The Promise and Challenges in Implementing ICT for Agriculture

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While agricultural productivity in the developing world has made tremendous advances in the past half century, productivity still lags well behind the developed world. One particularly promising path to improve agricultural productivity is to employ mobile phones to enable farmers to make better decisions: through advice on input choices, farming decisions, and input and output prices.

This paper takes a close look at the potential of ICT to improve input decisions by assisting with the delivery of customized information about soil nutrient status ("health"). In South Asia, fertilizers are often overused or applied in inefficient proportions. Governments in India have invested heavily in soil testing, with the goal of distributing 140 million "Soil Health Cards" (SHCs) directly to farmers. Yet absent additional information, farmers may have difficulty acting on the information provided in SHCs.

The primary contribution of this paper is to evaluate the prospects for ICT to assist in the delivery of information about site-specific agricultural practices. We report on results from a field experiment examining whether audio and video supplements contribute to the understanding of information in SHCs.

We begin examining the reach of traditional extension services in India, and find that they fall far short of universal coverage. If extension agents are not available, many farmers turn to local agricultural sales agents for advice. We describe results from an audit study evaluating the nature and quality of advice from these agents in the field.

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Introduction and Motivation

It is difficult to overstate the importance of improving agricultural productivity for human welfare. A large fraction of the world's poor are engaged in agriculture. Moreover, as global incomes rise, the growing demand for meat will dramatically increase requirement for foodgrains, potentially increasing prices as well.

Long-term Indian agricultural productivity growth has been around 3-3.5, yet a substantial yield gap remains (World Bank, 2014). Early in this century, the concept of "site specific crop management," or precision agriculture, began to gain traction, particularly in developed countries. The basic idea is that, because conditions vary locally, precise targeting of inputs may lead to significantly higher yields, potentially at lower cost. In countries such as the United States, this may take place via tractors equipped with GPS devices, and equipment that varies seeding or fertilizer rate every few meters. A developing country equivalent, much less reliant on technology, would be to provide smallholder farmers with better information about local conditions (soil, weather, temperature, etc.), such that they may make more informed decisions. However, it is worth noting that the cost of many sensors is declining, such that technology-enabled solutions may become viable at scale in developing countries quite soon.

Among the most important inputs, for both farmers and the government, are fertilizers. India itself has witnessed a dramatic increase in fertilizer use. Indeed, experts argue that in many cases, farmers apply too much fertilizer (e.g. Blaise 2006).

Local variability in soil quality has helped motivate the governments of many Indian states, and now the central government as well, to conduct farmer-level soil tests. It is hoped that if farmers are directly provided highly detailed information, they will be in a position to optimize their input usage, increase productivity and profitability, and safeguard the quality and fertility of their soil.

However, a number of things must happen for the government's ambitious intervention to have the desired effect. In addition to managing the daunting logistical challenge of testing millions of plots and returning the information to farmers, these conditions include: (1) soil tests administered by the government must generate meaningful and useful information about soil quality; (2) farmers must understand, trust, and be willing to act upon the information provided by SHCs; and (3) the desire to act must not be impeded by availability of inputs, credit constraints, or other factors.

This paper examines the first two of these conditions. We evaluate the information content of soil tests by collecting soil from a set of randomly selected farmers and having these soil samples evaluated in certified laboratories. We also compare the test results and the corresponding recommendations against government SHCs for these farmers.

Second, we provide SHCs to farmers and evaluate their understanding of the cards and corresponding recommendations. We show that the typical level of understanding is very poor, but that it is dramatically improved when accompanied by additional explanation, such as an agronomist might provide.

Unfortunately, it does not appear feasible to have an agronomist consult with every farming family in India. We document that the reach of agricultural extension officers is quite limited—nationwide, only about 6% of farming families report having interacted with an extension officer in the previous year.

Our primary contribution is to document the efficacy of ICT as an aid in understanding SHCs. In a field experiment with approximately 550 farmers, we test farmer understanding when provided with an SHC with no supplement against understanding when provided with an audio supplement (which could currently be delivered via mobile phone), a video supplement (which will likely be deliverable in a cost-effective way in the next couple of years), or an in-person explanation with an agronomist.

Finally, we consider the possibility that farmers may be able to take advantage of other resources to make sense of their cards. Previous research suggests that agricultural input dealers frequently provide advice and guidance to farmers; farmers report seeking advice from commercial agents at a roughly similar rate to government extension agents. The final contribution of this paper is to report on a separate exercise that evaluates the quality of agricultural advice provided by input dealers.

This paper builds upon an important piece of research (Fishman et al, 2016) that evaluated the distribution of soil health cards in Bihar, India. Their field experiment sought to mimic efforts being scaled up throughout India. The authors tested soil samples of over 800 farmers across three districts and produced soil health cards modeled after government SHCs. The authors' team subsequently returned to the farmers, providing them with a copy of the SHC, along with an in-person description of its results and implications, for farmers seeking to grow rice and wheat.

The authors returned several months later to collect information on actual fertilizer use. They find that the SHCs did not affect fertilizer use.

Examining why the SHCs were ineffective, the authors note that farmers reported preferring to continue following their traditional input decisions, and that survey questions indicated that approximately 70% of farmers distrusted recommendations given by extension workers.

Our experiment was designed, in some part, to overcome this lack of trust. The audio, video, and agronomist scripts explained in detail how soil samples were collected, why they were collected, and how they were tested. Please see Appendix II for more details on the scripts used.

This paper contributes to two additional, related literatures. The first evaluates the ability of agricultural extension services to promote productivity (Feder et al., 1987 Gandhi et al., 2009; Duflo et al., 2011). We see the evidence here as generally mixed, though the ability to make certain claims is limited by the difficulty of solving traditional identification problems. A recent RCT in Africa (BinYishay and Mobarak, 2017) found positive effects of extension on adoption of new technologies.

A second, more recent literature examines the role of ICT in agriculture (Aker, 2011). The early evidence in this space was somewhat mixed, with, for example, Fafchamps and Minten (2012) finding no effect of SMS-based agricultural advice services on farmer outcomes in Maharashtra. Cole and Fernando (2016) implement an RCT to evaluate an ICT-based extension service called "Avaaj Otalo" in Gujarat over a period of two years. The service was developed by Neil Patel, Tapan Parikh, and others, as a social enterprise (Awaaz De). Key features of the service included 3-5 minute long "push messages" to farmers in the form of a weekly 3-5 minute message, along with the chance for farmers to call in and record specific questions about their farm, with an answer delivered back to them within 24 hours. The service, which was free for farmers to use, achieved broad adoption, as the median treatment respondent listened to 5.2 hours of content, and 88% of farmers called in to ask a question. The service caused systematic changes in farming practices, leading to higher cumin yields, and higher cotton yields for a sub-group that had received reminder messages.

In 2016, one of the authors of this paper (Cole), along with Michael Kremer, Dan Bjorkegren, and Heiner Baumann, founded a non-profit with the goal of improving the quality and features of mobile phone-based extension services, evaluating them rigorously and, if and when the evidence suggests an attractive benefit/cost ratio, scaling services up. Since 2016, the non-profit has operated a service similar to Avaaj Otalo, Krishi Tarang, for approximately 40,000 farmers in Gujarat state.

Existing Extension Landscape

Many view India's agricultural extension workers as critical to the spread of technologies that comprised the Green Revolution (e.g. Singh, 1999). However, traditional agricultural extension models are subject to a number of limitations, including limited reach, limited control, and limited ability to provide ongoing guidance.

At some level, Fishman et al. represents a "best case" scenario, as each farmer was visited in person by someone trained to deliver information about soil health cards. In reality, despite substantial efforts, agricultural extension in India falls well short of universal coverage.

Indian state governments collectively employ approximately 120,000 agricultural extension workers (Sajesh and Suresh, 2016), against an estimated 110 million farming households,[2] meaning, on average, each extension worker must cover approximately 750 farming households. Even if an agent could be on the road twenty days a month, visiting pre-arranged groups of farmers, it is difficult to see how most farmers could avail themselves of extension services.

The agriculture-focused Schedule 33 of the 70th round of the National Sample Survey conducted in 2013 includes a question specifically on agricultural extension. The survey asked respondents whether they had received technical advice on their crops, allowing them to specify whether they received the advice from extension agents, Krishi Vigyan Kendras, agricultural universities, private commercial agents, other farmers, media, veterinarians, or NGOs. In Table 1, we report the share of households that reported receiving technical advice from any source, alongside the share that reported receiving advice from extension agents.[3]

Our basic finding is that while many farmers report receiving technical advice from an outside party, relatively few interact with agricultural extension workers or KVK staff. India-wide, only 6% of farmers report receiving technical advice from an agricultural extension worker. The most popular sources of advice are "progressive farmers" and media (radio/TV/newspaper/internet). Veterinary departments and commercial agents are the third and fourth most common sources of advice.

The state in which the highest share of farmers reported receiving technical advice is Karnataka at 66%, yet only 11% of that state's respondents reported interacting with an extension agent. In Table 1, we examine geographic and demographic heterogeneity. Extension worker outreach is highest in Andhra Pradesh (29%), but most states achieve only single digits. Gujarat reports 49% receiving any technical advice, with only 7% interacting with an extension agent. Men appear to

[2] http://pib.nic.in/newsite/PrintRelease.aspx?relid=113796, accessed June 2017
[3] These statistics have been adjusted for the sampling weights

interact with extension agents marginally more frequently than women, and fewer of those with small landholdings report seeking advice. However, we find no clear pronounced pattern in extension agent access by landholding and income.

In contrast, column (1) demonstrates that mobile phone penetration is quite high throughout all the states examined in our table. It is above 70% in all states except Orissa (69%), Bihar (68%), Assam (59%), and West Bengal (54%). This number likely overstates rural penetration, as it is a measure of the number of active lines divided by the total population. However, it is also likely that individuals without their own phone may be able to obtain access to phones through friends, families, or neighbors. India is also well covered by networks: Ericsson's June 2016 Mobility Report estimates that 95% of the country's population is covered by GSM or EDGE as of 2015, with lower coverage rates for high-speed data.[4]

The key take-away, in our view, is that while mobile phones are widely accessible, agricultural extension workers reach, at best, a small fraction of the Indian farming population.

[Table 1 here]

Soil Health Cards Data

Background

Fertilizer use in India has grown more than ten-fold, from 11 kg per hectare in 1970 to 128 kg per hectare in 2010-11. However, positive yield response to fertilizers is sharply declining, from about 25 kg of crop per kg of fertilizer in 1970, to only 8 kg of crop per kg of fertilizer in 2003 (Wani et al. 2016). A growing body of research and policy work suggests that public subsidies for urea have skewed farmer behavior to over-apply nitrogen-based fertilizer, which may degrade the soil and may cause farmers to neglect other important inputs, such as secondary nutrients or micronutrients (e.g., Fishman et al. 2016). A recent World Bank report on agricultural productivity in India expressed concern that subsidies led to overuse of some fertilizers, not just to an extent that the marginal product was below the marginal cost, but that overuse of fertilizer actually depressed yields (World Bank, 2014, p xxvi). This imbalanced fertilizer use is likely to blame for stagnating crop response (Wani et al. 2016)

There is some evidence from small-n studies on experimental plots that site-specific nutrient management practices have the potential to increase yields and improve net returns to fertilizer use for wheat (Sapkota et al. 2014, Khurana et al. 2008), rice (Singh et al. 2011, Das et al. 2009), and cotton (Shivaraja et al. 2017).[5] In each of these studies, researchers control for other agricultural inputs such as irrigation, pesticides, and sowing distance, while varying fertilizer use across sections of the same field. Although sample sizes range from only 1 to 56 fields, positive results on these experimental plots portend the tantalizing possibility (not yet systematically

[4] https://www.ericsson.com/assets/local/mobility-report/documents/2016/india-ericsson-mobility-report-june-2016.pdf, accessed June 2017

[5] Sample size in Sapkota et al. (2014) is 15 fields with 5 different treatments on each field (within-field design); in Khurana et al. (2008) is 56 fields with 3 different treatments on each field; in Singh et al. (2011) is 1 field with 5 different treatments; in Das et al. (2009) is 20 fields with 7 different treatments on each field; and in Shivaraja et al. is 1 with 9 different treatments.

demonstrated in real farm settings in India, as far as we know) that farmers could boost yields while reducing costs and therefore dramatically increase profits.[6]

Since at least 1845, scientists have attempted to design means of measuring soil fertility (Anderson, 1960). Modern soil tests identify the amount of available nutrients in the soil, important among them nitrogen, phosphorus, and potash, but also including micronutrients such as sulphur, zinc, and iron.

These soil tests are then combined with agronomic models to generate specific fertilizer recommendations. In the case of India, government agricultural universities have elected to characterize macronutrient levels on a three-level scale (low, medium, or high). Soil test reports typically recommend higher doses of fertilizers that supply nutrients that are deficient in soil and lower doses of those that supply nutrients abundant in soil. Optimal recommendations vary both by crop and by whether the plot being cultivated is irrigated or not.

Progress and Plans

The government has set high targets for distribution of soil health cards, stating in the 2016-2017 budget: "The target is to cover all 14 crore [140 million] farm holdings by March 2017." According to the 2017-2018 budget statement, 42.5 million SHCs had been distributed as of 31 December 2016[7]. In the 6 June 2017 Ministry of Agriculture update on the progress of the SHC program, the overall target for distribution of SHCs is about 123 million, while SHC distribution had increased to 81 million, or about 66% of the overall goal[8].

In Table 2, we display the Ministry's breakdown of progress for a selection of individual states. Thus far, the program appears to have made significant headway. However, progress is uneven, with states including Himachal Pradesh, Madhya Pradesh, Tamil Nadu, Karnataka and Maharashtra enjoying nearly full coverage in SHC distribution, and others such as Punjab and Assam at comparatively early stages in the distribution process.

[Table 2 here]

Data Validation of Soil Health Cards

Collecting tens of millions of soil samples, testing them reliably, and making the results known to smallholder farmers is a challenging logistical and organizational endeavor. In this section, we provide a validation check of a set of soil tests conducted by the government of Gujarat and a second set of independent soil tests that we commissioned.

In 2004, the state government of Gujarat embarked on an ambitious plan to test soil samples of at least one field for every farmer in the state. By 2015, the agricultural department reported having

[6] It is not obvious that profits would rise in real farm settings as they do in the case of experimental plots. In other countries, it has been found that fertilizer application has no net positive returns when farmers change other input use in response to fertilizer use, e.g. for marginal farmers in Mali, on account of costly labor inputs that accompany greater fertilizer use (Beaman et al. 2013), or in Kenya, because of high costs associated with fertilizer procurement (Suri 2011).

[7] Union Budget 2017-2018, "Implementation of Budget Announcements 2016-2017" pp 3-4. Available at: http://indiabudget.nic.in, accessed June 2017

[8] Ministry of Agriculture, "Statewise Status of Soil Health Card Scheme." Available at: http://soilhealth.dac.gov.in/Progresscdpt, accessed June 2017

met 85% of this goal (Swain & Kalamkar 2016). These soil health card results were made available online[9]. We digitized this database for Surendranagar, Rajkot, and Morbi districts of Gujarat. Between January and June, 2017, we collected and tested individual soil samples for a subset of these fields. Our soil sampling procedures are detailed in Appendix I. We engaged Junagadh Agricultural University (JAU) and Gujarat State Fertilizers and Chemicals' (GSFC) soil testing laboratories to conduct soil tests; the testing procedures are internationally standard and endorsed by the government.[10] JAU is certified by the Indian Council of Agricultural Research (ICAR) to perform agricultural research and is part of the consortium of state agricultural universities that prescribes fertilizer recommendations for different crops in Gujarat.

Our research follows similar work in Tanzania and Kenya, where Berazneva et al. (2017) compare the results of plot-wise soil tests with high-resolution geospatial data that is interpolated from point observations across geography. The authors find that publicly available geospatial data is unable to capture local variability in soil chemistry. While the spirit of our comparison is similar, its nature is different in that the publicly available soil health card results to which we compare independent lab test results are based on tests of individual plots as opposed to interpolation across a number of plots.[11]

Sample Selection

Our soil samples were collected in two waves.

- January 2017: As part of a pilot study in Surendranagar and Morbi districts of Gujarat, we made a list of all farmers in five villages whose test results from post-2014 were available in the state government's online and publicly available database of soil health cards. We then approached these villagers in a randomized order with the goal of conducting approximately 50 soil tests. We collected and tested a soil sample from this field for the first 54 farmers who agreed to participate. All 54 fields form part of the cross-check sample.

- March - June 2017: As part of a larger, longer-term study on soil fertility in Surendranagar, Morbi, and Rajkot districts of Gujarat, we identified 24 villages with a substantial number of individuals using the Krishi Tarang mobile agricultural extension service. In each of these villages, we randomly selected 50 Krishi Tarang users and tested soil from their most important plot. We also administered a survey collecting data on number of plots, crops grown, irrigation status of plots, and fertilizer practices. For 10% of these farmers per village, we also collected samples from and tested the soil of up to four neighboring plots. Farmers not in the original sample of 50 but whose plots were tested as neighboring plots were not surveyed. Soil samples were tested in the soil testing labs of JAU and GSFC, (about 50% in each). We have thus far received test results for 936 plots of the study sample and 196 plots of the sample of neighboring plots (1132 total). We matched these results with the Gujarat government's publicly available

[9] http://shc.aau.in/guj/home/soil

[10] For available nitrogen: potassium permanganate distillation and titration; for available phosphorus: Olsen method; for available potash: distillation on flame photometer; for organic carbon: Walkley & Black method. Descriptions: http://www.dird-pune.gov.in/L_R_GUIDELINES/LAB_MANUAL22052014.pdf

[11] The central government's soil health card scheme looks to collect a single sample for a number of neighboring plots and to then interpolate results of this one test to all the neighboring plots. The soil health cards we compare to individual soil tests were, however, part of the Gujarat state scheme, which prescribed individual tests for every plot.

database of soil test results on the basis of village, plot, and farmer identifiers, and were able to definitively match 239 (21%).

The total sample thus comprises 293 (54 + 239) plots, for which we have both a government soil health card and our own independent test. We are able to match 52% of these based on the survey number of the field, which is a number assigned by the government to each plot. The remaining 48% of fields are identified by a farmer's first, middle, and last name, as well as village. We describe our matching algorithm in Appendix I. Over 96% of soil health card data among matched samples is from after 2010.

Table A1 in Appendix I describes farming practices in this sample. Over 46% of plots are irrigated. About one in three plots is the only plot cultivated by a farmer. 87% of irrigated plots and 82% of un-irrigated plots are used to cultivate cotton. We observe high use of urea (nitrogen-rich) and DAP (phosphorus-rich) fertilizers, with 87% and 79% of irrigated and un-irrigated plots, respectively, using the former, and 81% and 84% of irrigated and un-irrigated plots, respectively, using the latter. Average expenditure on these fertilizers totals Rs.4100/hectare for farmers cultivating irrigated plots and Rs.3476/hectare for those cultivating un-irrigated plots.

Cross Validation of Soil Health Card Data

Comparing results from the two independent soil tests is relatively straight forward, as both tests report the same set of nutrients: nitrogen, phosphorus, and potash. However, since the JAU tests report nitrogen content directly, we only compare numerical nitrogen values between GSFC and government tests, both of which report organic carbon (which serves as a proxy for nitrogen availability). Phosphorus and potash are reported in all three reports.

Nutrient status

Fig. 1 plots the distribution of the measured quantities of three macronutrients, nitrogen (N), phosphorus (P), and potash (K), in the independent test against their corresponding values in the soil health card. These nutrients are critical for plant growth and form the basis of the three most widely recommended and used fertilizers: urea, di-ammonium phosphate (DAP), and muriate of potash (MOP). Because fertilizer recommendations are based on the category (low, medium, or high) into which numerically measured quantities fall, we report both the correlation of numerically measured values and rank correlation among their corresponding categories.

[Fig. 1 here]

We observe very low levels of correlation in measured values across the two reports—0.034 for nitrogen, 0.045 for phosphorus, and 0.080 for potash. The Spearman rank correlation coefficient is also low—0.078 for nitrogen, 0.028 for phosphorus, 0.052 for potash; we are never able to reject the null that it is equal to zero. These magnitudes are much lower than 0.5-0.6 correlation coefficients observed between two different soil test results of the same plot in other contexts such as Kenya (Kremer et al. 2017).

There are several possible explanations for weak correlation: the tests were taken at different times and by different organizations—in particular we believe the government sampling took soil tests at two points in the year, while we collected soil only in April, after Rabi harvesting. In addition, there may be substantial micro-level variability, meaning the method of soil sampling, moisture, and temperature can all affect test results. While nitrogen measures are less sensitive to the last two, phosphorus and potash can be affected. The first of these—timing of tests—is particularly important as soil health quality is known to change over time.

One possibility that we would like to rule out is that our methodology or the laboratory we chose were flawed and provided "pure noise" rather than useful results. To evaluate this (problematic) hypothesis, we exploit a fortuitous feature of our data—in 42 cases (of 1132 in the March-June, 2017, soil sample collection), pairs of farmers who cultivate the same plot were randomly picked for soil sampling from our sampling frame (all Krishi Tarang users) in a village. We thus have two independent test results for these plots. In Fig. 2, we plot the analog of Fig. 1 for these pairs of tests. Here, we observe high numeric correlation—0.667 for nitrogen[12], 0.418 for phosphorus, and 0.558 for potash. These magnitudes are consistent with across-test correlations found by others (Kremer et al. 2017). The rank correlation is 0.342 for nitrogen, 0.491 for phosphorus, and 0.224 for potash. For the first two, we are able to reject the null hypothesis (5% significance) that this rank correlation coefficient is equal to zero.

[Fig. 2 about here]

A vast majority (over 96%) of soil health card data is from after 2010; however, at least one extension service recommends testing soil every 3-4 years, as nutrient quantity may change over time.[13] As the soil health card scheme's intended goal is to furnish an updated soil health card every three years, we replicate the above analysis after restricting the sample to just those observations where the soil health card corresponding to the independent test was generated in the last three years (2014-2017). Fig. 3 plots the analog of Fig. 1 for this sample. There are no substantive differences in measured correlation and rank correlation after excluding all observations older than three years. While the data are noisy, we can reject, at the 5% level, the hypothesis that the correlation in nutrient quality is .6.

[Fig. 3 here]

Geographic variability: As described previously, when collecting soil and survey data for the study sample during March – June 2017 (see p. 7), we also collected soil samples from immediately neighboring plots of 10% of the original sample. As of now we have test results for 80 sets of neighboring plots, with each set having an average of 3.04 plots in it. Appendix Table A2 describes geographic variability in nutrient categories assigned to plots within the same set of neighbors and within the same village. For sets of neighboring plots, we observe that 46% (n=80) are characterized by the independent tests as belonging to the same potash category (either low, medium, or high), 54% are characterized as belonging to the same phosphorus category, and 75% are characterized as belonging to the same nitrogen category. For villages, 6% (n=30) are characterized as having all plots in the same potash category, 3% are characterized as having all plots in the same phosphorus category, and none have all plots in the same nitrogen category. In terms of numerical values, the standard deviation across villages is double that across neighboring sets of plots. In sum, we observe relative similarity in nutrient status across immediately neighboring plots, but variability in nutrient status across different plots in the same village.

Recommended fertilizers & costs

Measured quantities of nutrients are important because they are used to determine fertilizer recommendations. We translate nutrient status reported in soil health cards and independent tests

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[12] Note that here, too, we are only comparing nitrogen values in organic carbon.
[13] https://ask.extension.org/questions/156342

into fertilizer recommendations based on the most recently approved recommendations for BT cotton in the Saurashtra region of Gujarat, where our study area lies. These recommendations are detailed in appendix Table A4. They were agreed upon during the twelfth annual meeting of the agricultural research council of Gujarat state agricultural universities in 2015-2016.[14] We choose cotton as it is cultivated by over 80% of farmers in our sample, and compare soil health cards and independent tests in terms of fertilizers that each would recommend for a farmer growing either irrigated or un-irrigated BT cotton.

Appendix Table A3 reports the quantities of urea, DAP, and MOP fertilizers recommended by the independent tests and government SHCs. For each fertilizer, this recommendation can take one of three values — high (if the corresponding nutrient is found to be low in soil), medium (if the corresponding nutrient is present in average quantities), or low (if the corresponding nutrient is high in soil)[15]. Soil tests conducted by the government, on average, generate results that are more likely to prescribe medium levels of fertilizer use (in the case of urea and DAP) and low levels of fertilizer use (in the case of MOP) than the recommendations that come from our tests. There is more variation in recommendations in the independent lab test reports.

Both government soil health cards and independent tests recommend, on average, higher doses of nitrogen and potash-based fertilizers than currently used by farmers in our sample who cultivate cotton on irrigated plots. For un-irrigated plots, the independent tests recommend higher doses of nitrogen and potash-based fertilizers than currently used, while soil health cards recommend higher doses of potash-based fertilizers than currently used. Recommended phosphorus matches farmers' current use patterns.

The fact that farmers in our sample who are cultivating irrigated cotton are using less nitrogen-based fertilizers than recommended (by almost 50%) is contrary to conventional wisdom, which dictates that high subsidies for these fertilizers would lead to their overuse. Indeed, overuse of nitrogen-based fertilizers is documented in other states such as Bihar (Fishman et al. 2016) and even among hybrid (albeit not BT) cotton-growing farmers in the Surat district of Gujarat (Blaise et al. 2005). We expect that the reason for this discrepancy is twofold: first, that poor rainfall in our study area depressed farmers' use of nitrogen-based fertilizers in later parts of the 2016 kharif season. These fertilizers are applied in multiple doses over the season and farmers use less when they do not have enough groundwater to irrigate fields.[16] Indeed, we find that farmers from these blocks reported using between 10-25% more of these fertilizers when surveyed for a different study in 2014 (data from Cole & Fernando 2016).

Second, as described above, we translate nutrient status into fertilizer recommendations using the latest update to these recommendations for BT cotton, which occurred in 2016. Prior to this, the set of recommendations being disseminated by universities were generated in 2010-2011 and were for the hybrid cotton crop G-cot6. G-cot6 has only about 2/3 the nitrogen requirement of BT

[14] Fertilizer recommendations are based on experimental plots cultivated in the region for which recommendations are being made. These recommendations are adopted at annual meetings of the joint agricultural research council (AGRESCO), i.e. meetings of all agricultural universities in Gujarat. Our sample lies within the Saurashtra region of Gujarat, and the latest recommendations come from the proceedings of the 12th AGRESCO meeting, held in 2015-2016.

[15] Urea recommendations are adjusted downward from the prescribed high/medium/low quantities according to DAP recommendations, as 100 kg of the latter adds 46 kg of phosphorus and 18 kg of nitrogen to soil. Therefore, for irrigated plots recommended high, medium, and low amounts of DAP, the corresponding urea recommendation is reduced by 50kg, 42kg, and 32kg respectively, from the amounts described in Table A4. For un-irrigated plots, the corresponding reduction is 21kg, 17kg, and 13kg.

[16] Total rainfall over the season was only about 50% of the last 50-year average for the region.

cotton, and does not come with any phosphorus or potash recommendations at all. While a vast majority of cotton farmers in the area have transitioned to growing BT cotton in the past decade, they might still be following nitrogen-recommendations for hybrid cotton, as no specific BT-related recommendations existed until 2016. [17] Farmers' use of DAP—a subsidized fertilizer which adds both nitrogen and phosphorus to soil—would then be consistent with the theory of overuse in relation to latest recommendations to which the general population, and farmers' typical sources of information, including farmer friends, or agrodealers, had access.

Finally, we note that our sampling frame was not designed to be representative of all India – the farmers we sample, or the blocks in which we work may, for example, be poorer, or use less fertilizer, in general, than other farmers.

Potash fertilizers are neither subsidized nor were recommended for cotton until 2015-2016, which could explain their low use compared to the recommended amount.

Table 3 directly compares the independent test with the soil health card for the same plot in terms of quantities and costs of recommended fertilizers. Columns (1)-(4) report results for the entire sample, while columns (5)-(8) restrict the sample to those for whom the soil health card was generated within the last three years. For the full sample, in 39% of cases, the independent test and SHC both recommend that the same quantity of nitrogen be applied to the plot; this rate of agreement is 29.9% for phosphorus and 42% for potash. When the independent test and soil health card recommend different doses of fertilizers, the former tends to recommend higher doses.

[Table 3 here]

In the remainder of Table 3, we present the agronomic and economic implications of the divergent recommendations for un-irrigated cotton (Panel B) and irrigated cotton (Panel C). We report the difference in recommended amount (kg of fertilizer per hectare) and the difference in estimated cost per hectare in terms of mean and percentages. We choose cotton as it is cultivated by over 80% of farmers in our sample. On average, it is more expensive to follow recommendations from the independent test than from the soil health card. For an un-irrigated plot, it would cost a farmer, on average, an additional Rs.108/hectare to follow the urea recommendation from the independent test than from the soil health card. This represents 12% of a farmer's current average expenditure on urea. For DAP, the difference is 0.3% of current average expenditure, and for MOP it is 259% (as fewer than 4% of farmers use potash-based fertilizer average expenditure is only Rs. 4/hectare). On an irrigated plot, it would cost a farmer 25%, 0.59%, and 952% (more) of average expenditure on urea, DAP, and MOP, respectively, to follow recommendations from the independent lab tests over those in the SHC.

There is no substantive change in these findings when we restrict the sample to the last three years (columns (5)-(8) of Table 3) or when we restrict to observations matched by survey number only (Appendix Table A5). When we restrict urea (nitrogen-rich) recommendations to GSFC tests versus the soil health card (Appendix Table A6), we observe that differences in magnitude fall by half, but recommendations still differ about 50% of the time.

[17] That this recommendation for G-cot6 was to be used for BT cotton was last reiterated during the eleventh AGRESCO meeting in 2014-2015, prior to the release of new recommendations for BT cotton in 2015-2016.

In sum, we find high rates of disagreement between recommendations in the soil health card and independent tests. It is difficult to gauge the impact of this on farmer yields in the absence of an experiment wherein each recommendation is applied to a subset of plots, as we do not know the underlying truth with certainty.

We conclude, however, by emphasizing that soil testing is a difficult enterprise. We believe further work is warranted to cross-validate the information provided by soil health cards nationwide. One further, promising avenue of attack is to use kriging (a regression interpolation technique) to reduce the variability of individual-level soil tests. If kriging is currently being used to generate SHC results, this may also explain some of the discrepancy between our test results and those of the government.

Evaluating the SHC Intervention

Experimental Design and Estimation

Through a "lab-in-the-field" experiment with cotton farmers in Gujarat, we explore how farmers' understanding of and trust in government-issued SHCs evolves when the SHC is accompanied by different forms of ICT-based or in-person advisory explaining its recommendations in an easy-to-understand manner.

Across 12 villages in two blocks of Gujarat where the Krishi Tarang service is operational, we selected approximately 600 farmers to be assigned at random to one of four conditions: an SHC only (C), an SHC along with an audio recording (T1), video clip (T2), or agronomist visit (T3) conveying its contents. Farmers in groups T1-T3 were also handed a written supplement converting fertilizer recommendations from kg/hectare as in the soil card to kg/bigha (the common unit of area used in this setting).[18] For logistical simplicity, the SHCs were not from soil tests of farmers' own fields; instead, a farmer was presented with an SHC and asked to evaluate it as if it belonged to a friend or cousin who was asking for agricultural advice.

Our provision of a supplement to the SHC is similar in spirit to an intervention conducted by Usman et al. (2011) in Pakistan, which redesigned immunization cards for children in Pakistan to include graphics conveying the benefit of various vaccines. The authors reported significant increases in completion of the diphtheria-tetanus-pertussis immunization in the treatment group.

Our experimental design permits both a within-individual design for the approximately 400 participants in groups T1, T2, and T3, as well as an across-subject design.

We first evaluated farmer beliefs without providing any soil nutrient information, by asking the farmer to provide fertilizer recommendations to a hypothetical friend or cousin cultivating irrigated cotton. Second, each farmer in our sample was shown a soil health card and asked to answer (i) factual questions about specific urea, DAP, and MOP recommendations contained therein, and (ii) opinion questions gauging his perception of the trustworthiness of these

[18] This design decision represented a trade-off: our early experiences with farmers suggested that very few were familiar with hectares, the unit of measure on government SHCs. The disadvantage of our approach is that we cannot distinguish between hectare-based soil cards and the combination of, say, hectare-based soil cards with audio messages; however, we feel that converting cards to local units is a sufficiently simple modification to the SHC that we chose to evaluate the combined intervention of a redesigned (or supplemental) health card alongside the audio/video/agronomist information.

recommendations. Finally, as per assignment, the SHC's recommendations were also explained through an audio recording, video clip, or agronomist visit (scripts of these interventions are included in Appendix II). Farmers were then asked to answer these questions again. At this time, they were also asked other questions regarding their knowledge of soil fertility, trust in recommendations under different scenarios, and willingness to participate in lotteries whereby, if chosen, they would have to pay Rs.250 (or Rs.200, or Rs.150) to have a soil test worth Rs.250 performed for their field.

Comparing farmers' understanding of specific fertilizer recommendations and trust in them from when they are only exposed to the card to when they have received information from an audio, video, or an agronomist visit, allows us to glean the effect on these variables from the additional advisory.

The sequence of activities remained the same for the soil health card-only group, except they were only asked to provide their interpretation of the soil health card once.

In addition to inducing random variation in the mode of information delivery, we also randomly varied an important aspect of the information itself—in particular, whether the results of the SHC recommended higher fertilizer use than is typically practiced by farmers in the area or lower fertilizer use than is typically practiced. Each set of recommendations was plausible, given the soil composition in the area. This was done to understand whether trust in information is driven by a bias towards believing that more fertilizers are always better than less (Fishman et al., 2016). Half of the participants in groups T1, T2, T3, and C1 each received one type of SHC (high/low). Fig. 4 depicts the randomization scheme and sample sizes in each group.

[Fig. 4 here]

The scripts for the audio recording, video clip, and agronomist visit were designed to convey information in a manner that is easy to understand and directly relevant to farmers: for example, recommended fertilizer use was converted from kilograms per hectare, as in the soil health card, to kilograms or bags per bigha (the unit of land area commonly used by farmers). It also acknowledged that the recommendations provided a benchmark, which would have to be adjusted according to rainfall—a common practice among farmers, and one they cared about as we engaged in early pilots. The link between soil nutrient status and fertilizer recommendations was clearly established, and the benefits of using university-sanctioned recommendations were explained in terms of potential gains in yields/reduction in costs.

To ensure that participants pay attention to the information contained in this SHC for a hypothetical friend, we informed participants in advance that we would provide a mobile phone top-up of Rs.10 for every correct answer to a question about specific recommendations in the SHC. We were very clear in stating that trust-related questions had no such associated incentive, and that for these questions, we were interested in understanding the participant's honest opinion of the cards, potential reservations about its use, and the extent to which s/he would endorse its recommendations to a friend or relative.

We report results of two specifications for understanding and trust-related variables. The first compares members of the SHC-only group with those assigned to the audio, video, and agronomist interventions.

$$y_{iv} = \alpha + \beta_1 audio_{iv} + \beta_2 video_{iv} + \beta_3 agronomist_{iv} + \lambda_v + \varepsilon_i \quad (1)$$

Here, y_{iv} is an outcome variable for individual *i* in village *v*. *Audio*, *video*, and *agronomist* indicate assignment into each of these treatment groups (the omitted category is SHC-only). λ_v is the village fixed effect and ε_i is an individual-specific error. β_1, β_2, and β_3 are the coefficients of interest.

We also report results from a within-individual specification among those in the audio, video, and agronomist groups.

$$y_{it} = \alpha_i + \delta post_{it} \quad (2)$$

Here, $post_{it}$ is an indicator equal to 0 when individuals are only shown the soil health card, and equal to 1 after individuals are played the audio or video or provided advisory by an agronomist as per their treatment assignment. δ is the coefficient of interest.

To evaluate differences in trust among those who receive soil health cards with high and low fertilizer recommendations, we first restrict to the sample of individuals in the audio, video, and agronomist group (as we expect and observe higher levels of understanding among these groups). We then evaluate the following specification, where π is the coefficient of interest and $high_i$ is an indicator equal to 0 if an individual receives a card with lower than typical recommended fertilizer use and 1 if s/he receives a card with higher than typical recommended fertilizer use:

$$y_{iv} = \alpha + \pi high_i + \lambda_v + \varepsilon_i \quad (3)$$

Baseline characteristics

Table 4 reports baseline characteristics of farmers and checks for balance on demographic variables, knowledge of soil health, and baseline understanding of the SHC's contents (prior to exposure to ICT or in-person advisory explaining its recommendations). Panel A reports demographic and basic farming characteristics. Participants are, on average, about 36 years old. About 70% are literate, nearly all are male, over 94% grow cotton, and, for between 60% and 70%, the most important plot is irrigated.

[Table 4 here]

Panel B reports knowledge of soil fertility and testing. Between 20% and 30% understand that the purpose of soil testing is to assess the level of nutrients in soil and/or to recommend fertilizers based on soil quality. Only 7% demonstrate familiarity with the government's SHC scheme, and about 10% report having ever had their soil tested.

Panel C reports participants' ability to interpret the soil health card after they are shown it without any (audio, visual, or in-person) aids. Only between 2% and 10% are able to correctly answer questions on specific fertilizer quantities recommended in the card. Yet over 90% of individuals in each group anticipate that they can either fully or somewhat trust the recommendations (Panel D).

Experimental Results

Effect of ICT and in-person extension on trust and understanding

In Tables 5 and 6, we explore how the audio, video, and agronomist treatments affect farmers' understanding of SHC recommendations, trust in them, and general knowledge of soil fertility and testing. We find significant improvements in understanding as well as trust.

Table 5 compares the SHC-only group with audio, video, and agronomist treatments. All three treatments dramatically improve participants' ability to interpret fertilizer recommendations from the SHC, with between 36 and 50 percentage points higher comprehension among treated individuals. Of the three treatments, gains are found as being highest in the agronomist intervention, followed closely by video and audio.

[Table 5 here]

We also find that farmers in each of the three treatment groups (audio, video, agronomist) are more likely to report trusting recommendations compared to those in the SHC-only group. Farmers visited by an agronomist are 11.1 percentage points more likely than the SHC-only group to report fully trusting recommendations in the SHC, and those played the audio or video treatment are 5-7 percentage points more likely to report fully trusting recommendations. Those visited by an agronomist are also more likely to be willing to enter a lottery wherein, if selected, they would have to pay a certain amount of money to have a soil sample from their own field collected and tested.[19]

In terms of knowledge, those in the audio, video, and agronomist treatment groups are more likely than the SHC-only group to know which fertilizers can add phosphorus, potash, and nitrogen to the soil. While this difference is only consistently significant for the agronomist and video groups, all point estimates are positive. Pair-wise comparisons between the three treatment groups reveal the agronomist visit as having the greatest impact on knowledge-related measures.

We find no evidence that those in the SHC-only group are any more or less likely than any treatment group to understand the purpose of soil testing, or that they are more or less likely to know that SHC recommendations differ by plot.

Table 6 reports results of the within-individual specification described in Eq. (2). As before, we find very positive and significant results on participants' ability to interpret the soil health card, with between a 35-40% improvement in comprehension. The coefficient for trust is positive and significant for the pooled sample as well as the audio and agronomist treatment.

[Table 6 here]

To address concerns about multiple hypothesis testing, we create indices by averaging all variables separately for understanding, trust, and knowledge, and assess impact of treatment on these indices. All treatments significantly improve understanding and fully trusting SHC recommendations, although the trust index for audio and video is insignificant due to them not moving a participant's willingness to pay to obtain a soil test. Video and agronomist treatments significantly improve knowledge.

Heterogeneity by literacy

[19] The monetary amounts vary from Rs. 150 - Rs. 250; the cost of the test is Rs. 150, but the total cost of test, sample collection and transportation is Rs. 250

Table 7 explores heterogeneity of results by literacy. One might expect that the impact of ICT or in-person extension over only giving the SHC is different for literate and illiterate farmers, as only the former are able to read SHCs. Additionally, we want to explore if results are being driven by written supplements accompanying the audio, video, and agronomist interventions.

[Table 7 here]

We find that all three interventions positively affect understanding among illiterate as well as literate farmers, and trust among illiterate farmers.

Fewer than 4% of illiterate farmers are able to interpret any recommendation in the absence of audio, visual, or agronomist aids. In contrast, comprehension rises by between 12 and 21 percentage points when the soil health card is accompanied by an ICT-based or agronomist intervention. All effects are statistically significant ($p<0.01$). Farmers exposed to the audio, video, or agronomist advice are also more likely to report fully trusting SHC recommendations. This effect is about 25 percentage points for the audio and agronomist groups, and 17 percentage points for the video group. All differences are significant at conventional levels. Only the agronomist intervention moves farmers' willingness to enter a lottery wherein, if selected, they would pay to have a soil test performed on their own field.

For this subgroup of illiterate farmers, the audio treatment performs best on measures of both understanding and reported trust, followed by the agronomist and video treatments. While the difference between audio and the other interventions is not statistically significant for all measures, point estimates for those assigned to audio are consistently higher. As before, knowledge of soil fertility rises in the agronomist group.

Among literate farmers, comprehension of SHC recommendations rises between 40 and 55 percentage points and is significantly greater for all three interventions when compared with the SHC-only group. Trust is not appreciably affected by being exposed to the audio and video, although is positively affected by an agronomist visit. Unlike the subgroup of illiterate farmers, knowledge of soil fertility is positively affected by both video and agronomist interventions, and knowledge of the relationship between specific nutrients and fertilizers rises among all three treatment groups.

Effect of high/low fertilizer recommendations on trust

Table 8 reports differences in trust among those who receive SHCs recommending higher doses of fertilizers than typically practiced by farmers in the area, and those who receive SHCs recommending lower doses than typically practiced. Each set of recommendations was plausible given the soil chemistry in the area.

We are not able to reject the null hypothesis that levels of trust among those who receive SHCs with low recommendations are the same as among those who receive SHCs with high recommendations.[20]

Limitations

We acknowledge a number of limitations to this experiment.

[20] This is an intent-to-treat estimate.

(i) Lower bound estimate of baseline understanding: The study likely offers lower bound estimates of baseline understanding of soil health cards among farmers. Participants in our sample were not allowed to consult with others when interpreting the soil health card, although such consultation is likely to occur in real life.

(ii) Questions administered a different number of times to treatment and control group participants: Participants in the treatment groups (audio, video, agronomist) were asked twice to report their interpretation of fertilizer doses recommended in the SHC—once after just seeing the SHC and once after being administered the treatment. They were also asked twice to respond to one question pertaining to their trust in these recommendations. Participants in the soil health card-only group were asked all questions only once. It is possible that because participants were able to venture two guesses instead of one, they were more likely to get the answer right the second time around.

(iii) Persistence of results: Since a participant was involved in the study for a total of up to two hours, during which he was administered a pre-survey, the intervention, and a post-survey, it is unclear whether the results related to understanding of SHCs as observed in the audio, video, and agronomists groups will persist over time.

(iv) Hypothetical trust may not translate into actual adoption: It is unclear whether stated trust in recommendations translates into actual adoption of recommendations. Fishman et al. (2016) observe very low adherence to SHC recommendations among farmers in Bihar, even after in-person extension was employed to explain these recommendations. Because we did not present farmers with their own SHCs, we are unable to track how stated trust translates into adoption of recommendations. However, an ongoing study with 1800 farmers in Gujarat attempts to answer this very question.

(v) A combined treatment: the audio, video, and agronomist treatments also included the provision of a supplemental sheet that conveyed the results from the soil-health card in a more user-friendly manner. In our view, this is a very policy relevant intervention, as it would not introduce any significant cost relative to simply distributing the soil health card. However, it means we are unable to identify the effect of ICT-only treatment (e.g., voice messages absent this paper supplement). Ongoing work is comparing the effect of the SHC only, to the SHC with the paper supplement. We do note that the fact that our intervention has important effects on illiterate individuals supports the view that our ICT and agronomist interventions do change understanding and beliefs.

Audit Study of Agro-Dealers

Many farmers seeking advice or guidance, particularly with respect to agricultural inputs such as pesticide and fertilizer, may turn to agro-dealers for advice. Agro-dealers, who often farm land in the same locality as their customers, observe a number of problems throughout the year and may be particularly well-suited to guide farmers. Unfortunately, the evidence on the quality of commissions-motivated advice is quite mixed (e.g., Anagol, Cole and Sarkar (2016)), should sellers seek to maximize profits rather than consumer surplus.

In this section, we describe an audit study of agro-dealers, designed to measure the quality of advice provided by input sellers.

In August 2012, a research team from the Center for Microfinance (IFMR) conducted an audit study of agricultural input dealers in two townships in rural Gujarat (Chuda and Limbdi). Our surveyors approached every agro-input dealer in the area, requesting permission to sit in and observe farmer purchasing decisions over the period of a day. Agro-dealers were informed that the purpose of the study was to "understand the purchasing patterns of farmers," and agro-dealers were offered a nominal amount (Rs. 100) to participate in the study. Approximately 90% of dealers agreed, resulting in a study with 36 agricultural input dealers.

Accurately measuring the quality of advice is challenging, as both problems and solutions are often nuanced and based on local context. To address this challenge, we selected surveyors who were very familiar with local farming and provided them with intensive training, beginning with two days of classroom training in our Ahmedabad office. The focus of the training was on familiarizing the auditors with the various product names (ie. pesticides, fertilizers, seeds) and the survey forms, including the inventory sheet, and on conducting mock audits. These run-throughs helped the auditors to develop listening and recording skills. The final day of training was comprised of actual field visits, followed by a half-day debriefing to review the critical pieces of information for data collection and to discuss strategies for scrutiny.

Each visit to an agro-dealer took approximately four hours. The surveyor would find an inconspicuous location and sit and take notes of all conversations between the agro-dealer and his farmer customers. This included documenting in writing the agro-dealer/farmer dialogue, covering points such as: the farmer complaint or issue, whether the farmer requested a specific product, what further questions the agro-dealer asked, and, finally, the advice provided by the agro-dealer to the farmer, including the recommended products and dosage. On average, there were 7.3 farmer observations per agro-dealer shop, with a maximum of 15 observations and minimum of three observations per shop. An 'Additional Comments' section was also included, and instructions provided the surveyor to record more general observations, such as the agro-dealer's attitude and store advertisements.

Finally, our surveyors conducted an inventory analysis with each agro-dealer, to collect data on the types of products available in his store. Both the type of pesticide and the brand/company name were collected. Survey teams later noted that some agro-dealers may have been dishonest in reporting some of the products available in their shops.

Following collection of the data, we had the recommendations analyzed by an agronomic expert with several years experience providing guidance in cotton farming in this area. We instructed him to characterize the advice on a scale of 1 to 5, where 1 was "strongly disagree," and 5 was "strongly agree," and also gave him an option to indicate "insufficient information to evaluate the recommendation.

Fig. 5 describes the main results of this study: in 40% of the instances, our auditing team did not record enough information such that the agronomist could characterize the advice as appropriate or inappropriate. However, for the remaining cases, the news is not good: our agronomist was much more likely to "strongly disagree" (28% of the answers given) than to "strongly agree" (17% of answers).

[Figure 5 here]

Much of the inappropriate advice centered on the recommendation of monocrotophos, a toxic pesticide that is not effective against many local pests, but which reportedly imparts a green sheen on leaves, leading farmers to (mistakenly) believe it enhances fertility. This apparent confusion motivated an undergraduate student at Harvard College to use the audit data, plus an additional field experiment, to document that farmers have an erroneous mental model, which equates use of monocrotophos with higher yields (even in the absence of pests) (Seo, 2016).

Discussion and Conclusion

The 2017-2018 Union budget increased funding for the agricultural sector by 24% and set an ambitious goal of doubling farm incomes within the next five years. The central government's SHC scheme is an important part of this strategy, with a budget allocation of over $100 million over three years, a plan to set up soil testing laboratories in all 648 Krishi Vigyan Kendras, and a goal to deliver customized fertilizer recommendations to every farming household in the country by 2018.

Our study seeks to test and document how the use of ICT might improve this specific but quite important undertaking to improve agricultural productivity. In our view, the news is mixed.

One of the most important challenges is logistical—we are not in a position to comment on the government's execution, except to note that the government appears to be taking a data-driven approach to SHC distribution. This includes publishing a live dashboard indicating the number of samples taken (over 25 million to date) and SHCs dispatched (over 86 million to date), and allowing farmers to track their sample in real time.

This study delivers the promising news that farmers display high levels of willingness to trust SHCs generated by the government. This stands in contrast to results from Bihar (Fishman et al., 2016), and more work is required to understand what drives these differences. We find that over 90% report that they would either fully or at least somewhat trust such a card if customized for their field, while 81% report that they would fully or somewhat trust such a card even if no KVK worker came to collect their individualized soil sample. The latter is particularly promising because the government's current strategy is to collect a single sample for every 10 acres of un-irrigated land and every 2.5 acres of irrigated land, and interpolated samples may play an important role in disseminating information.

Our paper examines several (but not all) steps along a theory of change in which soil testing leads to informed farmers, alternative input choices, and higher yields (at lower cost). Specifically, we evaluate the accuracy, accessibility, and comprehensibility of SHCS.

On the first, the research in this paper suggests a need to cross-validate the results of soil tests to ensure that farmers receive consistent, accurate, and trustworthy recommendations. While we find low correlation between measured nutrient status and fertilizer recommendations in an SHC and in an independent laboratory test for the same plot, we are encouraged by the high correlation observed between two different lab tests we commissioned for a subset of plots. This indicates that, subject to uniformity in sampling technique and a short enough window of time within which two samples are collected, recommendations can be at least verifiably consistent. The Government of India SHC scheme involves sending 1% of soil tests to a higher-level laboratory to ensure the lower-level laboratory results are accurate. We might suggest an alternative strategy, which would involve sending a separate, independent team to duplicate 1% of soil tests and make these cross-validations public.

On the second, we document significant gaps in current extension, which relies heavily on in-person visits. Only 11% of farmers report ever having had soil tests, and about half of this number report having ever received a report (though government records suggest Gujarat has achieved 59% of the targeted distribution of SHCs). In the absence of reliable information on how to manage soil fertility, farmers tend to rely on agro-dealers and farmer friends for agricultural advice (this pattern is not true just of Gujarat, but nationwide). An auditing exercise conducted in Gujarat raises some concerns about the quality of advice provided by agricultural dealers, who may be incentivized by a profit-maximizing motive, or might themselves not have access to accurate information on appropriate input use.

We find that ICT-based approaches offer a promising complement to a strategy of distributing soil health cards. When benchmarked against in-person extension, audio and video supplements perform comparably both in terms of enabling comprehension of SHC recommendations and eliciting trust in their accuracy. They perform significantly better on both measures than just providing a farmer with an SHC. Our experiment also suggests that these approaches might hold particular promise in reaching illiterate farmers, who are 32% of all farmers (NSSO, 2015).

Finally, we again acknowledge a range of limitations to our study. First, while we make use of national survey data, our most novel findings come from a single state, Gujarat, and even more specifically, from a few districts within that state. Second, a majority of farmers in our experiment are already receiving mobile phone-based agricultural extension, and so might be more accustomed and receptive to learning through ICT-based means than members of the general population. Third, our outcomes are short-term and focus primarily on understanding and self-reported beliefs and attitudes. In ongoing work, we are conducting a two-year field experiment to measure the impact of delivering customized soil health cards, along with a series of audio messages that will guide the farmer through fertilizer purchase and application decisions.

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Appendix I

Soil sampling technique

Trained individuals followed government guidelines to collect soil samples. Samples were collected from eight different points in a field, selected in a zig-zag manner. At each point, they were obtained from a depth of 15-20 cm by cutting the soil in a “V” shape. The sample thus collected was mixed thoroughly and then successively split into smaller quantities until a final sample between 250 and 500gm remained. Samples were bagged first in plastic bags and then in a cloth container. They were transferred immediately to soil testing laboratories for analysis.

Procedure for matching independent test results from March to June, 2017, with the government soil health card database

We first matched farmer-plot pairs with their corresponding publicly available soil health card using village names and plot survey numbers, which are unique identifiers assigned to every plot in a village. Farmers from 60% of the 1132 fields we tested reported their survey numbers, while 90% of records in the publicly available database contain survey numbers.

A conservative name-matching algorithm was subsequently employed to match as-yet-unmatched farmer-plot pairs with corresponding SHC results from the government database. From all plots matched by this algorithm, we remove all instances of more than one farmer-plot pair from our sample that matches with the same record in the government database or different records in the government database that match with the same farmer-plot pair. All matches were confirmed by hand. In effect, we are left only with unique name matches.

The name-matching algorithm described above is predicated on the assumption that no two different farmers in the government database have the same first, middle, and last names. To check robustness, we therefore also report results after excluding all observations that match by name. There are no substantive differences in results with and without this sub-sample.

Through this process, we were able to match 239 (21%) fields from our sample with corresponding government test results. Whenever a field had more than one test in the government database, we matched with the latest available test result. To these, we added the 54 fields from January, 2017, making a total of 293 matches. Of these, 52% are based on the survey number of the field, and 48% are based on the name of the farmer. Over 96% of public data among matched samples is from after 2010.

Table A1 summarizes characteristics of the overall sample and match characteristics.

[Table A1]
[Table A2]
[Table A3]
[Table A5]
[Table A6]

Appendix II

Scripts for audio, video, and agronomist explanation of SHCs.

GENERAL SCRIPTS

Script 1: Introduction (why get soil tested; that there is a relationship between nutrients, fertilizers, productivity, and costs)

Namskar, this is Krishi Tarang agriculture information service. In this message, we will talk about soil health management. In a recent survey of 500 farmers in Surendranagar and Rajkot, we found that over 90% use some form of fertilizer. Even as fertilizers have become prevalent in our farming, we are prone to knowingly or unknowingly use a higher or lower amount of chemical fertilizers than is actually advisable. The imbalanced use of fertilizers can severely lower productivity, often by as much as 50%. The overuse of certain fertilizers also directly increases our cost of production and pollutes both soil and water. Persistent imbalanced use of fertilizers affects long-term soil productivity and our earning capacity.

Before starting to grow any crop (like cotton, groundnut, or wheat), it is thus essential to plan our fertilizer requirements and application. This is easy to do once we know both which nutrients are required for our crop and the composition of those particular nutrients in our soil. Fertilizers can then help make up for any deficiency in nutrients particular to our soil. For example, if a cotton farmer's soil is deficient in sulphur, she can add ammonium sulphate; if her soil is deficient in nitrogen, she can apply urea, and so on. Local universities, like Junagadh Agricultural University and Anand Agricultural University, have analyzed actual farming experiences to develop optimal fertilizer recommendations for crops commonly grown by farmers like you in Surendranagar and Rajkot.

The first step to making use of these recommendations is to test our soil to identify its nutrient composition. A soil testing report based on our field's soil sample then gives us both the exact availability of different nutrients in our soil and, based on this, which and what amount of fertilizers need to be applied to it.

In the next message, we will discuss how to sample soil and where soil samples can be given for testing. Then, we will discuss how to interpret a soil testing report.

Script 2: How to interpret SHC

Namskar, this is Krishi Tarang agriculture information service. In previous messages, we talked about the importance of optimal(/proper) fertilizer application and how to sample soil and have it tested. Once you have submitted a sample for testing, any laboratory will give you a detailed soil testing report. In this message, we will describe the information contained in this report and how to interpret it. A soil testing report provides details on the status of particular nutrients in your soil—either low, medium, or high. It also describes the specific fertilizer requirements for your soil based on these test results.

Please look at this hypothetical soil health card.

On the front of the card, in order of appearance:

1. PH means reaction of the soil,
2. Electrical Conductivity (EC) means amount of salts in the soil,
3. Macro nutrients (nitrogen, phosphorus and potash) essential for crop growth and,
4. Micro nutrients (sulphur, zinc, and iron) which also promote growth.

On page 2, specific fertilizer recommendations for different crops are provided based on whether these elements are present in low, medium, or high concentration in the soil. For each crop, the specific nutrients (N, P and K) that you should apply appear in columns 1, 2, and 3, respectively, and the type and quantity of fertilizers that are required for these nutrients appears in the last three columns.

For example, urea fertilizers supply nitrogen to the soil, DAP fertilizers supply phosphorus, and muriate of potash fertilizers supply potash to the soil.
Gypsum of sulphur fertilizer provides sulphur to the soil, zinc sulphate fertilizer provides zinc, and ferrous sulphate fertilizer provides iron.

The specific recommended fertilizers are the ones on the card, and in the quantities also described in the card.

By looking at this soil report, we understand that we apply fertilizers to supply certain nutrients that are contained in the fertilizer, that are required by our crop, and that are deficient in our soil. We should only apply the amount of fertilizer according to the nutrients status in our soil and actual requirement. The selection of different brands of fertilizers can be done based on its availability in our area and our budget.

SPECIFIC SCRIPTS OF THE AUDIO AND VIDEO (SOIL HEALTH CARD)

Script 1
Namskar, this is Krishi Tarang agriculture information service. In this message, we will talk about a hypothetical soil health card report and the status of EC, PH, and status of macronutrients (nitrogen, phosphorus and potash) and micronutrients (sulphur, zinc and iron) according to that card.

Our key takeaway for this hypothetical report is that the soil is deficient in **a**, requiring the application of **more/less** fertilizer **x**. The soil has sufficient quantity of **b**, thus requiring less of fertilizer **y**.

Now, as per the soil testing report, EC is **low/medium/high** (which means this soil is normal/salted/highly salted); PH means reaction of the soil is normal/acidic/basic.
Macronutrients;
Proportion of **nitrogen** in this soil is **low/medium/high** relative to the general requirement.
Proportion of **phosphorus** in this soil is **low/medium/high** relative to the general requirement.
Proportion of **potash** in this soil is **low/medium/high** relative to the general requirement.
Micronutrients;
Proportion of **sulphur** in this soil is **low/medium/high** relative to the general requirement.
Proportion of **zinc** in this soil is **low/medium/high** relative to the general requirement.
Proportion of **iron** in this soil is **low/medium/high** relative to the general requirement.
This was the information on proportion of different macro and micro nutrients in soil as per this soil test report. In the next message, we will talk about recommendations of Macronutrients (nitrogen, phosphorus and potash) and which fertilizers are required for this crop.
** BOLD-UNDERLINE are dynamically changed according to report

Script 2A (Cotton)
Namskar, this is Krishi Tarang agriculture information service. In our previous message, we discussed the status of different macro and micro nutrients in soil according to a hypothetical soil

testing report. In this message, we will discuss recommendations on different macro nutrients (nitrogen, phosphorus and potash) and which fertilizer is required for an irrigated cotton crop.

According to this soil test report:

The proportion of **nitrogen** in this soil is **low/medium/high**, so it is advised to apply **50 kg/40kg/30 kg** of nitrogen per vigha for an irrigation cotton crop. To achieve this, the soil requires **100kg/80kg/60 kg** of **urea** fertilizer per vigha during the entire season.
The proportion of **phosphorus** in this soil is **low/medium/high**, so it is advised to apply **40 kg/30kg/20kg** of phosphorus per vigha for an irrigation cotton crop. To achieve this, the soil requires **70 kg/50kg/40kg** of **DAP** fertilizer per vigha during the entire season.
The proportion of **potash** in this soil is **low/medium/high**, so it is advised to apply **50 kg/40kg/30kg** of potash per vigha for an irrigation cotton crop. To achieve this, the soil requires **60 kg/50kg/40kg** of **potash** fertilizer per vigha during the entire season.
This was the information on macro nutrients for a hypothetical soil sample. In the next message, we will talk about recommendations for micronutrients (sulphur, zinc and iron) and which fertilizers would be necessary to apply accordingly for an irrigated cotton crop.

Script 3A (Cotton)
Namskar, this is Krishi Tarang agriculture information service. In our previous message, we discussed recommendations on using macro nutrients and fertilizers according to a hypothetical soil testing report. In this message, we will discuss recommendations on different micro nutrients (sulphur, zinc and iron) and which fertilizer is necessary for an irrigated cotton crop.
According to this soil test report:
The proportion of **sulphur** in this soil is **low/medium/high**, so it is advised to apply **15 kg/12kg/10 kg** of sulphur per vigha for an irrigation cotton crop. To achieve this, the soil requires **15kg/12kg/10 kg** of **sulphur** fertilizer per vigha at the time of sowing.
The proportion of **zinc** in this soil is **low/medium/high**, so it is advised to apply **10 kg/08kg/07 kg** of zinc per vigha for an irrigation cotton crop. To achieve this, the soil requires **10kg/08kg/07 kg** of **zinc sulphate** fertilizer per vigha at the time of sowing.
The proportion of **iron** in this soil is **low/medium/high**, so it is advised to apply **25 kg/20kg/16 kg** of potash per vigha for an irrigation cotton crop. To achieve this, the soil requires **25kg/20kg/16 kg** of **ferrous sulphate** fertilizer per vigha at the time of sowing.

Script 4A (Cotton)
Namskar, this is Krishi Tarang agriculture information service. In our previous messages, we spoke about the status and recommendations of different macro and micro nutrients according to a hypothetical soil testing report, and the type and amount of fertilizers that would be necessary based on this soil test report. In this message, we will talk about which fertilizers are required as a basal application at the time of sowing for an irrigated cotton crop.
At the time of sowing (as basal application) for an irrigated cotton crop, the soil requires:
Urea fertilizer 10 kg per vigha
DAP fertilizer 8 kg per vigha
Potash fertilizer 20 kg per vigha
Sulphur fertilizer 5 kg per vigha
Zinc sulphate fertilizer 2 kg per vigha
Ferrous sulphate fertilizer 3 kg per vigha.
Please calculate the total amount of these fertilizers that are required by multiplying these amounts with the area (number of vigha) for sowing irrigated cotton crop. This was information on the total amount of fertilizers needed to apply at the time of sowing.

TABLE 1: Access to mobile phones and technical advice

	Mobile	Technical advice								
		Any advice	Extension	Krishi Vigyan Kendra	Agricultural University	Private commercial agents	Progressive farmer	Radio, TV, newspaper, internet	Veterinary department	NGO
All-India	98%	41%	6%	3%	1%	8%	21%	21%	8%	1%
Men	-	41%	7%	3%	1%	8%	20%	21%	8%	1%
Women	-	40%	6%	3%	1%	8%	21%	20%	8%	2%
Landholding < 1 ha	-	41%	6%	3%	1%	8%	20%	20%	8%	1%
Landholding < 2 ha	-	57%	15%	5%	2%	10%	31%	31%	16%	2%
Landholding > 2 ha	-	60%	10%	5%	3%	16%	32%	35%	12%	1%
High agricultural incom	-	39%	6%	3%	1%	8%	20%	21%	7%	1%
Low agricultural incom	-	43%	7%	3%	2%	9%	22%	21%	10%	2%
Jammu & Kashmir	80%	58%	0%	14%	9%	1%	21%	48%	31%	4%
Himachal Pradesh	127%	39%	3%	3%	1%	0%	4%	28%	19%	0%
Punjab	110%	51%	3%	6%	11%	19%	15%	24%	27%	0%
Haryana	83%	45%	6%	6%	4%	9%	20%	30%	18%	1%
Rajasthan	82%	27%	3%	2%	0%	4%	15%	10%	3%	0%
Uttar Pradesh	72%	27%	1%	3%	1%	8%	11%	12%	3%	1%
Bihar	68%	33%	4%	1%	0%	2%	19%	13%	2%	0%
Assam	59%	58%	11%	1%	2%	6%	17%	45%	15%	1%
West Bengal	54%	51%	3%	2%	0%	22%	30%	22%	6%	2%
Orissa	69%	36%	10%	2%	0%	5%	22%	13%	6%	1%
Madhya Pradesh	81%	38%	3%	1%	0%	2%	20%	17%	4%	1%
Gujarat	100%	49%	7%	5%	3%	4%	39%	22%	9%	2%
Maharashtra	70%	43%	9%	4%	1%	9%	20%	24%	8%	1%
Andhra Pradesh	85%	64%	28%	1%	0%	37%	36%	36%	12%	0%
Karnataka	95%	66%	10%	6%	3%	9%	36%	44%	28%	3%
Kerala	99%	65%	14%	22%	1%	2%	16%	52%	21%	1%
Tamil Nadu	104%	40%	16%	1%	6%	12%	10%	33%	16%	7%

Source: National Sample Survey (NSS) 70th Round Schedule 33, Telecom Regulatory Authority of India (TRAI), Census of India 2011, World Development Indicators (WDI).

Notes: Statistics on access to technical advice calculated from NSS 70th Round Schedule 33, Visit 1 (January through July 2013). Access to mobile phones estimated using TRAI mobile phone subscription data for June 2017 by state and Census of India 2011 population data by state. The population numbers were adjusted using a rounded average of 2011-2015 population growth rate from WDI compounded for six years.

Low agricultural income farmers are those earning less than the median income from agricultural sales in their respective state, and vice versa for high agricultural income farmers.

TABLE 2: Reported progress of SHC distribution, June 2017

	Distribution target	Progress (% of target)
Jammu & Kashmir	914,044	27%
Himachal Pradesh	385,011	100%
Punjab	4,619,621	16%
Haryana	4,360,555	26%
Rajasthan	6,886,000	64%
Uttar Pradesh	26,391,089	35%
Bihar	7,236,233	53%
Assam	1,540,968	10%
West Bengal	5,040,510	65%
Orissa	3,696,881	58%
Madhya Pradesh	8,872,377	100%
Gujarat	5,108,923	59%
Maharashtra	12,977,232	95%
Andhra Pradesh	7,455,204	81%
Karnataka	7,832,189	96%
Kerala	705,420	55%
Tamil Nadu	7,000,000	97%

Source: Ministry of Agriculture, "Statewise Status of Soil Health Card Scheme." Accessed June 2017.
Available at: http://soilhealth.dac.gov.in/Progresscdpt

TABLE 3: Comparing lab test results with public data

	All years				Restricted to public data from the last 3 years			
Panel A	Fertilizer recommendation				Fertilizer recommendation			
Nutrient type	N	Same recommendation	Public data recommends higher requirement	Public data recommends lower requirement	N	Same recommendation	Public data recommends higher requirement	Public data recommends lower requirement
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Nitrogen^	290	39.31%	9.31%	51.38%	136	40.44%	8.09%	51.47%
Phosphorus	291	29.90%	30.93%	39.18%	137	26.28%	29.20%	44.53%
Potash	286	41.96%	14.69%	41.96%	133	44.36%	6.77%	48.87%
Panel B	Comparison for unirrigated cotton				Comparison for unirrigated cotton			
	N	Amount of fertilizer (lab test - public data) (kg/hectare)	Cost to farmer (lab test - public data) (Rs./hectare)	Difference in cost as % of avg. farmer expenditure	N	Amount of fertilizer (lab test - public data) (kg/hectare)	Cost to farmer (lab test - public data) (Rs./hectare)	Difference in cost as % of avg. farmer expenditure
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Urea (N)	290	18.00 (28.77)	108.02 (172.61)	11.68%	136	17.34 (27.37)	104.02 (164.22)	11.25%
DAP (P)	291	0.44 (11.60)	9.60 (255.13)	0.31%	137	1.23 (10.99)	27.14 (241.84)	1.06%
Muriate of Potash (K)	286	5.80 (15.26)	104.41 (274.73)	259.29%	133	8.59 (12.65)	154.56 (227.65)	3297.87%
Panel C	Comparison for irrigated cotton				Comparison for irrigated cotton			
		Amount of fertilizer (lab test - SHC) (kg/hectare)	Cost to farmer (lab test - SHC) (Rs./hectare)	Difference in cost as % of avg. farmer expenditure		Amount of fertilizer (lab test - SHC) (kg/hectare)	Cost to farmer (lab test - SHC) (Rs./hectare)	Difference in cost as % of avg. farmer expenditure
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Urea (N)	290	55.67 (87.83)	334.05 (526.99)	25.85%	136	54.04 (83.12)	324.26 (498.73)	25.08%
DAP (P)	291	0.92 (29.56)	20.41 (650.37)	0.59%	137	2.76 (27.84)	60.70 (612.43)	2.16%
Muriate of Potash (K)	286	21.27 (57.30)	382.85 (1031.39)	952%	133	31.80 (46.99)	572.48 (845.94)	1426%

Notes: Fertilizer recommendations are based on the available amount--low, medium, or high--of nitrogen (N), phosphorous (P) and potash (K) in the soil. Details on recommendations are provided in Table A3. Differences in recommended doses of fertilizers in the lab test results and public data (soil health card created by the government) are owing to differences in their assessment of available N, P, or K in a farmer's soil. Panel A reports the fraction of individuals for whom the government soil health card recommends the same, lower, or higher dose of fertilizer than the lab test result performed at Junagadh Agricultural University or GSFC. Panel B reports average differences in the amount of each fertilizer as well as cost of procuring that fertilizer for a 1 hectare plot of unirrigated land cultivating cotton. Panel C reports the analog for an irrigated plot of land. Columns (2)-(4) report results from the entire sample, while columns (6)-(8) report the same resultsafter restricting to the sub-sample of individuals whose soil health card was generated within the last 3 years.

^The rate of similarity in required nitrogen is an upper bound for the rate of similarity in required urea, as amount of urea to be applied depends on recommended nitrogen as well as recommended phosphorus. This is because every 100 kg of DAP provides 46 kg of phosphorus and 18 kg of nitrogen to soil. Farmers who are recommended DAP must thus accordingly adjust urea to supply the remaining nitrogen requirement. Every 100 kg of urea provides 46 kg of nitrogen to soil.

TABLE 4: Baseline understanding of Soil Health Card and balance checks

	SHC-only (Mean/sd)	Audio (β/se)	Video (β/se)	Agronomist (β/se)	aud=vid (pval)	aud=agr (pval)	vid=agr (pval)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
A. Farmer characteristics							
Literate	0.697	0.071	0.024	0.013	0.363	0.287	0.849
	0.461	(0.052)	(0.054)	(0.056)			
Male	0.986	0.014	-0.000	0.014	0.156		0.156
	0.117	(0.010)	(0.014)	(0.010)			
Age (years)	35.441	1.319	2.810**	0.970	0.261	0.785	0.168
	11.289	(1.298)	(1.354)	(1.305)			
Grows cotton	0.945	0.000	-0.001	-0.009	0.966	0.739	0.770
	0.229	(0.027)	(0.027)	(0.029)			
Most important plot is irrigated	0.676	-0.018	0.044	0.058	0.250	0.174	0.804
	0.470	(0.055)	(0.054)	(0.056)			
B. Knowledge of soil fertility & testing							
Can establish link between nutrients and fertilizer use	0.090	0.006	0.022	-0.025	0.657	0.342	0.170
	0.287	(0.034)	(0.036)	(0.033)			
Knows what a soil test is	0.276	0.039	0.011	-0.002	0.601	0.464	0.821
	0.448	(0.054)	(0.053)	(0.055)			
Knows that soil testing assesses nutrients/recommends fertilizers	0.221	0.033	-0.004	0.021	0.464	0.828	0.628
	0.416	(0.050)	(0.049)	(0.052)			
Knows about soil health card scheme	0.069	-0.014	0.001	0.012	0.596	0.404	0.742
	0.254	(0.028)	(0.030)	(0.032)			
Have gotten soil test	0.083	0.027	0.022	0.038	0.898	0.772	0.681
	0.276	(0.035)	(0.034)	(0.037)			
C. Pre-treatment understanding of soil health card							
Index: understand SHC recommendations	0.059	0.018	0.038	0.008	0.434	0.644	0.235
	0.161	(0.021)	(0.023)	(0.021)			
Correctly interprets Urea recommendation	0.069	-0.007	0.036	-0.021	0.185	0.634	0.080*
	0.254	(0.029)	(0.033)	(0.029)			
Correctly interprets DAP recommendation	0.069	0.027	0.050	0.004	0.530	0.491	0.197
	0.254	(0.032)	(0.034)	(0.032)			
Correctly interprets MOP recommendation	0.034	0.034	0.056**	0.022	0.484	0.684	0.280
	0.183	(0.026)	(0.029)	(0.026)			
Correctly interprets sulphur recommendation	0.062	0.020	0.008	0.027	0.695	0.849	0.574
	0.242	(0.030)	(0.029)	(0.033)			
D. Trust in soil health card							
Reports fully trusting recommendations in SHC	0.648	-0.018	0.023	-0.003	0.464	0.799	0.654
	0.479	(0.056)	(0.056)	(0.059)			
Reports somewhat trusting recommendations in SHC	0.324	0.005	-0.009	0.007	0.799	0.974	0.782
	0.470	(0.055)	(0.055)	(0.058)			
Knows local NGO AKRSP	0.462	0.052	-0.001	0.127**	0.377	0.217	0.037**
	0.500	(0.059)	(0.059)	(0.061)			
Trusts SHC more if by government than if by AKRSP (conditional on knowing AKRSP)	0.478	-0.051	-0.023	-0.012	0.741	0.635	0.896
	0.503	(0.084)	(0.087)	(0.085)			
N	145			558			

Notes: This table reports baseline summary statistics. Column (1) reports the mean for the SHC-only group.Column (1) reports the mean for the SHC-only group. Columns (2)-(4) report coefficients on indicator variables for belonging respectively to the audio, video, and agronomist treatments. Columns (5)-(7) report p-values associated with pairwise balance checks between the three treatment groups (audio, video, and agronomist). All regressions include robust standard errors. Asterisks denote statistical significance, where *** significant at 1% level; ** significant at 5% level; * significant at 10% level.

TABLE 5: Effect of ICT and in-person extension on understanding and trust in SHC

	SHC-only (Mean/sd)	Audio (β/se)	Video (β/se)	Agronomist (β/se)	aud=vid (pval)	aud=agr (pval)	vid=agr (pval)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
A. Understanding of soil health card							
Index: understand SHC recommendations	0.059	0.373***	0.411***	0.413***	0.408	0.428	0.972
	0.161	(0.037)	(0.036)	(0.042)			
Correctly interprets Urea recommendation	0.069	0.359***	0.460***	0.373***	0.072*	0.816	0.153
	0.254	(0.045)	(0.046)	(0.052)			
Correctly interprets DAP recommendation	0.069	0.366***	0.398***	0.387***	0.557	0.728	0.845
	0.254	(0.046)	(0.045)	(0.050)			
Correctly interprets MOP recommendation	0.034	0.385***	0.416***	0.444***	0.582	0.334	0.656
	0.183	(0.043)	(0.044)	(0.049)			
Correctly interprets sulphur recommendation	0.062	0.382***	0.371***	0.449***	0.849	0.259	0.194
	0.242	(0.046)	(0.046)	(0.050)			
B.. Trust							
Index: trust SHC recommendations	0.671	0.028	0.042	0.131***	0.753	0.014**	0.030**
	0.376	(0.043)	(0.043)	(0.043)			
Report fully trusting recommendations in SHC	0.648	0.057	0.069	0.111**	0.819	0.322	0.438
	0.479	(0.054)	(0.053)	(0.056)			
Willing to enter lottery where, if selected, would pay 250 for soil test	0.648	0.016	0.002	0.146***	0.793	0.016**	0.007***
	0.479	(0.056)	(0.056)	(0.054)			
Willing to enter lottery where, if selected, would pay 200 for soil test (includes those willing to enter at 250)	0.662	0.015	0.044	0.149***	0.595	0.011**	0.041**
	0.475	(0.055)	(0.054)	(0.053)			
Willing to enter lottery where, if selected, would pay 150 for soil test (includes above 2)	0.724	0.025	0.052	0.116**	0.582	0.061*	0.177
	0.448	(0.052)	(0.051)	(0.050)			
Trust recommendations from SHC: no extension worker visited to collect sample	0.393	0.063	0.050	-0.026	0.830	0.145	0.212
	0.490	(0.059)	(0.059)	(0.061)			
Trust recommendations from SHC: extension worker visited to collect sample	0.559	0.034	0.065	0.072	0.581	0.529	0.911
	0.498	(0.058)	(0.058)	(0.062)			
C. Knowledge of soil fertility & testing							
Index: Knowledge of soil fertility	0.346	0.032	0.063**	0.106***	0.352	0.037**	0.210
	0.272	(0.033)	(0.032)	(0.035)			
Knows purpose of soil testing	0.448	-0.016	0.020	-0.036	0.537	0.743	0.371
	0.499	(0.058)	(0.059)	(0.062)			
Knows why SHC recommendations differ by farmer	0.476	-0.007	0.010	0.001	0.777	0.896	0.891
	0.501	(0.059)	(0.059)	(0.062)			
Knows fertilizer to add phosphorus to soil	0.276	0.078	0.125**	0.252***	0.410	0.004***	0.037**
	0.448	(0.054)	(0.056)	(0.058)			
Knows fertilizer to add potash to soil	0.200	0.072	0.095*	0.083	0.650	0.841	0.818
	0.401	(0.050)	(0.051)	(0.053)			
Knows urea contains nitrogen	0.331	0.035	0.063	0.232***	0.611	0.001***	0.005***
	0.472	(0.056)	(0.056)	(0.060)			
N	145			558			

Notes: This table reports results from the specification described in equation (1). Column (1) reports the mean for the SHC-only group. Columns (2)-(4) report coefficients on indicator variables for belonging respectively to the audio, video, and agronomist treatments. Columns (5)-(7) report p-values associated with pairwise comparisons between the three treatment groups (audio, video, and agronomist). All regressions include village fixed-effects and robust standard errors. Asterisks denote statistical significance, where *** significant at 1% level; ** significant at 5% level; * significant at 10% level

TABLE 6: Effect of ICT and in-person extension on understanding and trust in SHC (within-individual)

	Pooled sample		Audio only		Video only		Agronomist	
	Pre-interventio n	Post	Pre-audio	Post	Pre-video	Post	Pre-agronomist	Post
	(Mean)	(β/se)	(Mean)	(β/se)	(Mean)	(β/se)	(Mean)	(β/se)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
A. Understanding of soil health card								
Index: understand SHC recommendations	0.081	0.386***	0.077	0.360***	0.096	0.378***	0.067	0.425***
	(0.200)	(0.020)	(0.189)	(0.034)	(0.224)	(0.034)	(0.183)	(0.037)
Correctly interprets Urea recommendation	0.073	0.404***	0.062	0.370***	0.105	0.427***	0.048	0.419***
	(0.260)	(0.025)	(0.241)	(0.040)	(0.307)	(0.044)	(0.215)	(0.044)
Correctly interprets DAP recommendation	0.097	0.368***	0.096	0.349***	0.119	0.357***	0.073	0.403***
	(0.296)	(0.025)	(0.295)	(0.041)	(0.325)	(0.044)	(0.260)	(0.044)
Correctly interprets MOP recommendatior	0.073	0.383***	0.068	0.356***	0.091	0.364***	0.056	0.435***
	(0.260)	(0.025)	(0.253)	(0.041)	(0.288)	(0.043)	(0.232)	(0.045)
Correctly interprets sulphur recommendati	0.080	0.387***	0.082	0.363***	0.070	0.364***	0.089	0.444***
	(0.271)	(0.026)	(0.276)	(0.045)	(0.256)	(0.042)	(0.285)	(0.049)
B. Trust								
Reports trusting recommendations in SHC	0.649	0.082***	0.630	0.082**	0.671	0.049	0.645	0.121**
	(0.478)	(0.023)	(0.484)	(0.036)	(0.471)	(0.036)	(0.480)	(0.051)
N		826		292		286		248

Notes: This table reports results from a within-individual specification aimed at assessing how understanding and trust in soil health cards changes when the same individual is first only presented with the card and is then presented with a supplement explaining its meaning. Column (1) reports the pooled mean of pre-intervention variables among audio, video, and agronomist groups, i.e. just after they are shown the SHC but before they are administered their assigned treatment. Column 2 reports the coefficient on post, which equal one after they are administered the assigned treatment and 0 before. Columns (3)-(4), (5)-(6) & (7)-(8) report analogs for the sample restricted to audio-only, video-only, and agronomist-only groups. All regressions include individual fixed-effects. Asterisks denote statistical significance, where *** significant at 1% level; ** significant at 5% level; * significant at 10% level.

TABLE 7: Heterogeneity by literacy in effect of ICT and in-person extension on comprehension & trust

	Not literate							Literate						
	SHC-only (Mean/sd)	Audio (β/se)	Video (β/se)	Agronomist (β/se)	aud=vid (pval)	aud=agr (pval)	vid=agr (pval)	SHC-only (Mean/sd)	Audio (β/se)	Video (β/se)	Agronomist (β/se)	aud=vid (pval)	aud=agr (pval)	vid=agr (pval)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
A. Understanding of soil health card														
Index: understand SHC recommendations	0.006	0.213***	0.144***	0.121**	0.340	0.223	0.727	0.082	0.422***	0.514***	0.542***	0.087*	0.037**	0.611
	0.038	(0.058)	(0.046)	(0.052)				0.187	(0.044)	(0.043)	(0.047)			
Correctly interprets Urea recommendation	0.000	0.201***	0.253***	0.085	0.629	0.212	0.089	0.099	0.405***	0.549***	0.502***	0.024**	0.175	0.500
	0.000	(0.073)	(0.075)	(0.064)				0.300	(0.056)	(0.055)	(0.064)			
Correctly interprets DAP recommendation	0.000	0.225***	0.122**	0.123**	0.261	0.257	0.992	0.099	0.404***	0.491***	0.498***	0.180	0.189	0.926
	0.000	(0.072)	(0.062)	(0.059)				0.300	(0.056)	(0.055)	(0.062)			
Correctly interprets MOP recommendation	0.000	0.180***	0.102*	0.147**	0.379	0.714	0.573	0.050	0.449***	0.537***	0.573***	0.186	0.088*	0.620
	0.000	(0.068)	(0.058)	(0.062)				0.218	(0.052)	(0.052)	(0.059)			
Correctly interprets sulphur recommendation	0.023	0.247***	0.099	0.131**	0.120	0.217	0.705	0.079	0.428***	0.477***	0.596***	0.460	0.015**	0.084*
	0.151	(0.079)	(0.069)	(0.066)				0.271	(0.055)	(0.055)	(0.058)			
B.. Trust														
Index: trust SHC recommendations	0.562	-0.025	0.098	0.176**	0.211	0.043**	0.360	0.718	0.037	0.010	0.099**	0.568	0.170	0.059*
	0.393	(0.100)	(0.087)	(0.090)				0.360	(0.047)	(0.050)	(0.048)			
Report fully trusting recommendations in SHC	0.432	0.235**	0.172*	0.250**	0.594	0.899	0.505	0.743	-0.022	0.004	0.046	0.666	0.280	0.504
	0.501	(0.114)	(0.106)	(0.112)				0.439	(0.060)	(0.061)	(0.064)			
Willing to enter lottery where, if selected, would pay 250 for soil test	0.568	-0.124	0.043	0.170	0.160	0.013**	0.233	0.683	0.055	-0.024	0.118*	0.211	0.303	0.026**
	0.501	(0.121)	(0.109)	(0.111)				0.468	(0.063)	(0.066)	(0.063)			
Willing to enter lottery where, if selected, would pay 200 for soil test (includes those willing to enter at 250)	0.568	-0.125	0.099	0.167	0.052*	0.013**	0.498	0.703	0.055	0.019	0.124**	0.548	0.238	0.080*
	0.501	(0.121)	(0.105)	(0.111)				0.459	(0.061)	(0.064)	(0.062)			
Willing to enter lottery where, if selected, would pay 150 for soil test (includes above 2)	0.682	-0.085	0.076	0.116	0.149	0.070*	0.681	0.743	0.058	0.041	0.106*	0.751	0.380	0.238
	0.471	(0.115)	(0.106)	(0.107)				0.439	(0.058)	(0.060)	(0.058)			
Trust recommendations from SHC: no extension worker visited to collect sample	0.250	0.052	0.121	0.028	0.556	0.844	0.441	0.455	0.052	0.008	-0.055	0.517	0.138	0.394
	0.438	(0.110)	(0.106)	(0.113)				0.500	(0.069)	(0.071)	(0.074)			
Trust recommendations from SHC: extension worker visited to collect sample	0.432	0.064	0.059	0.239**	0.968	0.169	0.140	0.614	0.013	0.048	-0.002	0.590	0.827	0.481
	0.501	(0.117)	(0.111)	(0.118)				0.489	(0.067)	(0.068)	(0.073)			
C. Knowledge of soil fertility & testing														
Index: Knowledge of soil fertility	0.300	0.008	-0.052	0.075	0.322	0.281	0.039**	0.366	0.040	0.107***	0.123***	0.074*	0.056*	0.698
	0.271	(0.061)	(0.060)	(0.064)				0.271	(0.039)	(0.037)	(0.043)			
Knows purpose of soil testing	0.432	0.009	-0.159	-0.007	0.139	0.900	0.192	0.455	-0.013	0.102	-0.043	0.090*	0.687	0.053*
	0.501	(0.113)	(0.107)	(0.118)				0.500	(0.069)	(0.070)	(0.075)			
Knows why SHC recommendations differ by farmer	0.409	-0.042	0.010	-0.030	0.671	0.925	0.744	0.505	0.007	0.008	0.006	0.985	0.995	0.981
	0.497	(0.116)	(0.116)	(0.119)				0.502	(0.069)	(0.071)	(0.075)			
Knows fertilizer to add phosphorus to soil	0.295	0.017	-0.066	0.268**	0.429	0.020**	0.003***	0.267	0.105*	0.196***	0.254***	0.186	0.040**	0.434
	0.462	(0.104)	(0.108)	(0.112)				0.445	(0.064)	(0.067)	(0.070)			
Knows fertilizer to add potash to soil	0.227	-0.070	-0.051	-0.107	0.835	0.662	0.529	0.188	0.115*	0.152**	0.167**	0.554	0.444	0.837
	0.424	(0.093)	(0.090)	(0.093)				0.393	(0.060)	(0.062)	(0.066)			
Knows urea contains nitrogen	0.136	0.125	0.004	0.252**	0.185	0.265	0.015**	0.416	-0.014	0.076	0.231***	0.182	0.001***	0.030**
	0.347	(0.097)	(0.077)	(0.106)				0.495	(0.068)	(0.070)	(0.072)			
N	44			154				101			404			

Notes: This table reports results from the specification described in equation (1) separately for the subsample who are literate and those who are not. Column (1) reports the mean for the SHC-only group among those who are not literate. Columns (2)-(4) report coefficients on indicator variables for belonging respectively to the audio, video, and agronomist treatments, restricted to the sample of those who are not literate. Columns (5)-(7) report p-values associated with pairwise comparisons between the three treatment groups (audio, video, and agronomist). Columns (8)-(14) report analogs for the subsample of literate individuals. All regressions include village fixed-effects and robust standard errors. Asterisks denote statistical significance, where *** significant at 1% level; ** significant at 5% level; * significant at 10% level.

TABLE 8: Effect of high fertilizer recommendations on trust in SHC

	Pooled sample		Audio only		Video only		Agronomist	
	Low (Mean)	High (β/se)	Low (Mean)	High (β/se)	Low (Mean)	High (β/se)	Low (Mean)	High (β/se)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
A. Trust in recommendations								
Reports trusting recommendations in SHC	0.740	-0.018	0.722	-0.020	0.746	-0.052	0.754	0.024
	(0.440)	(0.044)	(0.451)	(0.075)	(0.438)	(0.075)	(0.434)	(0.077)
Believes urea recommendations right	0.520	-0.017	0.556	-0.015	0.620	-0.022	0.361	-0.011
	(0.501)	(0.049)	(0.500)	(0.083)	(0.489)	(0.082)	(0.484)	(0.087)
Believes dap recommendations right	0.515	0.045	0.556	0.080	0.592	0.020	0.377	0.036
	(0.501)	(0.049)	(0.500)	(0.082)	(0.495)	(0.082)	(0.489)	(0.088)
Believes mop recommendations right	0.382	-0.014	0.389	0.044	0.465	-0.006	0.279	-0.088
	(0.487)	(0.048)	(0.491)	(0.082)	(0.502)	(0.084)	(0.452)	(0.076)
Believes sulphur recommendations right	0.304	0.098**	0.319	0.140*	0.380	0.120	0.197	0.026
	(0.461)	(0.047)	(0.470)	(0.080)	(0.489)	(0.083)	(0.401)	(0.074)
Willing to enter lottery where, if selected, would pay 250 for soil test	0.716	-0.008	0.639	0.077	0.718	-0.121	0.803	0.022
	(0.452)	(0.045)	(0.484)	(0.078)	(0.453)	(0.079)	(0.401)	(0.070)
Willing to enter lottery where, if selected, would pay 200 for soil test (includes those willing to enter at 250)	0.745	-0.008	0.653	0.077	0.761	-0.094	0.836	-0.011
	(0.437)	(0.043)	(0.479)	(0.077)	(0.430)	(0.076)	(0.373)	(0.068)
Willing to enter lottery where, if selected, would pay 150 for soil test (includes above 2)	0.814	-0.034	0.750	0.020	0.845	-0.123*	0.852	0.005
	(0.390)	(0.040)	(0.436)	(0.071)	(0.364)	(0.069)	(0.358)	(0.064)
N		413		146		143		124

Notes: This table reports results gauging how receiving a card containing higher than typical fertilizer recommendations (compared to one with lower than typical fertilizer recommendations) affects trust. Both sets of recommendations were plausible given the soil quality in the area. Column (1) reports the pooled mean of those in audio, video, and agronomist groups who received an SHC with lower fertilizer recommendations than typically practiced by farmers in the area. Column 2 reports the coefficient on high, which equal one if an individual receives a soil health card recommending higher than typically practiced fertilizer use. Columns (3)-(4), (5)-(6) & (7)-(8) report analogs for the sample restricted to audio-only, video-only, and agronomist-only groups. All regressions report robust standard errors. Asterisks denote statistical significance, where *** significant at 1% level; ** significant at 5% level; * significant at 10% level.

TABLE A1.1: Farmer characteristics

	Farmer characteristics	
	Irrigated	Unirrigated
	(1)	(2)
N	437	499
Cultivate only one plot	32.49%	37.68%
Grow cotton	87.84%	82.97%
Of cotton growers:		
use urea	87.20%	79.32%
use dap	81.07%	84.43%
use mop	4%	0.50%
Avg. expenditure on urea (per hectar	1292.42	925.39
	(1168.58)	(919.37)
Avg. expenditure on dap (per hectare	2823.36	2550.20
	(2351.56)	(2068.98)
Avg. expenditure on mop (per hectar	40.11	4.79
	(216.82)	(74.64)

TABLE A1.2: Match characteristics

N	293
Matched by	
Survey number	52%
Name	48%
Year of SHC generation	
2001-2010	3.07%
2010-onwards	96.93%
Lab test by GSFC or JAU	
GSFC	50%
JAU	50%

Table A2. Geographic variability in nutrient categories and values

	Neighbor plots			Village		
	N	P	K	N	P	K
No. of groups (N)	80	80	80	30	30	30
Avg. no. of plots per group	3.04	3.04	3.06	38.2	38.2	38.2
% of groups for which all plots in same nutrient category	75.00%	53.75%	46.00%	6.66%	3.33%	0%
Avg. mean	-	31.07	307.77	-	31.23	319.37
Avg. sd	-	9.90	107.92	-	18.77	164.66

Notes: This table depicts geographic variability in nutrient categories. Columns (1)-(3) report on groups of neighboring plots, whereas Columns (4)-(6) report of plots within a village. The third row reports the percentage of groups for which all plots in the group are characterized as having either low, medium, or high levels of N, P, and K respectively. For example, in column (1): among 80 sets of neighboring plots, where each set has on average 3 plots with soil test results available, 75% (i.e. 60 sets) have all plots in them categorized as possessing the same (high, medium, or low) level of nitrogen. Row 4 reports the mean numeric value of nutrients assigned to groups (average of average value assigned to groups) and row 5 reports the mean standard deviation in this assigned value across groups. Values of nitrogen were in some cases reported in organic carbon (if test performed by GSFC) and in other cases were reported directly (if test performed by JAU), and are therefore excluded in the numeric reporting.

TABLE A3: Quantity & cost of recommended fertilizers

Lab test recommendation

	N	High use	Medium use	Low use	Avg cost for irrigated cotton (Rs./hectare)	Avg cost for unirrigated cotton (Rs./hectare)
	(1)	(2)	(3)	(4)	(5)	(6)
Urea (N)	290	72.85%	27.15%	0.00%	3142.74	1004.22
DAP (P)	291	49.14%	27.84%	23.02%	2553.15	1014.27
Muriate of Potash (K)	286	11.81%	43.75%	44.44%	4137.98	1104.03

Government recommendation

	N	High use	Medium use	Low use	Avg cost for irrigated cotton (Rs./hectare)	Avg cost for unirrigated cotton (Rs./hectare)
	(1)	(2)	(3)	(4)	(5)	(6)
Urea (N)	290	32.30%	61.51%	6.19%	2807.4	895.74
DAP (P)	291	39.73%	43.15%	17.12%	2532.30	1004.48
Muriate of Potash (K)	286	9.31%	13.79%	76.90%	3747.37	997.50

Government recommendation restricted to last 3 years

	N	High use	Medium use	Low use	Avg cost for irrigated cotton (Rs./hectare)	Avg cost for unirrigated cotton (Rs./hectare)
	(1)	(2)	(3)	(4)	(5)	(6)
Urea (N)	136	35.29%	62.50%	2.21%	2852.58	912.00
DAP (P)	137	37.23%	56.20%	6.57%	2580.12	1021.64
Muriate of Potash (K)	133	0.74%	10.37%	88.89%	3516.38	936.13

Notes: Fertilizer recommendations are based on the available amount--low, medium, or high--of nitrogen (N), phosphorous (P) and potash (K) in the soil. Differences in recommended doses of fertilizers in the independent lab test results and soil health card created by the government are owing to differences in their assessment of available N, P, or K in a farmer's soil. To calculate average cost per hectare, we first estimate the average recommendation in kg/hectare as per prescribed standards linking nutrient status to fertilizer use for irrigated versus unirrigated plots (documented in Table A3). We then multiply this average recommendation by the cost per kg of the fertilizer (also documented in Table A3) to arrive at average cost per hectare. Since DAP provides both phosphorus and nitrogen to soil, whereas urea provides only nitrogen, we adjust required quantity of urea based on recommended DAP for every observation prior to calculating cost.

TABLE A4: Standard fertilizer recommendations and fertilizer cost

	Recommendations for irrigated cotton (kg/hectare)			Recommendations for unirrigated cotton (kg/hectare)			Cost (Rs./kg)
	High	Medium	Low	High	Medium	Low	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Urea (N)^	600	480	360	196	157	118	6
DAP (P)	136	109	82	54	43	33	22
Muriate of Potash (K)	313	250	188	83	67	50	18

Source: Proceedings of the Twelfth Meeting of Combined Joint Agricultural Research Council of State Agricultural Universities in Gujarat, 2015-2016

Notes: This table reports standard fertilizer recommendations generated by local agricultural universities in Gujarat. These recommendations are based on experimental plots cultivated in the region for which recommendations are being made. They are adopted at annual meetings of the joint agricultural research council (AGRESCO) of Gujarat, i.e. meetings of all state agricultural universities in Gujarat. Our sample lies withing the Saurashtra region. Columns (1)-(3) report the quantity of fertilizers to be applied in kg/hectare on an irrigated plot which has low, medium, and high availability of nitrogen, phosphorus, and potash or, respectively, which requires high, medium, and low quantities of urea, DAP, and MOP fertilizers. Columns (4)-(6) report the analog for an unirrigated plot. Column (7) reports the per kg cost of fertilizers.

^ Urea recommendations are to be adjusted based on recommended values of DAP, as every 100 kg of the latter

TABLE A5: Cross-validation of fertilizer recommendations (only keeping observations that match by survey num

Panel A		Fertilizer recommendation		
Nutrient	N	Same recommendation	Public data recommends higher requirement	Public data recommends lower requirement
	(1)	(2)	(3)	(4)
Nitrogen^	151	41.06%	7.28%	51.66%
Phosphorus	151	24.50%	26.49%	49.01%
Potash	149	40.94%	14.76%	44.30%
Panel B		Comparison for unirrigated cotton		
	N	Amount of fertilizer (lab test - public data) (kg/hectare)	Cost to farmer (lab test - public data) (Rs./hectare)	Difference in cost as % of avg. farmer expenditure
	(1)	(2)	(3)	(4)
Urea (N)	151	18.60 (28.40)	111.61 (170.40)	12.54%
DAP (P)	151	2.12 (11.57)	46.77 (254.49)	1.84%
Murate of Potash (K)	149	6.24 (15.28)	112.35 (275.07)	2382.98%
Panel C		Comparison for irrigated cotton		
	N	Amount of fertilizer (lab test - SHC) (kg/hectare)	Cost to farmer (lab test - SHC) (Rs./hectare)	Difference in cost as % of avg. farmer expenditure
	(1)	(2)	(3)	(4)
Urea (N)	151	58.10 (86.47)	348.56 (518.80)	26.93%
DAP (P)	151	5.18 (29.37)	114.08 (646.03)	4.04%
Murate of Potash (K)	149	22.92 (57.24)	412.55 (1030.25)	1029.67%

Notes: This table restricts the sample to those individuals who match with the government database on survey number of their field. Fertilizer recommendations are based on the available amount--low, medium, or high--of nitrogen (N), phosphorous (P) and potash (K) in the soil. Differences in recommended doses of fertilizers in the lab test results and public data (soil health card created by the government) are owing to differences in their assessment of available N, P, or K in a farmer's soil. Panel A reports the fraction of individuals for whom the government soil health card recommends the same, lower, or higher dose of fertilizer than the lab test result performed at Junagadh Agricultural University or GSFC. Panel B reports average differences in the amount of each fertilizer as well as cost of procuring that fertilizer for a 1 hectare plot of unirrigated land cultivating cotton. Panel C reports the analog for an irrigated plot of land.

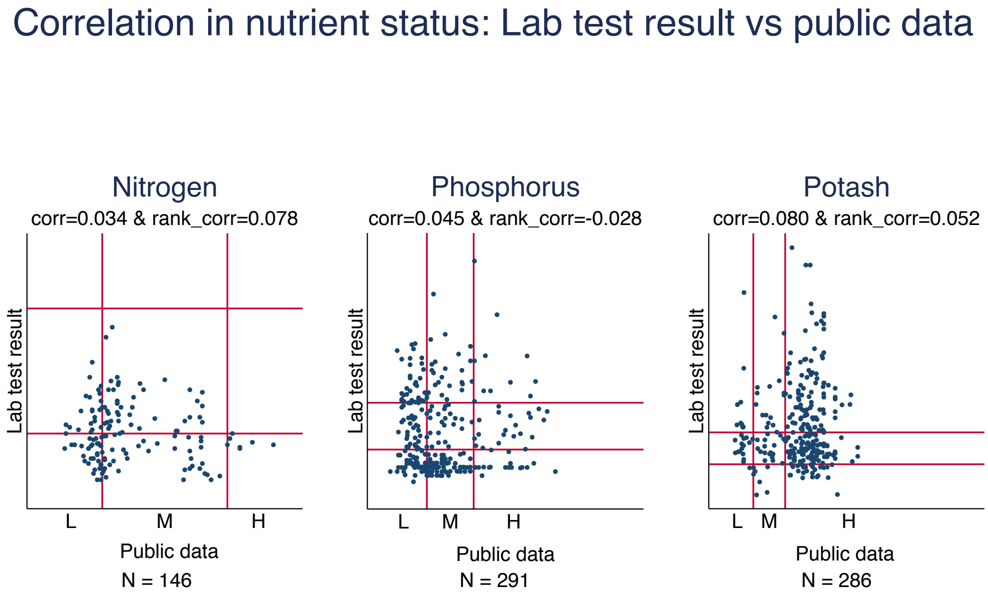
^The rate of similarity in required nitrogen is an upper bound for the rate of similarity in required urea, as amount of urea to be applied depends on recommended nitrogen as well as recommended phosphorus. This is because every 100 kg of DAP provides 46 kg of phosphorus and 18 kg of nitrogen to soil. Farmers who are recommended DAP must thus accordingly adjust urea to supply

'ABLE A6: Comparing lab test results with public data (restricting nitrogen comparison to GSFC versus governmen

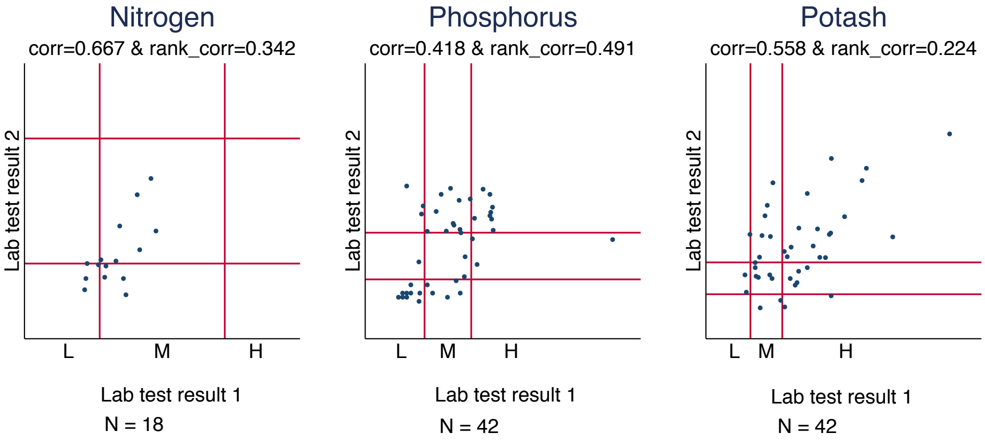
	All years			
Panel A	Fertilizer recommendation			
Fertilizer	N	Same recommendation	Public data recommends higher requirement	Public data recommends lower requirement
	(1)	(2)	(3)	(4)
Nitrogen^	146	51.37%	15.07%	33.56%
Panel B	Comparison for unirrigated cotton			
	N	Amount of fertilizer (lab test - public data) (kg/hectare)	Cost to farmer (lab test - public data) (Rs./hectare)	Difference in cost as % of avg. farmer expenditure
	(1)	(2)	(3)	(4)
Urea (N)	146	6.27 (28.29)	37.64 (169.74)	4.07%
Panel C	Comparison for irrigated cotton			
		Amount of fertilizer (lab test - SHC) (kg/hectare)	Cost to farmer (lab test - SHC) (Rs./hectare)	Difference in cost as % of avg. farmer expenditure
	(1)	(2)	(3)	(4)
Urea (N)	146	21.57 (87.36)	129.45 (524.15)	10.02%

Notes: Urea recommendations are based on the available amount--low, medium, or high--of nitrogen (N) in the soil. Differences in recommended doses of fertilizers in the lab test results and public data (soil health card created by the government) are owing to differences in their assessment of available N in a farmer's soil. Panel A reports the fraction of individuals for whom the government soil health card recommends the same, lower, or higher dose of fertilizer than the lab test result performed at GSFC. Panel B reports average differences in the amount of fertilizer as well as cost of procuring that fertilizer for a 1 hectare plot of unirrigated land cultivating cotton. Panel C reports the analog for an irrigated plot of land.

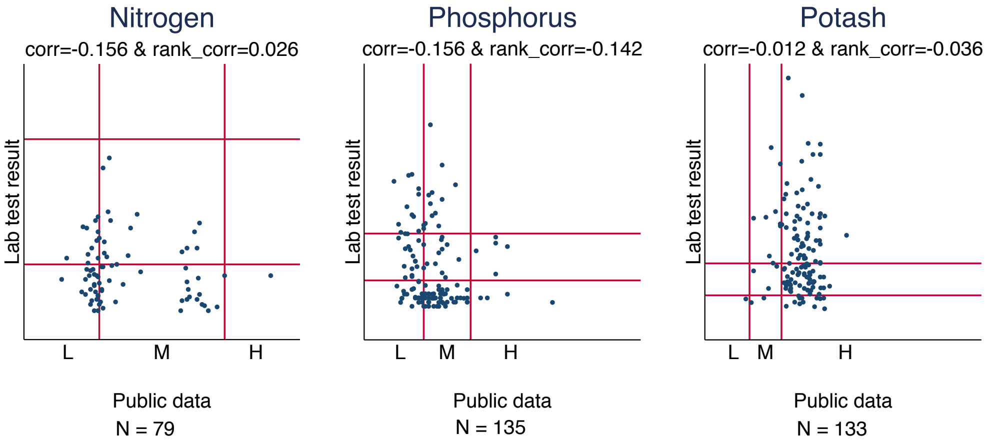
^The rate of similarity in required nitrogen is an upper bound for the rate of similarity in required urea, as amount of urea to be applied depends on recommended nitrogen as well as recommended phosphorus. This is because every 100 kg of DAP provides 46 kg of phosphorus and 18 kg of nitrogen to soil. Farmers who are recommended DAP must thus accordingly adjust urea to supply the remaining nitrogen requirement. Every 100 kg of urea provides 46 kg of nitrogen to soil.

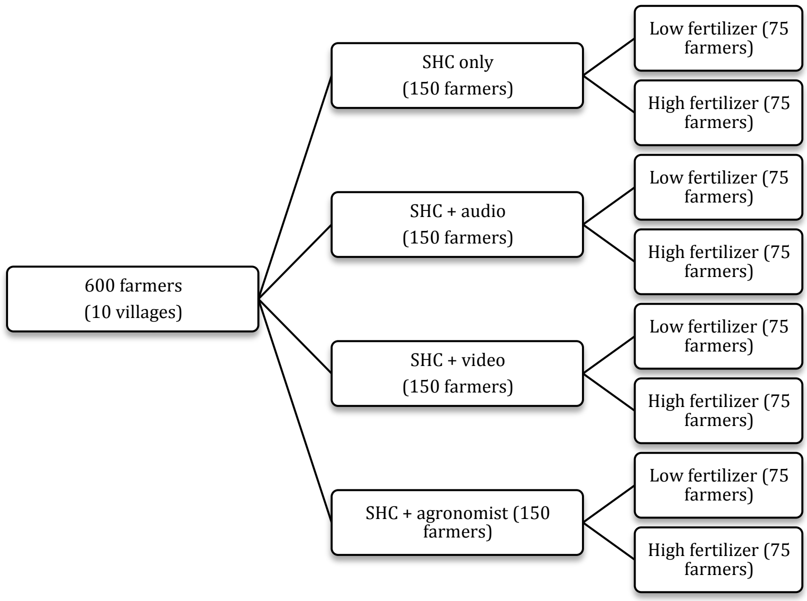

Correlation in nutrient status: Lab test result vs public data
Nitrogen
corr=0.034 & rank_corr=0.078
Lab test result
L
M
H
Public data
N = 146
Phosphorus
corr=0.045 & rank_corr=-0.028
Lab test result
L
M
H
Public data
N = 291
Potash
corr=0.080 & rank_corr=0.052
Lab test result
L
M
H
Public data
N = 286

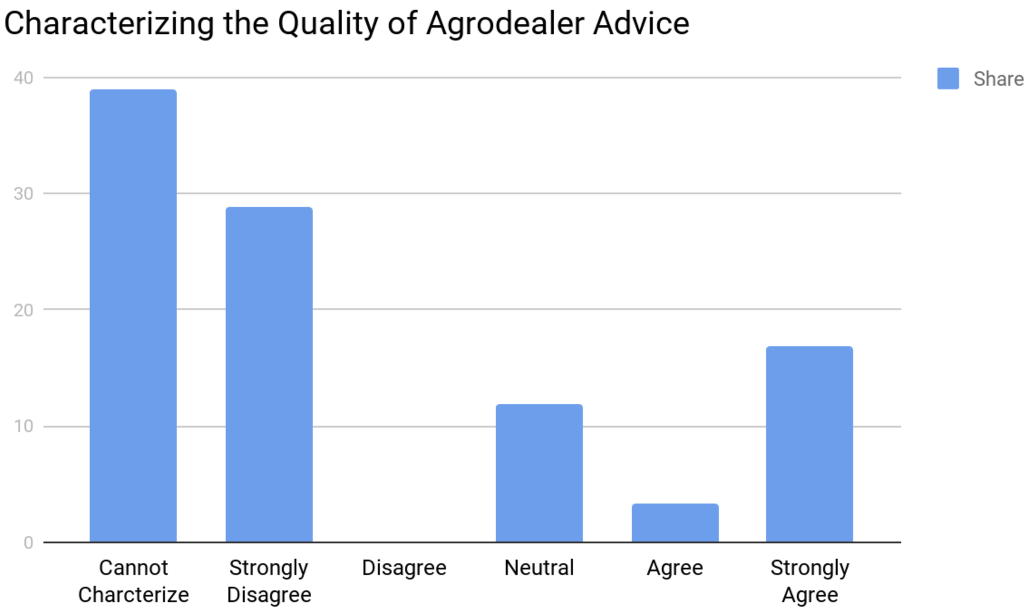
Correlation in nutrient status: two independent lab test results



Correlation in nutrient status: Lab test result vs public data (last 3 years)




600 farmers (10 villages)
SHC only (150 farmers)
SHC + audio (150 farmers)
SHC + video (150 farmers)
SHC + agronomist (150 farmers)
Low fertilizer (75 farmers)
High fertilizer (75 farmers)
Low fertilizer (75 farmers)
High fertilizer (75 farmers)
Low fertilizer (75 farmers)
High fertilizer (75 farmers)
Low fertilizer (75 farmers)
High fertilizer (75 farmers)


Characterizing the Quality of Agrodealer Advice
Share
40
30
20
10
0
Cannot Charcterize
Strongly Disagree
Disagree
Neutral
Agree
Strongly Agree

જમીન આરોગ્ય પત્રક
(સોઈલ હેલ્થ કાર્ડ)
ખેતીવાડી ખાતું, ગુજરાત રાજ્ય

ભાગ - 1

વર્ષ : 2014-2015

જમીન આરોગ્ય પત્રક નંબર : SHC08197700

ખેડૂતનું નામ: લવજી ખાતા નંબર:

ગામનું નામ: જીવાપર ટંકારા તાલુકો: ટંકારા જિલ્લો: રાજકોટ

સર્વે નંબર: 17 વિસ્તાર (હેક્ટર): 01: જમીનનો પ્રકાર: કાળી મદ્યમ કાળી જમીન

(1) જમીનના ઈ.સી., પી.એચ. આંક તેમજ મુખ્ય તત્વોની ચકાસણીની વિગત:

ક્રમ	વિગત	પરિણામ	મદ્યમ રેન્જ	પરિણામની સમજ
1	પી.એચ. આંક (જમીન પ્રતિક્રિયા)	7.14	6.5-8.2	સામાન્ય
2	ઈ.સી.(કુલ દ્રાવ્ય ક્ષારો ડેસીસાયમન/મીટર)	0.08	1.0-3.0	સામાન્ય
3	સેન્દ્રિય કાર્બન (ટકા)	0.18	0.5-1.5	ઓછું
4	લભ્ય ફોસ્ફરસ (કી.ગ્રા./હેકટર)	26.00	28-56	ઓછું
5	લભ્ય પોટાશ (કી.ગ્રા./હેકટર)	255.00	140-280	મદ્યમ

(2) ગૌણ તત્વો ની ચકાસણી આધારીત ભલામણ: (નોંધ: સલ્ફર - ppm અને કેલ્શિયમ/મેંગ્નેશિયમ - meq/100gm)

ક્રમ	તત્વનું નામ	પરિણામ	મદ્યમ રેન્જ	તત્વનું પ્રમાણ	ભલામણ
1	સલ્ફર	4.80	10-20	ઓછુ	ગંધક ધરાવતું કોઈ પણ ખાતર/જીપ્સમ મારફતે ૨૦ કિગ્રા ગંધક પ્રતિ હેક્ટર જમીનમાં આપવુ
2	મેગ્નેશીયમ	7.00	1-2	પુરતુ	મેગ્નેશીયમ પુરતા પ્રમાણમાં છે.
3	કેલ્શિયમ	13.00	1.5-3.0	પુરતુ	કેલ્શિયમ પુરતા પ્રમાણમાં છે.

(3) સુક્ષ્મ તત્વો ની ચકાસણી આધારીત ભલામણ:

ક્રમ	તત્વનું નામ	પરિણામ (ppm)	મદ્યમ રેન્જ	તત્વનું પ્રમાણ	ભલામણ
1	તાંબુ (કોપર)	1.96	0.2-0.4	પુરતુ	તાંબુ તત્વ પુરતા પ્રમાણમાં છે.
2	લોહ (આયર્ન)	0.72	5-10	ઓછુ	ફેરસ સલ્ફેટ (૧૯ % લોહ) ખાતર ૫૦ કિગ્રા પ્રતિ હેક્ટર જમીનમાં આપવુ
3	જસત (ઝીંક)	0.31	0.5-1	ઓછુ	ઝીંક સલ્ફેટ (૨૧ % ઝીંક) ખાતર ૨૫ કિગ્રા પ્રતિ હેક્ટર જમીનમાં આપવુ
4	મેંગેનીઝ	2.42	5-10	ઓછુ	મેંગેનીઝ સલ્ફેટ (૩૦ % મેંગેનીઝ) ખાતર ૪૦ કિગ્રા પ્રતિ હેક્ટર જમીનમાં આપવુ

(4) જમીનની ચકાસણીને આધારે પાકવાર ખાતર ની ભલામણ:

(ખાતરો ભલામણ મુજબ પાયામાં અને પુર્તિખાતરમાં હપ્તામાં આપવા)

નોંધ: આ કાર્ડમાં દર્શાવેલ જમીનની તાસીર આ સર્વે નંબરને લાગુ પડે છે . જુદા જુદા સર્વે નંબરની જમીનની તાસીર અલગ હોઈ શકે છે. જેથી દરેકે પોતાની ખેતરની જમીનનું પૃથક્કરણ કરાવી તે પ્રમાણે ખાતરનો ઉપયોગ કરવો વધુ ફાયદાકારક છે

ઋતુ અને પાક		ખેતીવાડી ખાતાની ખાતરની સામાન્ય ભલામણ			છાણીયું ખાતર (ટન/ હેક્ટર)	રાસાયણીક ખાતરની ભલામણ		
		ના	ફો	પો		યુરીયા કિ.ગ્રા./ હેક્ટર	DAP કિ.ગ્રા./ હેક્ટર	MOP કિ.ગ્રા./ હેક્ટર
ખેડુતની પસંદગીના પાકો								
ખરીફ								
કપાસ	સંકર (બિનપિયત)	80	0	0	10	196	0	0
	સંકર (પિયત)	160	0	0	10	600	138	250
	દેશી કપાસ(બીન પીયત)	40	0	0	10	98	0	0
વિસ્તારના મુખ્ય પાકો								
ખરીફ								
અડદ	અડદ	20	40	0	10	16	98	0
આંબા	આંબા *	750	160	750	50	1645	380	1250
ચીકુ	ચીકુ *	1000	500	500	50	1923	1196	834
તલ	ચોમાસુ તલ	50	25	0	5	98	54	0
દિવેલા	પિયત દિવેલા	75	50	0	10	138	120	0
બાજરી	હા.બાજરી (વરસાદ આધારિત)	80	40	0	13	157	98	0
બોર	બિનપિયત બોર*	100	50	50	15	192	120	83
	પિયત બોર *	500	400	400	25	821	957	667
મગ	મગ	20	40	0	10	16	98	0
મગફળી	બિનપિયત	12	25	0	10	11	54	0
રવિ								
ગાજર	ગાજર	25	0	62	10	65	0	103
ઘઉં	સમયસર વાવણી	120	60	0	13	227	141	0
	મોડી વાવણી	80	40	0	13	157	98	0
ચણા	ચણા	20	40	0	10	16	98	0

ઋતુ અને પાક		ખેતીવાડી ખાતાની ખાતરની સામાન્ય ભલામણ			છાણીયું ખાતર (ટન/ હેક્ટર)	રાસાયણીક ખાતરની ભલામણ		
		ના	ફો	પો		યુરીયા કિ.ગ્રા./ હેક્ટર	DAP કિ.ગ્રા./ હેક્ટર	MOP કિ.ગ્રા./ હેક્ટર
જીરૂ	જીરૂ	30	15	0	6	63	33	0
ડુંગળી	ડુંગળી	75	60	50	13	129	141	83
રીંગણ	રીંગણ	100	50	50	8	192	120	83
લસણ	લસણ	50	50	50	13	73	120	83
ઉનાળું								
મગફળી	મગફળી	25	50	0	10	18	120	0

* (છાણીયું ખાતર-કિ.ગ્રા./છોડ : ના.ફો.પો.-ગ્રામ/છોડ)   ** (છાણીયું ખાતર-ટન./છોડ : ના.ફો.પો.-ગ્રામ/છોડ)

જમીન આરોગ્ય પત્રક
(સોઈલ હેલ્થ કાર્ડ)
ખેતીવાડી ખાતું, ગુજરાત રાજ્ય

ભાગ - 2

વર્ષ : 2014-2015

જમીન આરોગ્ય પત્રક નંબર : SHC08197700

ખેડૂતનું નામ: લવજી ખોડા   ખાતા નંબર: 164

ગામનું નામ: જીવાપર ટંકારા   તાલુકો: ટંકારા   જિલ્લો: રાજકોટ

સર્વે નંબર: 170p1   વિસ્તાર (હેક્ટર): 1.14   જમીનનો પ્રકાર: કાળી મધ્યમ કાળી જમીન

(1) જમીનના ઈ.સી., પી.એચ. આંક તેમજ મુખ્ય તત્વોની ચકાસણીની વિગત:

ક્રમ	વિગત	પરિણામ	મધ્યમ રેન્જ	પરિણામની સમજ
1	પી.એચ. આંક (જમીન પ્રતિક્રિયા)	7.14	6.5-8.2	સામાન્ય
2	ઈ.સી.(કુલ દ્રાવ્ય ક્ષારો ડેસીસાયમન/મીટર)	0.08	1.0-3.0	સામાન્ય
3	સેન્દ્રિય કાર્બન (ટકા)	0.18	0.5-1.5	ઓછું
4	લભ્ય ફોસ્ફરસ (કી.ગ્રા./હેક્ટર)	26.00	28-56	ઓછું
5	લભ્ય પોટાશ (કી.ગ્રા./હેક્ટર)	255.00	140-280	મધ્યમ

(2) ગૌણ તત્વો ની ચકાસણી આધારીત ભલામણ: (નોંધ: સલ્ફર - ppm અને કેલ્શિયમ/મેંગ્નેશિયમ - meq/100gm)

ક્રમ	તત્વનું નામ	પરિણામ	મધ્યમ રેન્જ	તત્વનું પ્રમાણ	ભલામણ
1	સલ્ફર	4.80	10-20	ઓછુ	ગંધક ધરાવતું કોઈ પણ ખાતર/જીપ્સમ મારફતે ૨૦ કિગ્રા ગંધક પ્રતિ હેક્ટર જમીનમાં આપવુ
2	મેગ્નેશીયમ	7.00	1-2	પુરતુ	મેગ્નેશીયમ પુરતા પ્રમાણમાં છે.
3	કેલ્શિયમ	13.00	1.5-3.0	પુરતુ	કેલ્શિયમ પુરતા પ્રમાણમાં છે.

(3) સુક્ષ્મ તત્વો ની ચકાસણી આધારીત ભલામણ:

ક્રમ	તત્વનું નામ	પરિણામ (ppm)	મધ્યમ રેન્જ	તત્વનું પ્રમાણ	ભલામણ
1	તાંબુ (કોપર)	1.96	0.2-0.4	પુરતુ	તાંબુ તત્વ પુરતા પ્રમાણમાં છે.
2	લોહ (આયર્ન)	0.72	5-10	ઓછુ	ફેરસ સલ્ફેટ (૧૯ % લોહ) ખાતર ૫૦ કિગ્રા પ્રતિ હેક્ટર જમીનમાં આપવુ
3	જસત (ઝીંક)	0.31	0.5-1	ઓછુ	ઝીંક સલ્ફેટ (૨૧ % ઝીંક) ખાતર ૨૫ કિગ્રા પ્રતિ હેક્ટર જમીનમાં આપવુ
4	મેંગેનીઝ	2.42	5-10	ઓછુ	મેંગેનીઝ સલ્ફેટ (૩૦ % મેંગેનીઝ) ખાતર ૪૦ કિગ્રા પ્રતિ હેક્ટર જમીનમાં આપવુ

<u>રિપોર્ટ મુજબ પિયત કપાસ માટે ખાતરની ભલામણ</u>

તમારી પાસે રહેલા જમીનના રિપોર્ટ મુજબ તે જમીનમાં **<u>પિયત કપાસ</u>** માટે નીચે મુજબ ખાતર આપવાની ભલામણ છે.

<u>(પિયત કપાસમાં આખી સીજન દરમ્યાન કુલ ખાતરની જરૂરિયાત નીચે કોઠામાં આપેલી છે.)</u>

<u>ખાતરનું માપ એક વીઘા દીઠ આપેલું છે.</u>

ખાતરનું નામ	કુલ ખાતરની ભલામણ (કિલો/વીઘા)	નોંધ
યુરિયા ખાતર	૯૬	એક સરખું માપ રાખી ચાર હપ્તામાં આપવું (ચાર વખત)
ડી.એ.પી. ખાતર	૨૨	એક સરખું માપ રાખી બે હપ્તામાં આપવું (બે વખત)
પોટાશ ખાતર	૪૦	બધુ પાયામાં આપવું
સલ્ફર (ગંધક)	૦૩	બધુ પાયામાં આપવું