments). These purchases were spread across 815 individuals, 563 men and 252 women.

A payout amount of GHS 25 per unit insured was triggered during the germination phase of the 2015 farming season in 160 out of the 162 DIRTS communities. The 2015 notification of the payout outcomes occurred beginning in January, 2016. Unfortunately, distribution of the payouts was delayed by roughly six weeks as a result of difficulty in processing the sums of cash required while managing the risks that came with traveling with this much cash. The payout distribution for this marketing period thus extended into May 2016, with policyholders collectively eligible to receive GHS 156,275.

2016 Farming Season

We introduced two main modifications in the 2016 farming season. First, Faarigu was offered over two time schedules during this season. Farmers in the region generally complete maize planting by late May, which is why Faarigu had originally been designed to begin at that time. However, irregular rainfall can result in failed germination, meaning that farmers may choose to replant. We thus offered a version of Faarigu with a coverage timeline designed for late maize planters targeted towards farmers in this situation.

Second, we randomly divided the 1,618 households that would receive insurance grants into a light insurance grant group that would receive 3 acres (618 households) and a heavy insurance grant group that would receive 42 acres (1,000 households). A total of 43,854 acres of Faarigu were thus given out in the form of grants. Our hope was that this division would provide us a better sense of the level of insurance required to significantly spark agricultural investment.

During the 2016 farming season, the CBMs and IPA field staff marketed the insurance product in all communities between April 15 and May 16. This was several months later than planned, as a result of delays from GAIP in providing policy details and time-lags between requests for clarification on the product and GAIP's responses. However, this delay is not likely to have influenced purchase rates since data from the first two years of implementation suggest that sales tend to concentrate towards the end of the sales period anyway (i.e., early to mid-May). Additionally, though the actual marketing days in the communities only took place as late as April, community members knew that drought insurance would be available this year after having been exposed to marketing for the previous two years. Finally, the upside of the delayed timeframe was that payouts from the 2015 season had been almost fully distributed shortly before the onset of marketing, thus potentially providing a well-timed nudge to buy insurance.

In total, 1,801 Faarigu policies were sold during the 2016 farming season, in addition to the 43,854 given out as grants. Because rain patterns were classified as adequate according to the Faarigu criteria, no payouts were issued.

II.D Inputs Treatment Design

Insurance may motivate farmers to invest more in productivity, but this motivation will not translate into productivity gains if farmers cannot access important inputs conveniently, at the right prices, and at the right times

But input markets in northern Ghana are fraught with bottlenecks. For instance, fertilizer marketing has typically occurred after subsidy rates are announced in the spring, rather than immediately after the fall harvests when farmers have more cash on hand. And the subsidized fertilizer tends only to become available after the recommended time to apply it to the land has passed. From a supply-side perspective, retailers may be hesitant to invest in marketing over the course of the season because it is difficult to predict demand before the season's fertilizer subsidies have been announced.

To address these frictions, we sought to assemble an inputs retail supply chain tailored to the needs of the region's small-scale farmers. For the inputs treatment, we offered farmers the opportunity to purchase a variety of agricultural input products at market prices during several strategically selected periods throughout the farming season. We also provided free delivery. We worked directly with local retailers, given their direct interest in gaining information on demand for their products at different points throughout the season, as well as insight on which marketing strategies are likely to be effective.

To establish a network of private retailers, we conducted a market assessment in September, 2013. The process identified retailers who seemed viable based on the types of inputs they offered, their location, and their capacity to stock the needed quantities. We also made direct contact with wholesalers in the area to ensure the likely stability of the supply chain.

Between September and November of 2013, IPA developed a catalog of inputs that would be provided through consultations with a wide range of stakeholders, including community members, inputs retailers, and District Directors of the Department of Food and Agriculture, and scientists from MoFA and SARI. The consultations culminated in a November workshop that was aimed at introducing the program to District Directors and retailers and sharing ideas on how best to operationalize the supply chain, in addition to selecting the specific inputs to sell. Although initially we had planned only to market fertilizers, we ended up opting for a wide variety of inputs, including certified seeds, weedicides, pesticides, and even boots, gloves, and goggles. Total inputs in the initial catalog numbered around 100.

As with the insurance treatment, we elected to hire and train one resident from each community to be a CBM. These CBMs would process the farmers' input orders and act as the program's frontline agent. We expected that relying on CBMs rather than on retailers or other professional staff to manage day-to-day transactions would help reduce costs and build trust in the program among community members. For the inputs treatment, CBMs were initially unpaid volunteers nominated by their communities, but received phones as an incentive to participate and in order to facilitate the communications needed to process orders. Criteria for eligibility included being a permanent resident in the community, ability to speak and write in English, basic bookkeeping skills, and willingness to work for a commission, rather than a wage or salary. The selected CBMs were trained on how to record orders and the protocols of the intervention. During the second season of the intervention, CBMs were also paid a commission in an effort to improve sales rates. CBMs collected orders and, in conjunction with IPA, arranged for bulk shipments of the orders to the community. IPA covered marketing and transportation costs for the intervention. The inputs treatment thus sought to provide an efficient and cost-effective response to the supply chain constraints that had been hypothesized to bind productivity-inducing investment.

Representatives from IPA and the input retailers visited input treatment communities several times throughout the year. During each visit, these representatives held community-level meetings to market the various inputs to the farmers. Each visit by the representatives was followed by a three-week period during which farmers could buy the inputs from CBMs. Three marketing rounds were planned annually: (1) January/February shortly after harvesting when farmers have cash in hand; (2) March/April before the planting season, to enable farmers to use certified seeds and apply fertilizers within two weeks after planting, and, crucially before the end of the insurance marketing period; and (3) June/July once fertilizer subsidies are announced, which is when historically most inputs have been sold in the past.

IPA covered costs for marketing and transportation of the goods (although the retailers were responsible for arranging transportation), but farmers would pay retailers the market rates for the goods net of marketing and transportations. The inputs treatment thus sought to provide an efficient, cost-effective response to the supply chain constraints that had been hypothesized to bind productivity-inducing investment.

II.E Inputs Treatment: Implementation, Process, and Takeup

CBMs for the first season were recruited in 59 communities in January 2014. Selections were made based on nominations from their respective communities. During this time, IPA also entered into the initial contracts with partner retailers stating the details of their commitment to supplying the inputs and arranging delivery.

In February 2014, one week into the beginning of the first marketing round, the prices of inputs and fuel increased due to the devaluation of the local currency, the Cedi (GHS). As a result, IPA was forced to renegotiate to some extent the transportation rates and decided to cover the price difference between the inputs prices communicated to farmers at the beginning of the marketing round and the market prices at its end. The Cedi devaluation continued to affect inputs prices in the rest of the marketing rounds. Starting from the second round, IPA communicated updated prices to communities on a weekly basis and only paid the difference if prices changes in the week-long timespan between one price update and the next.

As explained in the preceding section, three marketing rounds were initially planned (January/February, March/April, and June/July). However, we decided to add an additional round, in May. Farmers in the extension treatment had just received messages on planting and the use of certified seeds (which had not been available before May) at this point, and this round would provide them the opportunity to put knowledge gained from the extension treatment into practice. The June/July round had been scheduled to coincide with the release of the government's announcement of the year's fertilizer subsidies, but these were delayed and we were forced to commence with this fourth marketing round before the announcements had been made.

The four rounds of marketing produced total sales of GHS 73,015 for 2014. 328 units were sold in during the first round (GHS 6,946), 601 during the second round (GHS 17,659), 889 during the third round (GHS 20,555), and 531 during the fourth round (GHS 27,854). The relatively low sales from the first round did not come as a surprise given that the retailers reported that, prior to the DIRTS intervention, it was very uncommon to sell agro-inputs in the first few months of the year.

Six rounds of marketing were held during the 2015 season, totaling GHS 84,775: 231 items in the first round (GHS 4543.5), 625 items in the second (GHS 10,869), 790 items in the third (GHS 11,891), 902 items in the fourth (GHS 23,087.5), 990 items in the fifth (GHS 34,384) and 691 items in the sixth (GHS26,640).

In view of a lack of response to the inputs marketing intervention both in terms of farm productivity and even agro-chemical inputs' use, a decision was made to discontinue this treatment in 2016. Following the decision to phase out the "Access to Input Technologies" Intervention from the DIRTS project for the 2016 Implementation year, the IPA staff carried out exit sessions to properly inform all key stakeholders. These exit sessions were carried out in all 60 communities with the CBMs and community members in group gatherings. All ten partner retailers and an additional ten non-partner retailers were interviewed in a round of qualitative surveys to gather their views on the intervention and ideas for potential adoption and scale-up of the intervention. Findings from these interviews were used to inform discussions in the final exit workshop held with retailers during which sales made through the project in 2015 and implementation reports were also shared.

II.F Extension Treatment Design

The extension treatment consisted of hiring, training, and deploying Community Extension Agents (CEAs) within the treatment area, with the objective of providing target farmers with guidance on agricultural best practices. Even if farmers have insurance and access to inputs, they may lack technical information on how to optimize the use of these resources. Clear and actionable instructions on the use of inputs from trusted sources might change farmers' practices and thereby assist them in improving their yields and profits.

Agricultural Extension Agents (AEAs)—professionally-trained specialists employed by Ghana's Ministry of Food and Agriculture—make routine visits throughout the region to hold group trainings. But there are not enough AEAs to fill the demand for services. The extension treatment thus followed a model pioneered by the Grameen Foundation through its Community Knowledge Worker program in Uganda, employing community residents to do extension work as a lower-cost alternative to professional state-provided services. This concept ties in closely with the CBM approach used in the insurance and inputs treatments. Our extension treatment was piloted in 2013 in 30 communities, which helped to improve the delivery of extension information, as well as the content itself. In order to generate the possibility for testing for within-community knowledge spillover effects, and to increase statistical power, we designed the intervention model so that only a randomly selected half of respondents in each community would themselves receive the messages.

Within each of the communities that received the extension treatment, implementers solicited applications and hired one community resident to be that community's CEA (along with one back-up per community). CEAs typically had been farmers themselves, but lacked formal training in agronomy. No fixed salary was provided to the CEAs, but they were compensated per extension visit conducted. Applicants for the CEA post completed a screening test to ensure that they met the requirements, which included fluency in English as well as the local language, and a literacy level sufficient for the extension tasks at hand. A panel, consisting of an AEA, an IPA staff member, and a distinguished community member, convened within each treatment community to interview shortlisted candidates and make the final selection. The newly hired CEAs were then provided with three weeks of training, along with practice field trips and additional refresher courses in advance of the later seasons.

Once trained, each CEA was tasked with providing extension services to ten farmers within his or her community, randomly selected from the community's 20 DIRTS study households. CEAs would then visit each of these farmers once per week for 30 weeks each year of the intervention to communicate a specific, predesignated message relating to agricultural best practices. For the first year of program implementation, the content that was communicated pertained exclusively to maize agriculture. However, because maize in northern Ghana is overwhelmingly cultivated by men, material for legume agriculture was added for the second and third extension seasons, beginning in 2015. Women in the study area most commonly cultivate three types of legumes, groundnuts, soya, and cowpeas, so the additional extension material focused on these three crops.

A key component of the extension treatment was the use by CEAs of a mobile software application. The CEA model derived its potential in part from the low cost of hiring CEAs relative to AEAs or other professionally trained individuals who would have required higher wages. This means that CEAs' technical knowledge was likely limited relative to that of AEAs or other professionals. The software application compensated for this gap by providing customized information in an engaging multimedia format.

Specifically, CEAs were equipped with an Android device (a smart phone during the 2014 season, replaced with a tablet during the 2015 season to make it easier to watch videos) that contained 20 video messages and 10 audio messages, as well as a diagnostic tool programmed using Open Data Kit software. The diagnostic tool prompted the CEA to ask several questions relating to farm activities and plans and, based on the respondents' answers, to indicate which recorded extension message the CEA should activate. Messages covered a variety of topics spanning the growing season from land clearing to fertilizer use, and from seed varieties to weeding and field maintenance. The information entered by CEAs was also captured by the device as data to be analyzed by the researchers, in order to gain an additional window into prevalent farming practices, beliefs, and concerns. In addition to the mobile device (smartphone or tablet), the CEAs were provided with a handbook containing more detailed information to share with farmers.

Following recommendations from study respondents, the method of extension delivery was redesigned for the third year of the interventions - CEAs began delivering extension messages to groups of farmers, instead of holding one-on-one meetings with individuals. Groups were segregated by gender and crop of interest. Control farmers in treatment villages were no longer excluded from the treatment under the new treatment model—all farmers in the community could join. However, the CEAs were required to ensure that the 10 CEA treatment households attended the sessions, and to hold catch-up meetings with any treatment household who missed a session. To aid in showing extension videos to groups, videos were shown on 21-inch LED TVs instead of mobile devices. Selection of which video messages to watch at each meeting was determined by administering of a modified version of the CEA diagnostic tool used in the preceding two years. This key change in method allows us to test variations of the intervention and gauge the impact of a revised and more scalable model, since group extension services are, all else equal, significantly less costly than one-on-one extension services.

The CEAs remained in close contact with AEAs throughout the treatment period, and sought advice from AEAs when farmers had questions that the CEAs had not been trained to address. The AEAs also supplemented the CEAs' work by holding community trainings on relatively complex topics like pest and disease control. The program makes provisions for AEAs to visit each CEA twice during the course of the season to provide on-ground technical support in the delivery of messages and in addressing concerns of farmers. The efforts of the CEAs and AEAs in conjunction with the software application thus attempted to provide a comprehensive and customized training package for productivity-maximizing practices.

II.G Extension Implementation and Process

Between October 2013 and March 2014, IPA contracted Countrywise Communications, a video making company, to produce the video extension messages. The contractor shot videos in various locations of the Northern and Brong-Ahafo Regions, as well as on a demonstration farm arranged for by IPA and managed by SARI from November 2013- April 2014. This farm also served as the on-field practical training cite for the March/April 2014 CEA training.

CEA recruitment for the first year of the intervention occurred in December, 2013. The position was advertised through bulletins posted in treatment communities, and interested candidates were invited to complete application forms. Women were particularly encouraged to apply. The candidates then went through the interview procedure described above. CEAs were trained in March and April of 2014 in the content, use of mobile technologies, and field protocols. All but two CEAs passed the test, and a third CEA resigned after being accepted for tertiary education, so three replacements were subsequently hired and trained. Message delivery began on April 28 and continued for 33 weeks. During the first five weeks, CEAs delivered a total of 3,163 messages, averaging 632.6 messages per week, slightly but not far below the intended 810 messages per week (81 CEAs each delivering one message per week). Message delivery preceded as planned, with only small adjustments throughout to align the message delivery schedule with the relevant points in the farming season.

By the end of the maize farming season in 2014, the CEAs had delivered 14,767 need-sensitive agricultural extension messages in video or audio formats. The farmers in turn asked 4,115 questions after receiving the agricultural extension messages.

Between September and November 2014, the CEA team hosted two separate workshops with Agricultural Extension Agents (AEAs) from the Ministry of Food and Agriculture (MoFA) to develop content for the legume messages on soya, cowpea and groundnut which was added to the extension program for the 2015 farming season. A second member of each treatment household, in almost all cases the wife of the primary respondent or the most senior female cultivator in the household, was added as an extension recipient. The CEAs delivered a total of 45,247 extension messages over the 2015 farming season.

Following the 2015 farming season, a qualitative survey was conducted in which CEAs, AEAs, and a sample of respondents from 41 Extension treatment communities were interviewed.

These interviews focused on what they found useful or not useful from the extension training. Feedback from these questions and subsequent focus group discussions were used to inform content development activities of extension messages for 2016. The aim of the content development were the following: reduce the overall number of extension messages by merging topics which addressed related practices or topics; and provide additional information on topics which were perceived as not promising to yield any impact in terms of increased learning or adoption.

Development of draft extension messages was carried out in March. These draft extension messages were shared with agronomic specialists for validation of content in the first weeks of April. Videos and manuals were updated accordingly.

For the 2016 implementation of the extension intervention, several key changes were introduced, informed by the qualitative survey. Key changes include reduced monitoring presence of IPA field staff to supervise and support work of CEAs and increased involvement of AEAs in taking over these responsibilities; and a switch from one-on-one visits between CEAs and respondents to group meetings. Groups were segregated by gender and crop of interest, and these meetings did not put a rigid filter on control farmers: all farmers in the community were free to join, but payment to the CEAs remained contingent upon attendance by treatment housholds. Farmers watched the extension messages on a 21-inch LED TV set. At the group meetings, CEAs administered a diagnostic tool survey using a tablet, and showed two videos recommended based on the responses of farmers to the survey questions. Message delivery of the 2016 farming season of the program ended with a total of 8,687 maize and 8,318 legume messages successfully delivered.

During the 2016 farming season, the Department of Agriculture intensified the support for CEAs in project communities. The AEAs visited their assigned CEA communities once a month to discuss with farmers issues beyond the understanding of CEAs, and also to monitor CEAs' performance. This partial handover of responsibilities from IPA to the Department of Agriculture was designed to pave the way for scale-up and adoption of the CEA model by the Department, if chosen.

In the week of May 23, all equipment and logistics were distributed to the CEAs in their respective communities. In the same week, 81 CEAs resumed delivering extension messages to farmers in their communities. The messages were delivered over 23 weeks, and as in the past, they were divided into three groups: pre- and early season, mid-season and late-season messages. In-between groups we built in a mop-up period to allow all CEAs to keep abreast with the deliveries. 46 messages were shown over the course of the season for maize and another 46 for legumes.

CEAs were encouraged to consult the extension handbook that IPA, SARI and the Department of Agriculture put together for them; and encouraged to contact their AEA whenever they were faced with technically challenging questions from a farmer or issues on a farmer's field.

II.H Overlaid Experiments

In addition to estimating the impacts of the three interventions described above, we tested two additional treatments through overlaid experiments that cut across the experimental groups described so far: a weather forecast treatment and a market price information treatment.

In order to test the effects of reducing weather uncertainty on farming practices, we collaborated with the company Ignitia Tropical Weather Forecasting to provide rain forecasts to farmers via text messages. These forecasts were delivered to 10 households each in 108 communities, while the remaining 54 communities remained untreated. This design allowed us to test first the effect of receiving forecasts on farming operations for treatment households contrasted against households in control communities, and second whether the information from the forecast spread to control farmers in treatment communities, i.e., those who did not directly receive the forecasts but live in treated communities.

Target farmers received three types of forecasts: seasonal forecasts intended to help decide which crops to cultivate and how much land to farm, monthly forecasts intended to help decide on a planting date, and daily forecasts hypothesized to influence a range of shorter-term activities. Forecasts were customized to recipient households' locations. Daily forecasts included information on the likelihood of rain, as well as on the rough time of day the rain was expected, and whether the rain was likely to be heavy.

The second overlaid experiment tested a market price intervention treatment. Because preliminary data analysis suggested that the DIRTS program was succeeding in helping farmers to learn and adopt new practices but that profits were remaining stable, we hypothesized that lack of information on market prices might be constraining profits. To alleviate this constraint, we partnered with the agricultural information and communication service provider Esoko to send selected respondents market information via text message. DIRTS communities were randomly divided into three groups of 54 each: one in which all study households received the text messages, one in which only five households received the text messages, and a control group with no text messages. The text messages contained information on the prices of maize and groundnuts at six markets within the Northern Region.

II.I Data Collection

The goal of our study is to estimate the extent to which the DIRTS treatments affected farming activities —i.e., size of cultivated area, labor use, employment of recommended farming practices, and use of inputs like agrochemicals, tractor services and seeds—and benefited target households by improving crop yields, farm profits, and household welfare. To measure these outcomes, and to gather a rich set of complementary data, we designed and utilized a series of mutually complementary data collection instruments. All surveys were subjected to monitoring and random audits to ensure quality.

The central set of instruments was a series of Comprehensive Annual Surveys (CAS), which consisted of a baseline survey, two midline surveys, and an endline survey. The purpose of these detailed household surveys was to collect socioeconomic data, information on cultivation practices and investment behavior, and yield and profit figures. The surveys were conducted by a team of well-trained field staff equipped with netbooks. Around the same time as each round of the CAS, enumerators also conducted a Market Survey. This involved collecting data on food prices from 21 markets in the region, in order to gain information on the local agricultural economy during the time period captured by the corresponding CAS.

To gain a more detailed picture of the effects of the extension treatment, we also administered a Knowledge and Practice Survey (KPS) following the 2014 farming season. The KPS instrument tested the extent to which farmers were absorbing new knowledge and changing their practices accordingly. The KPS contained a section on agricultural knowledge, one on agricultural practices, and one on insurance. The agricultural knowledge section was essentially a quiz on agricultural best practices. Questions from this section were divided into "curriculum" items relating to content from the extension treatment on one hand, and "placebo" items on the other that related to farming but would not have been covered within the treatment curriculum. The ideas was that, if the extension treatment were working as planned, we would expect to see impact on curriculum items but not on placebo items. The agricultural practices section asked about the inputs and techniques that the respondent used in farming, and the insurance section asked about knowledge of, opinions on, and future demand for insurance. After the 2015 and 2016 farming seasons, the KPS questions were integrated with the Comprehensive Annual Survey.

The data on farming practices collected through the KPS were self-reported, and thus potentially subject to bias. For instance, farmers exposed to the extension treatment may have remembered which practices the curriculum had recommended, and falsely reported having carried out these practices to please the interviewer. In an effort to avoid this problem, we employed another instrument, the Practice and Observation Survey (POS), which was conducted once in the 2015 farming season. For the POS, enumerators visited farmers' fields to directly observe and document farming activities through photographs and GPS measurement.

Potential bias in self-reported responses also extends to yields. Respondents may not know or may misreport the quantity and value of their crops. To account for this possibility, we directly measured the yield of a randomly selected subset of the DIRTS sample in the Crop Cut Survey (CCS). For the CCS, enumerators harvested and weighed cobs from respondents' plots.

Given the central importance of labor investment in shaping profit outcomes, we complemented the instruments discussed thus far with a fine-grained, high-frequency instrument: the Biweekly Labor Surveys (BLS). The implementation of this survey followed a model similar to that of the extension treatment described above—local community members visiting farmers, asking them questions, and entering the answers into an electronic device. Employing local residents for data collection is significantly less costly than hiring professional surveyors, and was feasible for the BLS because this instrument did not ask for sensitive information. During each visit, the local enumerators asked whether each of the household's plot was under cultivation and, if so, the quantity and gender distribution of labor employed. In addition to providing detailed data, this approach helped to minimize recall bias by asking about labor almost immediately after it had been employed.

Like labor, accurate information on the location and size of farms is essential for correlating yield data to weather patterns. GPS measurement tools were used to measure plot size. Plot measurement surveys were designed to gather geo-referenced coordinates of respondents' plots and accurate size of their plots. Three plot measurement surveys were conducted over the project period. Like the BLS, the plot measurement surveys were carried out by community members.

In addition to the above instruments, which were designed to capture the study's main variables of interest, we also collected a variety of types of monitoring data. We kept detailed records of all input and insurance policy purchases, along with dates and demographic information on the buyers. Another source of monitoring data was the information collected over the course of the extension treatment by the CEAs as part of their weekly visits to farmers. As part of the intervention, the CEAs asked weekly during treatment periods about farming activities and entered responses into their devices. In addition to prompting the CEA to select the proper audio or video recording—the core of the extension treatment—the information entered was stored as data. In all, CEAs collected weekly information on farming activities for the 810 households in the extension treatment.

We also gathered data on target farmers' opinions of the treatments, both in order to gain a more nuanced understanding of the processes underlying impact and to improve the intervention. On the quantitative side, we conducted a follow-up survey in 2016 to find out whether treatment activities had occurred as planned. We also carried out regular qualitative research through focus group discussions and individual semi-structured interviews. The qualitative data helped us to better understanding why we were witnessing the patterns we were—for instance, why participating farmers were retaining and acting on some extension messages but not others.

III. **Results**

Figure 1 provides a timeline of the major project implementation and data collection activities. Figure 2 provides an overview of the randomization process.

III.A: Balance

The three core first year treatments were assigned based on only census data, so it is possible that the randomization resulted in imbalanced baseline characteristics. Table 1 shows that this indeed the case for some variables. There is a statistically significant imbalance in baseline maize harvest (with treatment group 11: household assigned to the extension and input treatments in communities assigned to the extension, input and insurance treatment having lower baseline maize harvests, while treatment groups 1 and 3 having higher baseline maize harvests) and in chemical expenditures (with treatment group 11 having lower expenditure and treatment groups 1, 2, and 3 having higher expenditure). The final three rows of Table 1 provide marginal effects of each of the three key treatments on each variable at baseline (evaluated at the mean values of the other two treatments); these marginal effects will be a central focus of the analysis to come. A small amount of baseline imbalance appears here as well, with the free insurance treatment being associated with lower baseline groundnut harvest. All subsequent analysis includes controls for baseline values of the dependent variable, except when otherwise noted. The subsequent treatments (heavy insurance, forecast and market price information text messages) were rerandomized with 10000 replications to minimize the maximum p-value of differences in baseline characteristics across treatment assignments, so there is no imbalance across these treatments.

III.B: Core Agriculture Results

We first examine the average marginal impact of the extension, free insurance (in its "light" and "heavy" variants) and input treatments on the main farming outcomes for households, over the three years of the project.

We examine seven household (and later, plot) level agricultural outcomes to evaluate the main impacts of these treatments. These outcomes are:

- Land area cultivated – for the main results we use self-reported area, but for robustness use GPS measured area as well
- Land preparation expenses – the value of tractor and animal ploughing services, plus the value of labor used for plot clearing
- Internal labor expenditure – the value of family labor used in post-land preparation farming activities, valued at gender- task- and community-specific wages
- External labor expenditure – the value of hired, exchange and community labor used in post land preparation activities
- Seed expenditures
- Chemical expenditures – for fertilizer and pesticides, also including the value of organic fertilizers
- Harvest value – the value at harvest period prices of all farm output

In addition, we sum the first six outcomes to calculate total farm expenditures, and subtract the latter from harvest value to calculate farm profits.

Let $I_{git} = 1$ if household i is assigned to treatment $g \in G \equiv \{extension, light\ insurance, heavy\ insurance, input\}$ in year t. For each dependent variable, the model is

$$y_{it} = \sum_{g \in G} \beta_g I_{git} + \sum_{g \in G} \sum_{f \in G} \beta_{fg} I_{fit} I_{git} + \sum_{g \in G} \sum_{f \in G} \sum_{e \in G} \beta_{efg} I_{eit} I_{fit} I_{git} + X_{it}\beta + \epsilon_{it}. \qquad (1)$$

The first three sets of terms each of the different treatment groups defined by the four basic interventions and their interactions. Not all interactions are realized in our design: heavy insurance was only introduced in the 2016 farming season, and the input treatment was only implemented in the 2014 and 2015 farming seasons. X_{it} includes the baseline value (in the 2013 farming season) of y_{it}, and the variables on which randomization was stratified. ϵ_{it} is permitted to be correlated within communities, so all standard errors are clustered at the community level.

Table 2 presents the average marginal effect of each of the four treatments on each of these 9 outcomes. The extension treatment lowered the area cultivated by treatment households, and reduced land preparation expenditures and total farming expenditures, with no impact on harvest values. Consequently, farming profits increased, although the change in profits is not statistically significantly different from zero at conventional significance levels. The changes in are small; 2%-3% of the baseline levels. Baseline profits are near zero, so the point estimate of the change in profits is large relative to the baseline level, but still small relative to harvest value or total farming expenditure.

We find no statistically significant impact of either the light or the heavy free insurance treatment on any of these agricultural outcomes. The point estimates of the marginal impacts of these treatments are small, and the 95 percent confidence intervals do not include increases or decreases of more than ten percent in any of the seven farming outcomes.

The input treatment reduced internal and external labor costs and increased expenditure on seeds. Total farming expenditures declined, and profits increased. The decline in internal labor costs were about 5 percent of the baseline value, and the decline in expenditures on hired labor was 8 percent. Total expenditure was 4.5% lower for those in the input treatment.

Table 3 examines the same outcomes, plus GPS – measured plot area, at the level of plots rather than household farms. The results are quite analogous to the household level analysis. The extension treatment lowered land preparation and total plot-level expenditures at no significant cost to plot-level harvest, and thus appears to generate an increase in plot profits. All of these effects are small relative to baseline levels.

Neither insurance treatment generates a change in any of these plot level farming outcomes.

The input treatment reduces internal and external labor costs, increases expenditure on seeds and increases profits at the plot level. Moreover, GPS-measured plot size increases as a result of the inputs treatment.

We examine treatment effects on plots cultivated by men and women separately in Table 4. The extension treatment has parallel effects on plots of women and men, although the impacts are generally stronger for men than for women.

There is some indication that the insurance treatments do have different effects on men and women, although the results are puzzling. The light free insurance treatment causes an increase in seed expenditure and perhaps in land cultivation expenditure for women and a large increase in harvest value and thus profits for women. The heavy free insurance treatment, in contrast, causes a decrease in harvest value and thus profits for women. For men, the results remain as before, with no significant changes in farming outcomes. The insurance results for women's plots underscore the potential importance of heterogeneous effects depending upon realizations of stochastic events such as rainfall: it could be the case that the heavy and light insurance treatments are inducing (differential) changes in cropping activities that affect the responsiveness of these outcomes to weather realizations.

The inputs treatment effects inputs on women's plots similarly to those on men's plots, but more strongly for the women's plots. Moreover, output goes up substantially with the input treatment on women's plots, but not on men's plots. As a consequence, the inputs treatment causes a much greater increase in the profits on women's plots than on the plots of men. The pathways through which the inputs treatment is affecting women's farming decisions and outcomes will be a focus of further work.

III.C: Extension, Learning and Diffusion

Knowledge Effects

The CEA treatment had statistically significant and economically meaningful effects on farmer knowledge. At the time of the annual survey after each harvest season (9 months after the annual start of the extension visits) administered a quiz about the extension content, and some placebo questions, to the full sample. Table 5 provides estimates of the effect of the extension treatment on the test performance of farmers on both curriculum based and placebo questions, in each season and over the full period of the study. As is the practice in the education literature, test scores are normalized by the mean and standard deviation of the control group. The test changed each year, so the normalization is done annually. The treatment effects, then, can be interpreted as the number of standard deviations change caused by the CEA treatment. The CEA treatment increases test scores by 0.17 standard deviations on average over the three years of the intervention. The p-values reported in this Table are generated through randomization inference using 1000 repetitions of the clustered randomization that was used to allocate households to treatment during the implementation.

These estimated effects include all households who did not directly receive the CEA treatment as control group households. If there are within-community spillovers of knowledge from the CEA treatment farmers to their neighbors, then these are underestimates of the causal effect of the CEA treatment on knowledge scores. Figure 3 demonstrates that such knowledge spillovers did indeed occur. The test scores of non-treated households in CEA treated communities (spillover households) are higher than those of non-treated households in control communities (the p-value of the difference in mean scores between spillover and pure control households is 0.00). Both the direct and the spillover effects on test scores of the CEA program are seen for curriculum questions but not for placebo questions.

Figure 4 shows that both female and male farmers, both directly treated and non-treated in treatment villages, do better on the knowledge test than control farmers.

We examine the pathways through which these knowledge spillovers occur in Table 6. We collected data on within-community network connections between farmers in our sample. Each farmer was asked if he knew each other farmer in our sample in that community. If the answer was affirmative, we asked a set of follow-up questions, including "Have you and NAME ever discussed about management of your farm?" We define an "advice network" link to exist between two farmers if either answers yes to this question. Does the knowledge generated by the CEA treatment pass along the farming advice network to otherwise untreated farmers?

The first row of the first column of Table 6 verifies that knowledge test scores are significantly higher for extension treatment farmers. The third row of the first column shows that test scores are higher for farmers who share a direct advice network linkage to an extension treatment farmer. Conditional (in row 2) on the size of the farmer's advice network, the presence in this network of an extension treatment farmer is random. Knowledge generated by the extension treatment is passing to untreated farmers through community social networks.

The second column of Table 6 examines the hypothesis that farmers who themselves are in the extension treatment benefit less from network connections to other farmers in the extension treatment than do farmers in the control group. The effect of having a treated farmer in the advice network a farmer who is herself treated is the sum of the coefficients in rows 3 and 4 – approximately zero. In contrast, the effect of having a treated farmer in the advice network of an untreated farmer is to significantly increase the knowledge test score. However, we cannot reject the null hypothesis that these coefficients are equal at conventional levels of significance.

The final column of Table 6 examines these network effects by gender, for the 2016 farming season. There is no evidence of knowledge spillovers through social networks for male farmers, but there are large spillovers to female farmers through their advice networks.

Practice Effects

The CEA treatment improved the performance of treated farmers on tests of farming knowledge. This improved knowledge spilled over to untreated farmers in the same community, and these knowledge spillovers passed through the network links between farmers defined by our measure of farming advice connections. In this section, we show that the CEA treatment also affected the cultivation practices of farmers. Figure 5 summarizes the main results. The five practices on the left of the figure (record keeping, germination testing, fertilizer application, row planting and the use of organic fertilizer) were promoted unambiguously in the extension curriculum. The curriculum was unambiguous as well in its condemnation of the practice of burning plots as part of land preparation. The curriculum in the first year was focused on maize cultivation, but extended to groundnut and soya production in the second and third year. The curriculum contained lessons on thinning and refilling plots after sowing, but these practices are conditional on need, utilized only if there is excessive or inadequate germination. The use of certified seeds was promoted in the extension curriculum, but the dangers of improperly stored or counterfeit commercial seed were also emphasized. The practice of intercropping has an ambiguous status in the extension curriculum: its virtues as a tool for benefitting from the complementary nutrient demands of grains and legumes is discussed, but so are the advantages of sole-cropping in properly-spaced rows.

Figure 5 reports the marginal effect of the extension treatment on these farmer-reported agronomic practices, based on a regression of the form of equation 1. Farmers in the extension treatment significantly increased their use of germination testing, fertilizer application, row planting and organic fertilizer use. They reduced the frequency of plot burning and (marginally) reduced replanting. The standard errors reported in Figure 5 are clustered at the community level.

There is a real danger of social desirability bias in the responses of farmers to questions about the adoption of recommended practices. The treatment households had been receiving extension messages regarding the value of these recommended practices over the full course of each farming season. That very message might induce treatment farmers to respond to questions about adoption in ways that reflect those messages. Indeed, we have some evidence that this is true for responses regarding burning: treatment farmers report less burning than control farmers in the year before the extension treatment began. However, there is no evidence of similar bias for other practices.

To address the possibility that self-reports of adoption are subject to social desirability bias, project enumerators visited the farm of each respondent to directly observe evidence of the adoption of specific practices. This exercise was carried out in the 2015 farming season only and focused on practices for which we could devise strategies for direct observation. The effects of the extension treatment on farmer practices as observed by our survey team are reported in Figure 6, along with the effects of the extension treatment on self-reported activities of farmers. The two sets of estimates are generally similar, with the notable exception that self-reported fertilizer use increases with the extension treatment, while direct observation (of the bag used for the fertilizer reported to have been used) is lower in the treatment group. Direct observation of evidence of recommended weeding practices is significantly greater in the treatment group, while self-reports of proper weeding show no effect of the extension treatment. Similarly direct observation of evidence of burning is significantly lower in the treatment group, while self-reports are not. The differences between observed and self-reported effects of treatment on weeding and burning are opposite to what one would expect from social desirability bias. The extension treatment effects on germination testing, row planting, and record-keeping are similar for the directly observed data and for the farmer self-reports. On balance, there is little evidence that concerns of social desirability are biasing the responses of farmers.

Treatment farmers changed their agronomic practices in accord with the recommendations of the extension curriculum. Figure 7 provides evidence of substantial spillovers of recommended practices to control farmers in communities assigned to the extension treatment. Untreated farmers in treated communities conducted germination testing, applied fertilizer and planted in rows significantly more than did untreated farmers in control communities. The practices of record-keeping and abstention from plot burning did not spread beyond directly-treated farmers.

Table 7 explores the pathways through which recommended practices spread through extension treatment communities. As was the case in Table 6, these results are conditional on the size of each respondents farming advice network, so the presence of a treated farmer in the advice network is random. The final row of Table 7 indicates that having a treated farmer in a respondent's advice network increases the respondent's likelihood of performing germination tests, and of planting in rows. Both of these effects are strong statistically significant and strong;

their magnitude is similar to the direct effect of receiving the extension treatment. The standard errors of these marginal effects are clustered at the community level.

The data on social networks is individual-specific, although collected at different times during the study. The baseline network data recorded connections between the primary respondents of sample households, who are overwhelmingly male. In the following year (when the extension treatment was planned to be extended to legume crops and targeted to female farmers), network connection data between female respondents was collected. In the endline, data on network links across genders was collected. This permits us to estimate the effects of having a treated male or female farmer in the advice network of a female or male respondent. Table 8 reports the results.

Male farmers are much more likely to use germination testing when there is a treated farmer – female or male – in their farming advice network. In contrast, female farmers respond much less to the presence of a treated farmer – female or male – in their farming advice network. The same pattern can be seen with respect to row planting; again female farmers respond less to information flowing through their advice networks than do male farmers. Decisions to cultivate maize reveal a different pattern: female farmers increase their cultivation of maize when a treated male farmer is in her advice network (but not when there is a treated female in her network). This may occur because the community extension agents focused most of their direct efforts with male farmers on the maize curriculum. Male farmers increased their maize cultivation when a female treatment farmer was in his advice network. The use of organic fertilizer by female farmers also responds differently to the gender of treatment farmers in the female's advice network. When a female farmer in a female respondent's network is treated, the respondent reduces her use of organic fertilizer. But when a male farmer in the female respondent's network is treated, she increases her organic fertilizer use. This differential response may reflect the different roles of information (from links with male farmers) and competition over scare resources (with other female users of manure and compost).

IV. Conclusions

The extension intervention increased farmer knowledge regarding recommended practices, and increased adoption of these practices. The increases in knowledge and the adoption of recommended practices spread to control farmers in treatment communities. Control farmers in treatment communities with direct farming advice links to treated farmers are particularly likely to take up recommended practices. All of these results are consistent with the community extension agent treatment being an effective tool for introducing information to communities in northern Ghana, sparking its diffusion throughout these communities, and encouraging adoption of recommended practices. Unfortunately, as documented in Tables 2-4, we have no evidence that the adoption of the recommended practices has substantial positive impacts on average yield, output or profits. There may be important heterogeneity hidden in these small average impacts; in particular, it may be the case that returns to the adoption of the recommended practices depends importantly on the characteristics of a farmer's land, her economic situation or the realization of weather outcomes in a given farming season. This is the focus of continuing research.

In contrast to earlier findings in the same region of northern Ghana, we find little effect of grants of rainfall index insurance on average investment choices or farming outcomes in this study. The index insurance product provided to farmers in the current intervention was less generous than that provided in Karlan *et al.* (2014). In particular, the current insurance did not protect against flooding. Concerns about basis risk and about the reliability of insurance payouts could imply that both the demand for and responses to the availability of index insurance are highly sensitive to the detailed structure of the index itself, implying a much more difficult path to success scaling of these financial products.

The very strong effect of the input marketing treatment on labor use on farms in treatment communities is unexpected, and is the primary source of the increased profits generated by this treatment. This result is not a simple consequence of increased use of laborsaving chemicals like pesticides, for there is no observed increase in the use of agrochemicals in input treatment communities. This result remains under investigation.

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Household Level Balance at Baseline, Balance Variables

	Size of Related Network	Size of Farming Advice Network	Harvest Quantity Maize	Harvest Quantity Groundnut	Harvest Quantity Yam	Harvest Quantity Soya Beans	Harvest Quantity Rice	HH Farmers Using Chemicals	Chemical Expenditures	Total Acreage	Grew Maize Last Season	HH Head Literacy
1-V: Insurance, HH: Control	22.37***	23.84***	12.64***	3.729***	8.104***	2.659***	3.493***	2.404***	3619.2***	17.79***	0.918***	1.790***
	(0.819)	(0.818)	(1.107)	(0.389)	(1.315)	(0.522)	(0.592)	(0.0633)	(645.9)	(1.204)	(0.0144)	(0.0205)
2-V: Ins & Ext, HH: Control	24.29***	25.94***	10.50***	4.173***	9.373***	2.281***	2.838***	2.440***	3488.9***	15.32***	0.865***	1.781***
	(0.757)	(0.841)	(0.959)	(0.516)	(1.618)	(0.499)	(0.598)	(0.0661)	(1196.6)	(1.221)	(0.0277)	(0.0275)
3-V: Insurance, HH: FreeIns	22.71***	24.03***	12.88***	3.678***	8.139***	2.509***	2.977***	2.428***	3134.4***	17.51***	0.930***	1.772***
	(0.752)	(0.769)	(1.188)	(0.513)	(1.128)	(0.613)	(0.442)	(0.0704)	(652.9)	(1.256)	(0.0143)	(0.0229)
4-V: Ins & Ext, HH: FreeIns	23.88***	25.56***	9.763***	5.318***	8.510***	2.822***	3.435***	2.467***	2261.6***	15.88***	0.900***	1.737***
	(0.830)	(0.900)	(0.654)	(0.774)	(1.300)	(0.607)	(0.750)	(0.0718)	(420.9)	(1.258)	(0.0208)	(0.0298)
5-V: Ins & Inp, HH: Inputs	22.85***	24.92***	10.69***	4.581***	7.436***	1.534***	3.749***	2.411***	2156.5***	17.70***	0.909***	1.775***
	(1.077)	(1.044)	(1.104)	(0.680)	(1.482)	(0.417)	(0.970)	(0.0777)	(477.9)	(1.823)	(0.0220)	(0.0364)
6-V: Ins, Inp & Ext, HH: Inputs	24.03***	26.89***	10.75***	4.873***	7.520***	1.350**	4.837***	2.536***	2171.5***	16.74***	0.895***	1.804***
	(1.265)	(1.306)	(1.313)	(1.004)	(1.367)	(0.567)	(1.200)	(0.111)	(442.0)	(1.500)	(0.0310)	(0.0371)
7-V: Ins & Ext, HH: Extension	23.40***	24.68***	10.00***	4.013***	7.870***	2.580***	3.448***	2.480***	2621.0***	14.30***	0.892***	1.754***
	(0.814)	(0.800)	(0.821)	(0.482)	(1.126)	(0.638)	(0.694)	(0.0684)	(429.9)	(0.897)	(0.0208)	(0.0331)
8-V: Ins & Inp, HH: FreeIns + Inputs	22.32***	24.29***	10.35***	5.158***	7.498***	1.639***	4.797***	2.381***	2528.1***	18.04***	0.907***	1.773***
	(1.012)	(1.148)	(0.833)	(0.885)	(1.320)	(0.397)	(0.960)	(0.0721)	(593.2)	(2.094)	(0.0164)	(0.0299)
9-V: Ins, Inp & Ext, HH: FreeIns + Inputs	25.15***	28.01***	11.80***	4.664***	10.24***	2.038***	4.920***	2.270***	2936.0***	17.60***	0.890***	1.742***
	(1.121)	(1.387)	(1.307)	(0.833)	(2.039)	(0.628)	(1.051)	(0.104)	(751.6)	(1.374)	(0.0235)	(0.0406)
10-V: Ins & Ext, HH: FreeIns + Ext	23.98***	25.62***	11.83***	4.787***	9.877***	2.715***	3.836***	2.455***	2434.6***	15.39***	0.892***	1.762***
	(0.808)	(0.939)	(0.991)	(0.655)	(1.564)	(0.494)	(1.043)	(0.0790)	(397.5)	(1.013)	(0.0228)	(0.0341)
11-V: Ins, Inp & Ext, HH: Ext + Inputs	25.89***	28.55***	8.434***	3.557***	5.714***	1.391***	3.076***	2.428***	1607.2***	19.32***	0.876***	1.738***
	(1.144)	(1.273)	(0.806)	(0.653)	(1.050)	(0.436)	(0.685)	(0.0998)	(193.2)	(3.865)	(0.0372)	(0.0428)
12-V: Ins, Inp & Ext, HH: FreeIns+Ext+Inputs	24.57***	27.35***	11.84***	4.601***	11.55***	2.112***	3.736***	2.264***	2302.4***	18.94***	0.903***	1.779***
	(1.128)	(1.063)	(1.274)	(0.983)	(2.348)	(0.682)	(1.148)	(0.118)	(426.9)	(2.999)	(0.0252)	(0.0371)
N	3229	3229	3225	3225	3225	3225	3225	3217	2810	3235	3235	3235
Control Mean	23.03	24.56	11.91	3.88	8.54	2.53	3.27	2.42	3,574.10	16.95	0.90	1.79
F Stat	1.210	1.589	2.227	1.187	1.607	1.316	1.172	1.224	1.851	1.011	0.642	0.522
P Value	0.284	0.106	0.015	0.300	0.101	0.220	0.311	0.275	0.050	0.439	0.790	0.887
Marginal Effects												
Extension	1.117	1.250	-0.830	-0.0645	0.554	0.0948	-0.118	0.00517	-595.5	-0.771	-0.0159	-0.0156
	(.614522)	(.6268995)	(.7017528)	(.4179137)	(.9352902)	(.3643924)	(.6031527)	(.0537261)	(326.0573)	(1.371597)	(.0139866)	(.0202053)
Light Insurance	0.0190	0.0271	0.593	0.474	0.991	0.212	0.257	-0.0376	-182.9	0.280	0.0110	-0.0137
	(.2649503)	(.268187)	(.4514684)	(.2080073)	(.5100013)	(.1758119)	(.3172709)	(.0285675)	(399.8446)	(.5195654)	(.0111851)	(.0162588)
Inputs	0.531	1.464	-1.011	0.502	-0.404	-0.937	0.899	-0.0531	-731.4	1.586	-0.00586	0.000428
	(.8809567)	(.9357234)	(.8510425)	(.6260201)	(1.264577)	(.4884968)	(.6944824)	(.0715515)	(404.0755)	(1.493895)	(.0162323)	(.0221636)

"V:" denotes the treatments the community was elligible for, while "HH:" denotes what treatments the households received

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 1

Marginal Effects of Treatment, Household Level Figures

	Acres Cultivated	Land Preparation Expenditures	Internal Labor Exp	External Labor Exp	Seed Expenditures	Chemical Expenditures	Total Expenditures	Harvest Value	Profits
Extension	-0.618	-23.16	-51.77	-40.83	-15.13	-21.93	-192.1	-4.840	168.3
	(0.268)	(10.36)	(31.58)	(33.05)	(9.005)	(31.20)	(77.12)	(113.3)	(106.4)
Light Insurance	-0.0398	5.029	-5.308	17.26	0.182	-21.90	4.140	33.31	49.50
	(0.211)	(8.226)	(27.95)	(31.26)	(5.890)	(44.25)	(72.20)	(90.22)	(99.41)
Heavy Insurance	0.371	18.69	-22.66	-25.93	-18.80	54.41	35.31	18.81	10.49
	(0.278)	(16.90)	(35.95)	(39.67)	(14.45)	(46.18)	(84.85)	(204.1)	(206.1)
Inputs	0.294	-13.23	-145.8	-99.50	13.28	-42.27	-293.0	-75.03	238.3
	(0.331)	(11.02)	(37.56)	(38.61)	(6.895)	(54.66)	(95.46)	(102.0)	(101.9)
N	9223	9223	9223	9223	9223	9223	9223	9223	9223
Baseline Mean	30.34	915.79	3,006.31	1,234.48	540.60	802.84	6,500.02	6,153.76	-298.80

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 2

Marginal Effects of Treatment, Plot Level Figures

	Acres Cultivated	Land Preparation Expenditures	Internal Labor Exp	External Labor Exp	Seed Expenditures	Chemical Expenditures	Total Expenditures	Harvest Value	Profits	Measured Acreage
Extension	-0.106	-6.809	-13.28	-10.90	-4.477	-13.46	-52.15	5.155	66.75	-0.0342
	(0.0703)	(2.959)	(8.127)	(8.983)	(2.597)	(15.09)	(20.12)	(37.11)	(35.44)	(0.0863)
Light Insurance	-0.0273	0.612	-8.766	-2.293	-1.043	-15.76	-17.79	-0.257	11.51	0.115
	(0.0558)	(2.553)	(7.420)	(8.813)	(1.752)	(22.78)	(20.15)	(28.81)	(32.07)	(0.0736)
Heavy Insurance	0.111	4.046	-9.284	-7.638	-3.987	22.57	7.039	18.81	24.15	0.0682
	(0.0924)	(5.202)	(9.386)	(10.38)	(3.850)	(20.02)	(22.16)	(69.93)	(67.41)	(0.0735)
Inputs	0.141	3.160	-26.24	-23.13	6.644	-14.52	-53.93	4.604	79.37	0.532
	(0.0823)	(3.204)	(9.799)	(11.54)	(1.995)	(29.07)	(26.95)	(31.94)	(33.72)	(0.120)
N	33,922	25,956	32,004	32,004	30,377	18,493	32,004	28,543	28,543	18,570
Baseline Mean	8.25	249.12	817.80	335.81	147.06	218.39	1,768.18	1,673.99	-81.28	

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3

Marginal Effects of Treatment, Heterogeneity by Gender, Plot Level Figures

	Acres Cultivated	Land Preparation Expenditures	Internal Labor Exp	External Labor Exp	Seed Expenditures	Chemical Expenditures	Total Expenditures	Harvest Value	Profits	Measured Acreage
Extension, Females	0.0712	-3.274	-2.452	-7.801	-2.347	-12.67	-30.48	-4.196	43.96	0.0266
	(0.0539)	(2.317)	(8.365)	(13.62)	(1.664)	(9.034)	(19.42)	(29.58)	(29.79)	(0.0859)
Extension, Males	-0.164	-8.006	-17.23	-11.56	-5.163	-11.75	-58.50	17.26	81.46	-0.0545
	(0.0937)	(3.948)	(9.534)	(10.05)	(3.418)	(18.87)	(24.59)	(51.28)	(48.21)	(0.108)
Light Insurance, Females	0.0674	4.205	-10.55	-6.830	3.125	-8.081	-15.27	76.10	61.04	0.125
	(0.0588)	(2.526)	(8.139)	(16.44)	(1.509)	(12.36)	(21.49)	(27.33)	(28.52)	(0.0770)
Light Insurance, Males	-0.0642	-1.161	-8.200	-0.583	-2.547	-18.69	-19.05	-29.25	-7.484	0.108
	(0.0692)	(3.161)	(8.519)	(9.525)	(2.363)	(27.12)	(24.36)	(37.62)	(40.98)	(0.0917)
Heavy Insurance, Females	0.0808	-2.698	1.252	-13.51	-2.887	10.32	6.135	-148.0	-96.11	-0.0319
	(0.0993)	(4.133)	(9.484)	(20.88)	(2.013)	(13.75)	(27.50)	(50.44)	(44.80)	(0.0710)
Heavy Insurance, Males	0.122	7.204	-14.70	-5.495	-4.369	29.37	5.972	96.91	81.09	0.115
	(0.110)	(6.809)	(11.99)	(9.166)	(4.995)	(29.00)	(28.22)	(96.54)	(93.46)	(0.0938)
Inputs, Females	0.118	0.601	-39.67	-40.91	8.291	-31.45	-99.72	135.9	202.5	0.884
	(0.0623)	(2.451)	(10.00)	(15.90)	(2.563)	(18.96)	(23.37)	(30.74)	(33.35)	(0.156)
Inputs, Males	0.158	5.367	-20.72	-17.21	6.127	-12.61	-36.32	-25.68	47.12	0.429
	(0.100)	(3.998)	(11.03)	(13.02)	(2.384)	(31.94)	(31.49)	(39.71)	(40.96)	(0.138)
N	33,922	25,956	32,004	32,004	30,377	18,493	32,004	28,543	28,543	18,570
Baseline Mean	8.25	249.12	817.80	335.81	147.06	218.39	1,768.18	1,673.99	-81.28	

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4

Impact of Extension on Agricultural Knowledge

			Curriculum Questions				Placebo Questions			
		N	Mean Score	SD	P-val	Normalized Effect	Mean Score	SD	P-val	Normalized Effect
2014 Farming Season	Control	2385	0.598	0.092			0.542	0.189		
	Treatment	800	0.614	0.099	0.004902	0.169	0.553	0.181	0.334314	0.055
2015 Farming Season	Control	2360	0.560	0.088			0.811	0.183		
	Treatment	800	0.566	0.093	0.258824	0.064	0.814	0.184	0.806863	0.012
2016 Farming Season	Control	4475	0.547	0.104			0.468	0.212		
	Treatment	1503	0.571	0.107	0.000000	0.232	0.475	0.207	0.396078	0.033
All Farming Season	Control	9220	0.564	0.100			0.575	0.244		
	Treatment	3103	0.581	0.103	0.000000	0.173	0.582	0.240	0.224510	0.029

Normalized Effect is effect standardized to Control Population SD, this includes Control HHs in Treated Communities

P-Value is result of performing randomization inference with 1050 repetitions

Table 5

Table 6: Fraction of Correct Answers on Curriculum Questions

	All farming seasons		2016 farming season
Extension treatment	0.0143***	0.0198***	0.0203***
	(0.00271)	(0.00537)	(0.00459)
Size of farming advice network	0.000102	0.000127	
	(0.000110)	(0.00011)	
Treated farmer in advice network	0.00577**	0.00712***	
	(0.00236)	(0.00253)	
Treated farmer in advice network * Extension treatment		-0.00768	
		(0.00613)	
Male*Size of farming advice network			0.000876*
			(0.0005)
Female*Size of farming advice network			-0.000866
			(0.0006)
Male*Treated farmer in advice network			-0.00841
			(0.0085)
Female*Treated farmer in advice network			0.0171*
			(0.0089)
N	11998	11998	2599
Control mean	0.6	0.6	0.6

Marginal Effects of Treatment & Social Networks on Practices

	Keep Farming Records	Perform Germination Tests	Apply Fertilizer	Perform Rowplanting	Use Organic Fertilizer	Cultivate Maize	Perform Thinning	Perform Refilling	Use Certified Seeds	Perform Intercropping	Field Burning
Extension	0.000544	0.0979	0.0223	0.0223	0.0102	0.0113	0.00524	-0.0209	0.00760	-0.0243	-0.0278
	(0.00200)	(0.0169)	(0.0193)	(0.0159)	(0.00959)	(0.0153)	(0.0120)	(0.0117)	(0.00953)	(0.0151)	(0.0182)
Light Insurance	0.00140	0.00610	-0.00251	-0.00763	0.00562	0.00675	-0.00481	-0.00578	0.00445	-0.00380	-0.0115
	(0.00121)	(0.00686)	(0.00835)	(0.00645)	(0.00429)	(0.00642)	(0.00491)	(0.00500)	(0.00381)	(0.00662)	(0.00771)
Heavy Insurance	0.00149	0.0158	0.0115	-0.0128	0.0124	0.0158	0.00573	0.00156	-0.00134	0.00696	-0.00177
	(0.00195)	(0.0126)	(0.0149)	(0.0119)	(0.00765)	(0.0116)	(0.00889)	(0.00978)	(0.00622)	(0.0109)	(0.0138)
Inputs	-0.00304	-0.00961	0.00368	-0.00865	-0.00529	-0.00683	0.0214	0.0309	0.00933	0.0187	0.0242
	(0.00162)	(0.0111)	(0.0123)	(0.0103)	(0.00594)	(0.0102)	(0.00806)	(0.00822)	(0.00746)	(0.00981)	(0.0118)
Add effect of having	-0.00115	0.0608	0.0155	0.0292	0.00470	-0.0111	-0.00106	0.00129	-0.00892	0.00575	0.0121
Ext Indv in Network	(0.00184)	(0.0110)	(0.0125)	(0.0101)	(0.00625)	(0.0102)	(0.00750)	(0.00778)	(0.00581)	(0.01000)	(0.0118)
N											

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 7

Marginal Effects of Treatment & Social Networks on Practices

	Keep Farming Records	Perform Germination Tests	Apply Fertilizer	Perform Rowplanting	Use Organic Fertilizer	Cultivate Maize	Perform Thinning	Perform Refilling	Use Certified Seeds	Perform Intercropping	Field Burning
Extension, Females	-0.000837	0.0717	0.0323	0.0264	-0.00451	0.00692	0.00994	-0.00475	0.00655	-0.0308	-0.0337
	(0.000844)	(0.0117)	(0.0135)	(0.0144)	(0.00601)	(0.0145)	(0.00780)	(0.00853)	(0.00616)	(0.0113)	(0.0140)
Extension, Males	0.00425	0.105	0.0174	0.0388	0.0152	0.0110	-0.00208	-0.0149	0.00196	-0.00976	-0.0254
	(0.00189)	(0.0126)	(0.0131)	(0.00971)	(0.00726)	(0.00898)	(0.00687)	(0.00785)	(0.00710)	(0.00991)	(0.0114)
Light Insurance, Females	-0.000351	-0.00204	-0.00672	-0.0134	-0.00892	-0.0176	-0.00231	-0.00295	-0.000758	0.00469	-0.00553
	(0.00110)	(0.00919)	(0.00956)	(0.0102)	(0.00451)	(0.0103)	(0.00691)	(0.00719)	(0.00412)	(0.00933)	(0.0102)
Light Insurance, Males	-0.000614	0.00633	-0.00555	-0.00626	-0.000904	-0.00144	-0.00217	-0.000536	0.00120	-0.0151	-0.0172
	(0.00160)	(0.00831)	(0.00930)	(0.00687)	(0.00535)	(0.00750)	(0.00523)	(0.00577)	(0.00526)	(0.00849)	(0.00832)
Heavy Insurance, Females	-0.000163	0.00706	-0.00811	-0.0224	0.00599	0.0305	-0.00586	-0.0139	-0.0188	-0.00521	0.0280
	(0.00163)	(0.0183)	(0.0179)	(0.0155)	(0.00925)	(0.0197)	(0.0101)	(0.0118)	(0.00590)	(0.0166)	(0.0179)
Heavy Insurance, Males	0.00182	0.0160	0.00914	-0.00168	0.00350	0.00891	0.0150	0.00696	0.00910	0.0169	-0.0144
	(0.00283)	(0.0187)	(0.0199)	(0.0126)	(0.00775)	(0.0115)	(0.0113)	(0.00860)	(0.00983)	(0.0158)	(0.0148)
Inputs, Females	-0.00181	-0.00803	-0.0171	-0.0238	-0.0141	0.00297	-0.00101	0.0170	0.00979	0.00779	0.00866
	(0.00158)	(0.0134)	(0.0176)	(0.0127)	(0.00663)	(0.0163)	(0.0101)	(0.0100)	(0.00606)	(0.0146)	(0.0201)
Inputs, Males	-0.00423	-0.0216	0.000460	-0.0184	-0.0108	-0.0120	0.0173	0.0288	-0.00198	0.00863	0.00778
	(0.00203)	(0.0159)	(0.0169)	(0.0106)	(0.00754)	(0.0126)	(0.00988)	(0.0107)	(0.00678)	(0.0158)	(0.0150)
Add Effect of Ext Male in Female's SN	-0.000568	0.0268	-0.00728	0.0305	0.0192	0.0255	0.00815	0.00869	0.00348	-0.00811	0.0162
	(0.00106)	(0.0113)	(0.0142)	(0.0132)	(0.00644)	(0.0129)	(0.00887)	(0.00836)	(0.00493)	(0.0139)	(0.0175)
Add Effect of Ext Male in Male's SN	-0.00124	0.0610	0.00928	0.0194	0.00383	-0.0161	0.00420	0.00288	-0.00840	-0.00784	0.0115
	(0.00160)	(0.00883)	(0.0135)	(0.00800)	(0.00605)	(0.00832)	(0.00548)	(0.00641)	(0.00426)	(0.00985)	(0.0114)
Add Effect of Ext Female in Female's SN	-0.000263	0.0125	-0.00232	-0.0134	-0.0148	-0.0181	-0.00405	-0.00807	0.0101	0.0125	-0.00534
	(0.00107)	(0.0120)	(0.0142)	(0.0134)	(0.00633)	(0.0129)	(0.00814)	(0.00875)	(0.00537)	(0.0154)	(0.0156)
Add Effect of Ext Female in Male's SN	0.00347	0.0621	0.0583	0.0722	0.00644	0.0623	-0.00691	-0.0234	0.0377	0.0769	-0.0117
	(0.00434)	(0.0255)	(0.0200)	(0.0139)	(0.0138)	(0.0156)	(0.0162)	(0.0149)	(0.0106)	(0.0253)	(0.0223)
N	17,038	17,038	17,038	17,038	17,038	17,038	17,038	17,038	17,038	17,038	17,038
Pure Control Mean	0.01	0.22	0.40	0.60	0.06	0.42	0.11	0.13	0.10	0.25	0.34

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 8

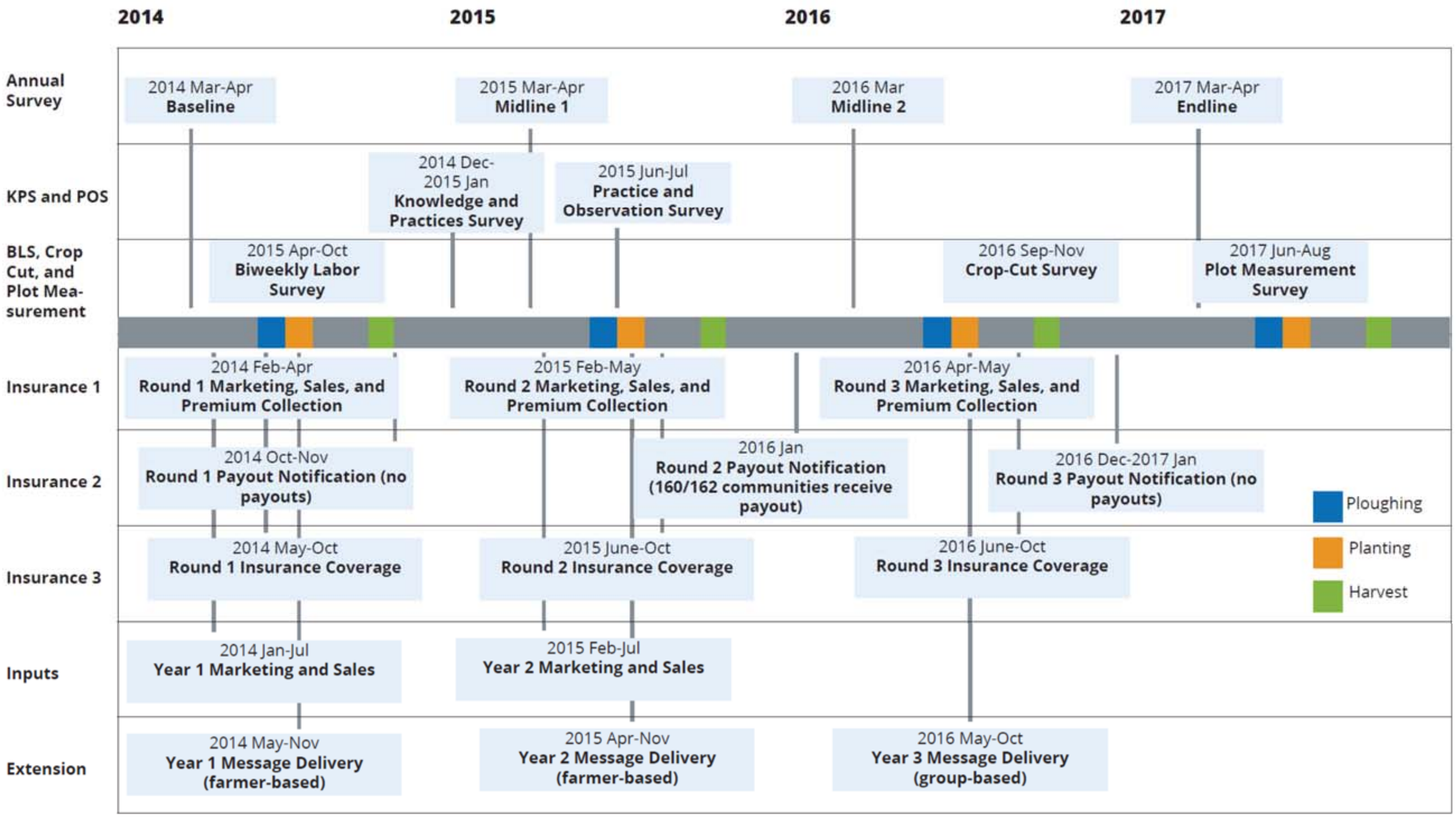
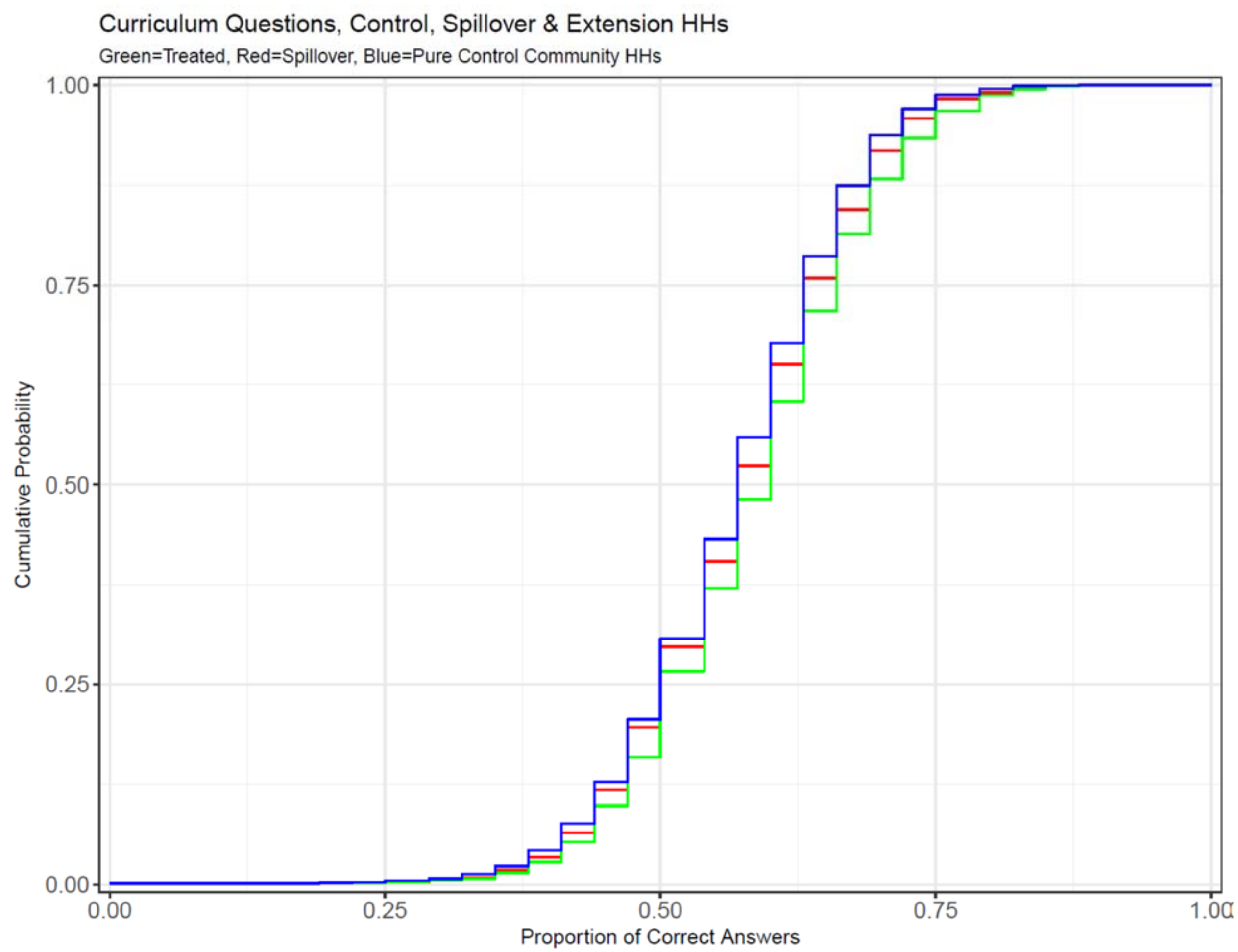


Figure 1: Timeline of Activities

Design

- Randomization across 162 Communities
  - Randomization within 20 sample households per community
- Control – 50 villages
  - 50% (10 farmers) farmers get insurance grant
  - 50% (10 farmers) pure control
- CEA – 52 villages
  - *25% (5 farmers per cell): CEA visits/insurance grant/both/control*
- Input markets – 31 villages
  - *50% (10 farmers) insurance + input market improvements*
  - *50% (10 farmers) input market improvements only*
- CEA + Input markets – 29 villages
  - 25% (5 farmers per cell): CEA visits+inputs/insurance grant+inputs/all 3/input market improvements only

Figure 2: Randomization of Core Treatments



Curriculum Questions, Control, Spillover & Extension HHs
Green=Treated, Red=Spillover, Blue=Pure Control Community HHs
1.00
0.75
0.50
0.25
0.00
Cumulative Probability
0.00
0.25
0.50
0.75
1.00
Proportion of Correct Answers

Figure 3

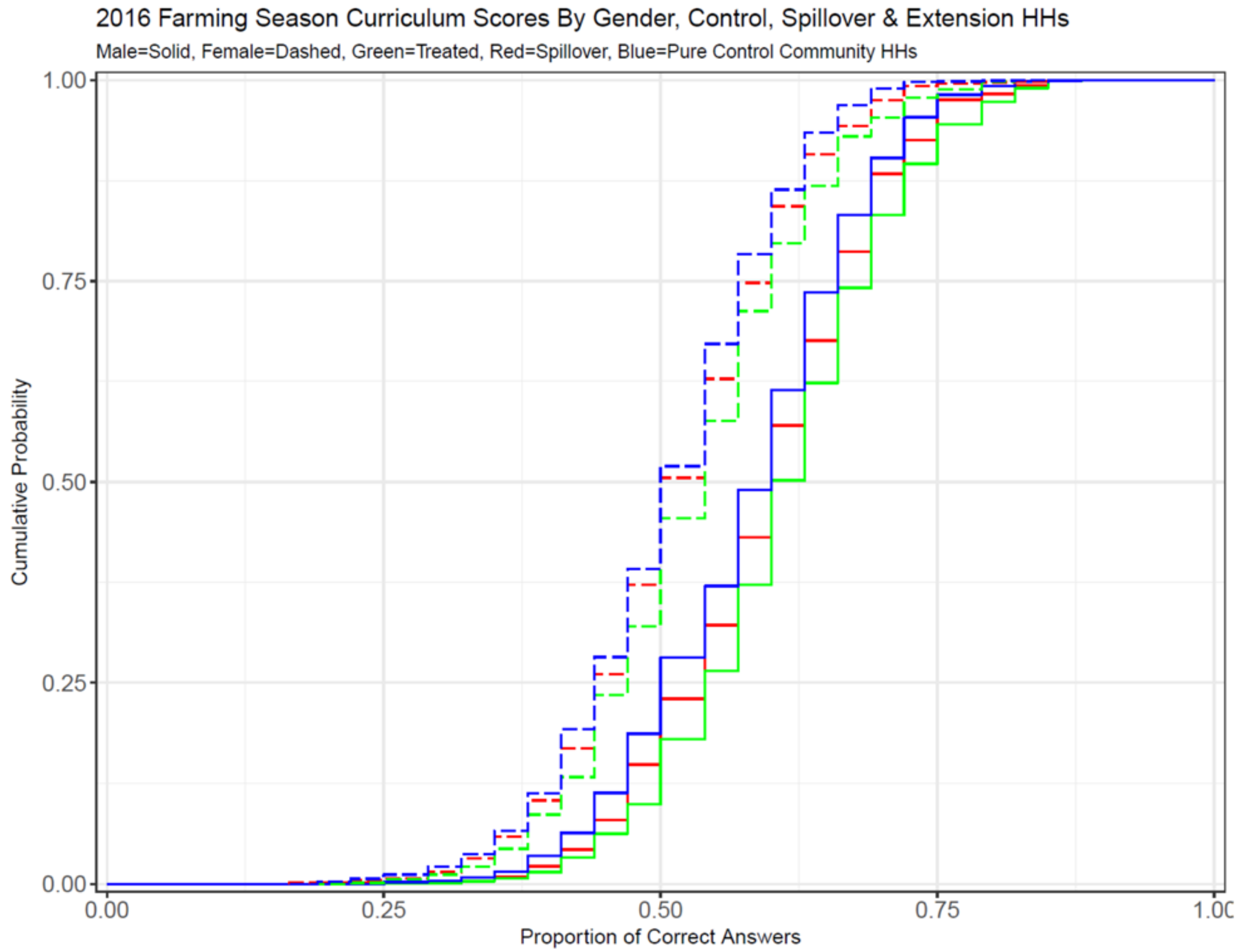

2016 Farming Season Curriculum Scores By Gender, Control, Spillover & Extension HHs
Male=Solid, Female=Dashed, Green=Treated, Red=Spillover, Blue=Pure Control Community HHs
Cumulative Probability
1.00
0.75
0.50
0.25
0.00
0.00
0.25
0.50
0.75
1.00
Proportion of Correct Answers

Figure 4

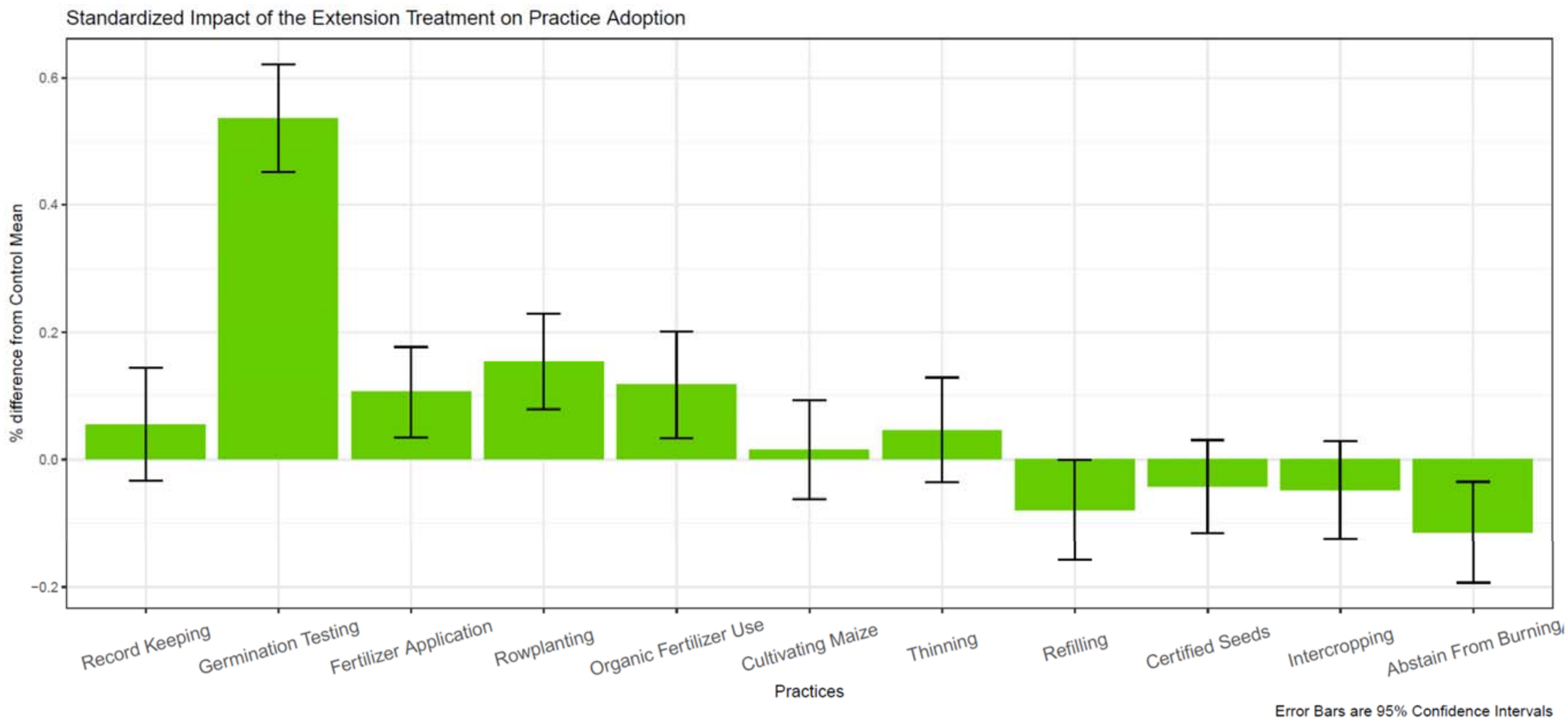

Standardized Impact of the Extension Treatment on Practice Adoption
% difference from Control Mean
0.6
0.4
0.2
0.0
−0.2
Record Keeping
Germination Testing
Fertilizer Application
Rowplanting
Organic Fertilizer Use
Cultivating Maize
Thinning
Refilling
Certified Seeds
Intercropping
Abstain From Burning
Practices
Error Bars are 95% Confidence Intervals

Figure 5

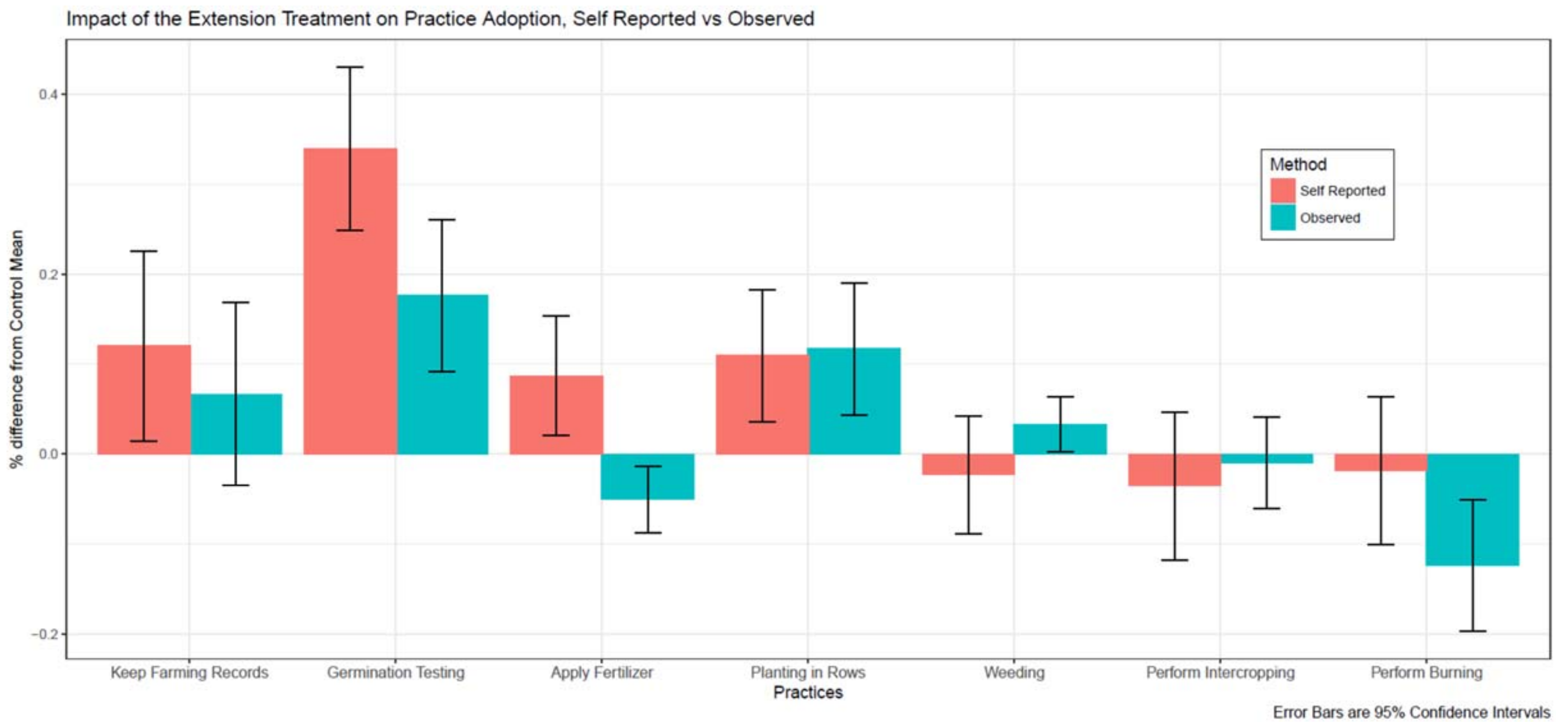

Impact of the Extension Treatment on Practice Adoption, Self Reported vs Observed
% difference from Control Mean
0.4
0.2
0.0
-0.2
Method
Self Reported
Observed
Keep Farming Records
Germination Testing
Apply Fertilizer
Planting in Rows
Weeding
Perform Intercropping
Perform Burning
Practices
Error Bars are 95% Confidence Intervals

Figure 6

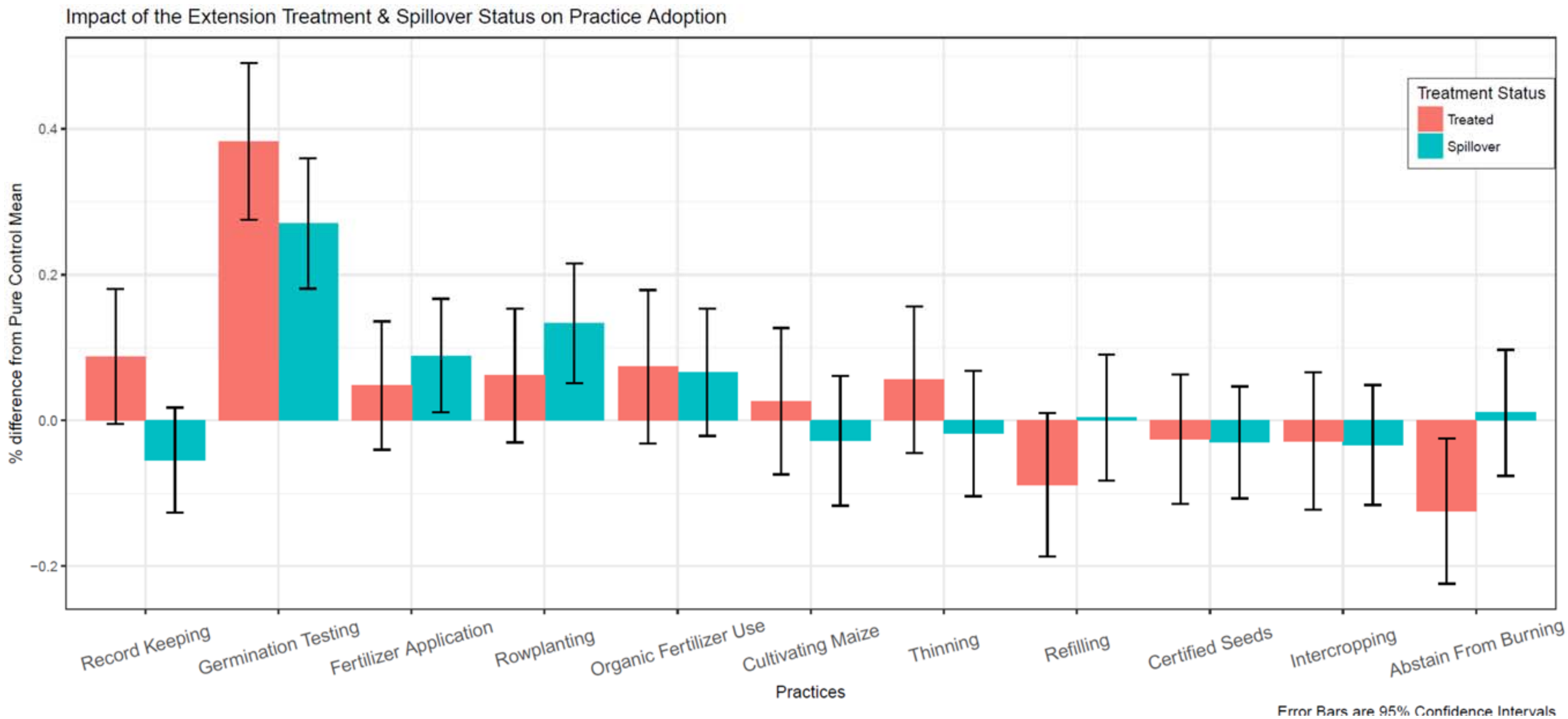

Impact of the Extension Treatment & Spillover Status on Practice Adoption
Treatment Status
Treated
Spillover
% difference from Pure Control Mean
0.4
0.2
0.0
−0.2
Record Keeping
Germination Testing
Fertilizer Application
Rowplanting
Organic Fertilizer Use
Cultivating Maize
Thinning
Refilling
Certified Seeds
Intercropping
Abstain From Burning
Practices
Error Bars are 95% Confidence Intervals

Figure 7