

# Pre-analysis Plan for The Impact of Site Specific Soil Fertility Recommendations: Experimental Evidence from Malawi

Thomas Assefa\*, Joachim De Weerd†, David Spielman‡, Bjorn Van Campenhout§, Edwin Siyame¶, Richard Ariong

October 7, 2024

## Abstract

Raising agricultural productivity among smallholder farmers in Sub-Saharan Africa is widely recognized as an important component of inclusive wealth creation and structural transformation. Central to this endeavor will be the adoption of sustainable soil and land management to improve the sustainability, resilience and productivity of agriculture. As such, government advise farmers to increase soil productivity by embracing the use of fertilizers and implement proper soil health management practices. However, these recommendations mostly come in the form of blanket one-size-fits-all recommendations that ignore heterogeneity in soil characteristics that individual farmers face. Using a cluster randomized control trial, we evaluate the impact of a bundled intervention that involves offering farmers a soil test on a plot they select and, using the results of this soil test, provide them with tailored advice on soil management to attain a desired yield for a particular crop the farmer chooses to plant on the plot. Furthermore, we also explore resource constraints as a potential barrier to the adoption of site specific fertilizer blends by adding a subsidy.

keywords: inorganic fertilizer, soil test, decision support tools, agricultural extension, fertilizer subsidies.

O33, Q12, Q16

---

\*Innovation Policy and Scaling Unit, IFPRI, Kenya

†Development Strategy and Governance Division, IFPRI, Malawi

‡Innovation Policy and Scaling Unit, IFPRI, United States

§Innovation Policy and Scaling Unit, IFPRI and LICOS Centre for Institutions and Economic Performance KU Leuven, Belgium - corresponding author: b.vancampenhout@cgiar.org

¶Development Strategy and Governance Division, IFPRI, Malawi

# 1 Introduction

Raising agricultural productivity among smallholder farmers in Sub-Saharan Africa is widely recognized as an important component of inclusive wealth creation and structural transformation. Central to this endeavor will be the adoption of sustainable soil and land management to improve the sustainability, resilience and productivity of agriculture. The USAID Bureau for Resilience and Food Security (RFS) has led a partnership with the International Fertilizer Development Center (IFDC) and other partners to build a low-cost “Space to Place” (S2P) approach for developing and disseminating localized fertilizer guidance. The S2P approach revolves around the delivery of spatially appropriate soil fertility management recommendations, guided by digitized soil maps (Space) combined with farm(er)-level characteristics (Place), for effective agronomic and fertilizer recommendations that increase fertilizer use efficiency to maintain or surpass current productivity levels, and reduce fertilizer wastage.

IFPRI was tasked in 2023 to do a rigorous impact evaluation of the S2P approach. However, at the start of the project it quickly became clear that the S2P application was not going to be ready in the first operational year of the evaluation (during the 2024/25 growing season). A full and rigorous evaluation of the S2P approach was therefore deferred to the 2025/26 growing seasons and beyond. As such, we decided that the 2024/25 growing season could be used to generate learning to inform S2P’s theory of change.

Building on recent rigorous impact evaluations, we decided to evaluate the impact of a bundled intervention that involves offering farmers a soil test on a plot they select and, using the results of this soil test, providing them with tailored advice on soil management to attain a desired yield for a particular crop the farmer chooses to plant on the plot. Furthermore, we also explore resource constraints as a potential barrier to the adoption of site specific fertilizer blends by adding a subsidy.

# 2 Motivation

Governments in developing countries are trying to increase adoption of Green Revolution technologies, seed of improved varieties and mineral fertilizer in particular, through agricultural extension advice. In general, these extension systems provide blanket recommendations. One important reason why farmers fail to adopt seemingly profitable yield improving technologies is heterogeneity in the farmer’s ability and context. For instance, high transacting costs may make a technology unprofitable for a farmer even though on average the technology would be profitable (Suri, 2011). A similar argument can be made for soil—another key production factor in agricultural production (Arouna et al., 2021). Also here, differences in soil composition and nutrient content may mean that blanket fertilizer recommendations are sub-optimal.

Information and Communication Technologies (ICTs) provide an opportunity to deliver advisory services that are more tailored to the specific needs

of farmers (Spielman et al., 2021). Numerous Site Specific Nutrient Management (SSNM) Decision Support Tools (DST) have been developed with the promise to reduce inefficiencies coming from grossly simplified recommendations, thereby raising the productivity and profitability from adopting improved inputs (Arouna et al., 2021).

However, decision support tools for tailored nutrient recommendations have generally fallen short of expectations. This is illustrated by the numerous apps and tools that are out there but fail to scale (Sida et al., 2023). Some of the reasons why such tools do not have more impact may be related to the following open questions:

- the issue of spatial resolution, or how site specific these tools really are. Many of the tools rely on models that predict soil composition and nutrients in fairly large areas. As such, it has been argued that, often, “...the numerous laboratory services and digital applications providing field-specific recommendations appear to promise more accuracy than soil analysis can realistically deliver” (Schut and Giller, 2020).
- just providing information: many of the apps implicitly assume that just providing farmers with information is sufficient for farmers to change behavior. An extension component, with a human intermediary, is missing.
- decision support tools often take a host of pre-conditions for granted, the most critical probably being the fact that the recommended blend of soil macro- and micro nutrients is available to the farmer at reasonable cost. Indeed, as we will see below, most RCTs that study the effectiveness of DSTs have at least one treatment arm that investigates the importance of a particular pre-condition (such as access to insurance, financial resources, or information).

### 3 Related literature

Recently, various studies have been done on site specific nutrient management recommendations. Below, we review some of the most relevant studies.

Beg, Islam, and Rahman (2024) is one of the few studies that has a treatment arm with a soil test (which is similar to one of the treatment arms in our study, see below). In particular, using rice farmers in Bangladesh as a case, they compare two types of site-specific fertilizer recommendations—community-level recommendations and plot-specific recommendations based on individual soil tests—and compare this to government provided recommendations. They find limited effects, except perhaps for a reduction in application error (difference between recommended quantity of a particular nutrient and quantity used). That is, some farmers were using more than the recommended TSP and as a result of the intervention cut back. Some even appear to over-react and stop using TSP altogether, leading to lower yield. They also find indications that farmers adapt seed use to match baseline fertilizer use. Another study with a

soil test treatment are is [Gars, Kishore, and Ward \(2022\)](#), which shows that plot-level soil testing and tailored input recommendations changed farmers’ fertilizer usage and increased the adoption of recommended practices, leading to improved yields.

[Arouna et al. \(2021\)](#) evaluate the effectiveness of a mobile application that provides personalized advice on rice nutrient management in Nigeria. In particular, they evaluate RiceAdvice, an Android-based application to provide personalized recommendations on nutrient management (type, quantity, and timing of fertilizer) in rice production. They find that the intervention increases yields by 7 percent. No soil tests are done. They also have a treatment that combines personalized advice with a grant that provides the recommended level of fertilizer. Here they estimate a treatment effect of 20 percent. They also found a 10% increase from the intervention on profit which increased to 23% when the intervention is combined with the grant. The mechanism behind the increase in yield and profitability seems to be a reallocation in the fertilizer mix, with farmers using less NPK and more Urea.

[Ayalew, Chamberlin, and Newman \(2022\)](#) evaluate the impact of targeted site-specific fertilizer blend recommendations to Ethiopian smallholder farmers on fertilizer usage, farm productivity, profits from maize production, and household welfare using a cluster randomized control trial. They also have a treatment arm that adds insurance to the recommendation. They find significant reduction of the application error, which in turn affects yields. In particular, they report a 13 percent increase in yield (437 on baseline yield of 3250 kg/ha) and a very similar increase in farmer profit.

[Oyinbo et al. \(2022\)](#) study maize in Nigeria. They study the impact of Site Specific Soil Nutrient Management extension advice through the Nutrient Expert tool. They have two treatment arms and one business-as-usual blanket recommendations control. T1 farmers who are exposed to SSNM information interventions on nutrient application rates and fertilizer management, and T2 farmers who are exposed to the same SSNM information and additional information on the variability of expected returns to fertilizer investment under different price scenarios. They find modest effects on yields and profits. See also [Maertens et al. \(2023\)](#).

[Corral et al. \(2020\)](#) implement a field experiment that combines tailored input recommendations based on soil sample tests, extension services and an in-kind grant. The grant comes in two flavors: in one treatment arm, the grant can only be spent on the recommended fertilizer blend; in the second treatment arm, the farmer can decide what inputs to get. They find that the intervention reduces overuse of fertilizer, and the effect was sustained more if the farmer was free to choose how to spend the grant.

## 4 Research Questions

Our research aims to look at a prototype S2P intervention, as well as assess the relative importance of two of the key components. It will also investigate the

role of resources constraints as a potential enabling factor and look into peer learning. In particular, we will answer the following research questions:

1. Does the provision of site-specific soil nutrient information derived from a soil test and the recommendation of a specific fertilizer blend based on this information change outcomes of interest?

2. Does the provision of site-specific nutrient recommendations combined with a subsidy to buy these nutrients at a local agro-dealer, change the outcomes of interest? This research question looks at the importance of cash/credit constraints in the effectiveness of S2P.

Other issues we will investigate are:

3. Do farmers face substantial heterogeneity in soil nutrient profiles? This will be done by comparing variability in soil macro and micro-nutrients across different areas (eg within villages, between village and between regions).<sup>1</sup>

4. Do farmers know their soils? This will be done by asking farmers what they think their soil is missing and comparing this with results from the soil tests. We also can use the revealed version of this by comparing what farmers are actually putting on their fields and what would be recommended by the soil tests.

## 5 Treatment Protocols

The study employs a randomized controlled trial (RCT) design involving 113 villages across four districts in Malawi (Lilongwe, Dowa, Ntchisi, and Mchinji). The villages are randomly assigned to one of three groups.

- **Farmers in the first group, Treatment 1 (T1)**, receives a soil report based on a soil test conducted on a plot chosen by the farmer for a specific crop the farmer plans to grow on the selected plot.
- **Farmers in the second group, Treatment 2 (T2)**, receives everything farmers in T1 get in addition to a voucher that can be redeemed to buy the recommended fertilizer blend.
- **Farmers in the third group, Control (C)**, do not receive a soil test offer, a customized fertilizer recommendation, and a voucher.

For the treatments, (T1 and T2) we cooperate with Meridian’s Farmer Support Unit (FSU). This private-sector player offers farmers spectral soil tests and site- and crop-specific recommendations. The model underlying the test was calibrated on wet-chemistry analyses conducted on 22,000 samples from across Malawi. The tool is part of a private-sector business model in which FSU Meridian forms a recommendation for a package of nutrients, which is then supplied through their network of 400 agrodealers. After the soil tests are conducted by Meridian, the results are communicated in a follow up visit to farmers, along with an agricultural extension/advice service on the proper use

---

<sup>1</sup>This can be done through standard analysis of variance or multilevel modeling.

(the 4 Rs ) of the recommended fertilizer blend from a private sector-trained extension agents, known as "agronauts.

Specifically, farmers in the T1 group of villages are visited by an enumerator accompanied by a private sector trained extension agents called "agronaut" and is offered the opportunity for a soil test on a plot chosen by the farmer.<sup>2</sup> The farmer is also asked what crop he/she plans to cultivate on this plot, as well as the target yield that the farmer would like to get from the crop on that plot. The soil sample is then analyzed, which results in a soil report (see example in Appendix 1) that is provided to the farmer. The report indicates the soil's texture, pH level, cation exchange capacity, percentage organic matter, total nitrogen, carbon to nitrogen ratio, as well as the parts per million of available P, exchangeable K, calcium, magnesium, iron, manganese, boron, copper and zinc. Beyond the exact measurements each soil property is given a score on a 4-point Likert scale (very low, low, high, very high), with emojis, color coding and bar charts indicating where the soil is deficient and where the levels are sound. After the results the soil test are communicated with extension service on the proper use of the recommended fertilizer, farmers are then informed where and how to obtain these nutrients (in the form of a particular fertilizer blend). We use open route service to link sample villages to the nearest agro-dealer. We assume farmers go to agro-dealers by motorbike or bicycle.

Farmers in the T2 group of villages receive a subsidy that they get in the form of a voucher that can be redeemed at a nearby Farmer World agro-input shop. The subsidy is tied to T1 in that it will be specific for the recommended fertilizer blend. The amount of the subsidy is determined based on Malawi's Agricultural Input Program (AIP) subsidy which allows farmers to buy one bag of fertilizer at a reduced rate (30 percent of full price). In particular, our subsidy will be equal to 70 percent of the AIP fertilizer bag value minus the cost of the soil test. This will allow us to directly compare our bundle as an alternative to Malawi's AIP.

Farmers in the C group of villages do not receive any of the treatments that T1 and T2 groups of farmers get. This group serves as a pure comparison group with which the T1 and T2 groups are compared to arrive at the estimates of the impact of the treatments.

#### **Some notes:**

---

<sup>2</sup>The fact that the farmer can choose the plot themselves (as opposed to the experimenter choosing the plot in some systematic way) has important consequences for the analysis. In particular, it makes it hard to compare information at the plot level, as the choice of the plot may be influenced by the treatment, and so the plot on which outcomes are collected for the treated farmers may differ in more respects from those of control farmers than just information about soil quality. We have thought hard about ways to assure a comparable plot level counterfactual, such as also doing soil tests in the control group but keeping farmers in the dark about when they will receive feedback (as is done in Corral et al) or randomly choosing a plot for the soil test, but eventually decided to keep the treatment as realistic as possible, which gives the farmer substantial agency in terms of what plot to choose and crops to cultivate. The trade-off is that it will become harder to compare plot level outcomes (eg fertilizer use on the plot on which the soil test was done versus control). At the same time, there are now also interesting household level outcomes that we can investigate, such as crops cultivated.

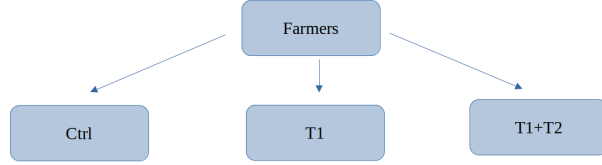


Figure 1: Experimental layout

Provide a brief explanation of the expert advice (extension service )  
Describe the amount of voucher and the logic behind in relation to the AIP.  
Maybe we can say site and crop specific fertilizer recommendation.  
Johnathan's point on the recommendation being affordable not the most effective in terms of yield  
Are farmers buying the right fertilizer recommended  
Farmers in T1 have the right to buy the fertilizer from anywhere.  
It might be one Agronaut for 3 or 4 villages - Johnathan will confirm.  
Data

## 6 Experimental Setup and Empirical Specifications

Households will be randomized at the village level following a parallel design with one control and two treatment arms. A first treatment arm will get the soil test and a recommendation based on this soil test which includes a recommended fertilizer blend. A second treatment is added incrementally on the first treatment. In this treatment arm, farmers get the soil test and a recommendation based on this soil test, and also receive a voucher that partially subsidizes the recommended fertilizer blend. The layout of the experiment is illustrated in Figure 1.

Due to the random assignment of participants to treatment and control groups, comparing outcome variable averages of treated and control participants provides unbiased estimates of the average treatment effects. We compare averages using OLS regression of the following form:

$$Y_i = \alpha + \beta_{T1}T1_j + \beta_{T2}T1_jT2_j + \varepsilon_i \quad (1)$$

where  $Y_i$  is the outcome of interest (agronomic practices, profits, return on investment, etc—see Section 8 below) of farmer  $i$ .  $T1_i$  and  $T2_i$  are treatment indicators at the village level that take the value of one if the farmer was located in a village that was allocated to the respective treatment group, and zero otherwise. The parameter estimate of  $\beta_{T1}$  is the treatment effect of the soil test

treatment,  $\beta_{T2}$  is the incremental effect of adding the voucher to the combined treatment.<sup>3</sup>

For outcome families with more than one outcome (knowledge, adoption, input use, and effort), we compute outcome indices, which is a common way to account for multiple hypothesis testing. To do so, we follow [Anderson \(2008\)](#), where each index is computed as a weighted mean of the standardized values of the outcome variables. The weights are derived from the (inverse) covariance matrix, such that less weight is given to outcomes that are highly correlated with each other. For these indices, signs of outcomes were switched where necessary so that the positive direction always indicates a “better” outcome.

## 7 Statistical Power and Sample Size Determination

We will run a simulation analysis to determine sample size for the design presented in section 6. Simulation, which involves instructing a computer to conduct an experiment thousands of times and tallying the frequency of significant outcomes under specific assumptions, is a considerably more flexible and intuitive approach to conceptualizing power analysis.<sup>4</sup>

Power calculations require the choice of an outcome variable. Normally, this outcome is assumed to be normally distributed, with a particular mean and standard deviation. However, when simulation is used, it is possible to draw from an actual distribution of the outcome variable if data is available. The outcome we consider in this study for our power calculations is maize yield. As such, we draw random samples from farmer level data that was collected for a study on smallholder market participation in the central region of Malawi ([De Weerd et al., 2024](#)). Using this data, we find that average yield is 2,574 kilogram per hectare (with standard deviation of 1145 kg per hectare).

Power is determined in the following way. Using this data, we find that average yield is 2,574 kilogram per hectare (with standard deviation of 1145 kg per hectare).

Power is determined in the following way. Our sampling frame is drawn from the previous study on smallholder market participation ([De Weerd et al., 2024](#)). We set the number of villages to the maximum number of villages that was used in this study, as this is a clustered design and we want to exploit inter-cluster variation to the maximum extent. We then search in two dimensions.

---

<sup>3</sup>To estimate  $\beta_{T1}$ , we will also estimate an alternative specification that boosts power by exploiting the fact that farmers T2 is provided on top of T1 (that is, farmers in the second treatment arm also receive T1). To do so, we consider T2 as covariate and enter it in deviations from its mean in the following way ([Lin, 2013](#)):

$$Y_i = \alpha + \beta_{T1}T1_j + \beta_{T2}T1_j (T2_j - \overline{T2}) + \beta_C (T2_j - \overline{T2}) + \varepsilon_i \quad (2)$$

See also this blog post: <https://blogs.worldbank.org/en/impactevaluations/what-should-you-do-experiments-factorial-designs>

<sup>4</sup>See also this methods guide: <https://egap.org/resource/10-things-to-know-about-statistical-power/>



First, we vary the share of villages that is allocated to the control (and equally divide the remaining villages to T1 and T2). In the second dimension, we vary the number of households that will be interviewed in each village. We model similar effects for T1 and T2 (a 13 percent increase over baseline yield). We run 1000 simulations and use 5 percent significance level and .8 is our target for power.

Figure 2(a) shows that when we allocate 25 percent of villages to the control group (and 75 percent to the treatments) and include about 16 households per village, we hit the 80 percent power level for the joint hypothesis that both  $\beta_{T1}$  and  $\beta_{T2}$  are significantly different from zero. However, to avoid that we are focusing on an isolated peak in the distribution, it seemed safer to move closer toward 30 percent in control (and hence 35 percent in T1 and 35 percent in T2) and aim for about 18 households per village. Figure 2(b) shows that at such a sample, we will get 85 to 90 percent power to identify a significant effect on T1. Figure 2(c) shows power to detect a significant difference between T1 and T2. Figure 2. From this, we conclude that we need about 30 percent in control (and hence 35 percent in T1 and 35 percent in T2) and aim for about 18 households per village.

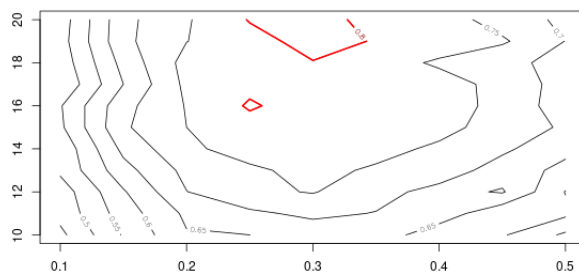
The sample for this study is drawn from a previous longitudinal study that involved 113 villages. This gives us the opportunity of leveraging two years' worth of data on Maize, Groundnut, and Soyabean growing farmers for our study design and analysis. In doing so, we ensure that we do not lose external validity and generalizability as we are relying on a specific sample drawn for a different purpose. Since the sample for the previous study was selected using the same approach we would have applied for this study—randomly drawing districts, villages, and households within villages—we believe that using this sample does not compromise external validity.

Based on a thorough power and sample size calculation, we have determined that we will need to sample 16 households per village, resulting in a total of 1,808 households. Out of the 113 villages, 41 villages will be assigned to Treatment 1 (T1), another 42 villages to Treatment 2 (T2), and the remaining 30 villages to the control group (C). During the initial visit, farmers in all 113 villages will be offered a soil test. Those who accept the offer will be asked to select a plot of their choice for the soil test. Additionally, they will be asked to specify the crop for which they would like to receive recommendations, as well as their target yield. In making these selections, all farmers, regardless of treatment assignment, will be informed that there is a two-thirds chance they will receive the results of the soil test in time for the 2024/25 growing season.

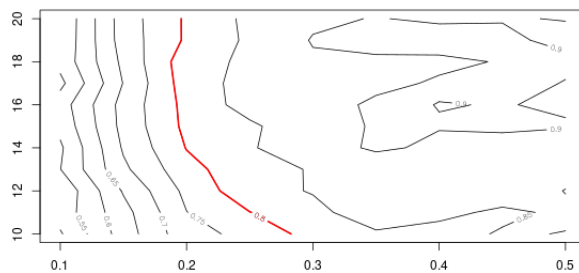
## 8 Outcomes of interest

Our outcomes of interest are agricultural practices (with a particular focus on the use of recommended inputs and practices), yields, return on investment in fertilizer, profitability of the crops and the return on investment for the subsidy. Focus will be on household level outcomes (as opposed to a narrow focus on the

(a)



(b)



(c)

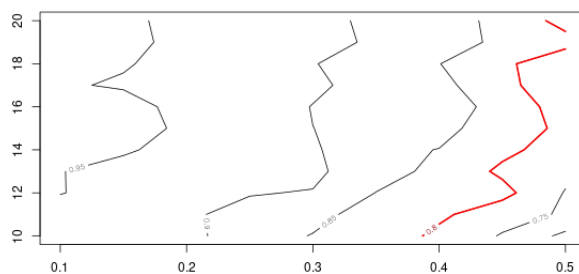


Figure 2: Power Plots

plot where the soil test was done), as the intervention may also affect the choice of the plot for testing, crop mix, allocation of crops to plots etc.

- use of inorganic fertilizer on the different plots. In particular, we will make sure we cover the 4 Rs (4 Rs: source, place, timing and rate)
- use of organic fertilizer on different plots (quantity)
- labour use in agricultural production
- yield on main plots (gps and subjectively measured plot area, estimated yield in bags and in kg)
- complementary input use and costs (seed used, chemical used)
- complementary agronomic practices, in particular those that also address soil health

We will also measure a range of intermediary outcomes to check uptake of the treatment, such that we can correct for differential uptake statistically if needed:

- was soil test done?
- did farmer receive tailored advice
- did the farmer receive a voucher?
- did the farmer redeem the voucher at a Farmers World nearby and if so, what transpired (was the blend available)

**Outcome:** Amount of fertilizer used by type, application error (gap from recommended rate, Yield, Farm revenue, Farm expenditure. We need to make sure that we also ask all questions needed to generate a recommendation via the fertilizer optimizer app.

**Outcome:** Fertilizer adoption, Amount of fertilizer used, Yield, profit.

**Outcome:** Fertilizer adoption rates, Yield, Profit.

**Outcome:** Fertilizer application rates, fertilizer management practices, maize yields, and revenues

We will also test for balance on fifteen pre-specified variables. First, we will use data previously collected to assess balance on the following five variables that are unlikely to be affected by the treatments: farmer's age (in years), sex of farmer, household size, land area for crop production (acres), and whether the household had difficulty in meeting food needs in the year preceding the survey. As this data was collected in May and June 2022, we can already establish balance at this point. Results are in Table 1. The table shows not a single significant difference for the five outcomes for pairwise comparisons between the different treatment groups. Joint tests of orthogonality confirm that we have good balance judged by these five outcome variables that were collected before the treatment administration.

Table 1: Balance table

	mean ctrl	T1	T2	nobs
Household head age (years)	42.434 (14.76)	1.158 (0.867)	-0.022 (0.901)	2007
Household head is male (1=yes)	0.781 (0.414)	0.012 (0.025)	0.01 (0.025)	2034
Household size (number)	4.902 (1.927)	0.129 (0.125)	0.159 (0.135)	2032
Land area (ha)	0.999 (0.627)	0.011 (0.053)	0.007 (0.051)	2033
Had difficulties feeding familiy in last year (1=yes)	0.276 (0.447)	0.041 (0.037)	0 (0.038)	2034
F-test C/T1 (p-value)	1.348	(0.241)		
F-test T1/T2 (p-value)	0.462	(0.805)		

Note: First column reports control group means (and standard deviations below); second column shows different between control and T1 (and standard errors clustered at the village level below); third column shows different between T1 and T2 (and standard errors clustered at the village level below). F-test test for joint significance in a regression with treatment status on the left hand side (T1/C or T2/T1). Likelihood ratio test is derived from a multinomial model where the left hand side has three levels (C,T1,T2).

Second, while we do not plan to do a dedicated baseline, we will collect data on some background characteristics on the previous season a few weeks after treatment administration. This will include whether the household was and AIP receipient in the previous season, total land size use for cultivation, number of crops grown, We also include five variables from among the outcomes of interest to test balance at baseline, in particular: use of organic fertilizer (yes/no), use of Urea (kg), yield, profit, crop in previous season was legume. At this time, we will also collect detailed information on the use of fertilizer in the preceding season on the plot that was selected for testing and we will ask detailed questions on what the farmer thinks the soil quality is to answer the fourth research question. This will help us in establishing if farmers under or overuse fertilizer when the do not know the soil quality.<sup>5</sup>

## 9 Timeline

Soil tests will be done in September 2024. Treatment administration (+ baseline data collection) will happen once results from the soil tests are available, which should be after about 2 weeks. In April 2025, endline data will be collected.

<sup>5</sup>Note that we can not use treatment versus control to answer this question given the fact that the farmer can select the plot on which the soil test is performed making it hard to identify an appropriate counterfactual.

## References

- Anderson, M. L. 2008. “Multiple Inference and Gender Differences in the Effects of Early Intervention: A Reevaluation of the Abecedarian, Perry Preschool, and Early Training Projects.” *Journal of the American Statistical Association* 103 (484): 1481–1495.
- Arouna, A., J. D. Michler, W. G. Yergo, and K. Saito. 2021. “One size fits all? Experimental evidence on the digital delivery of personalized extension advice in Nigeria.” *American Journal of Agricultural Economics* 103 (2): 596–619.
- Ayalew, H., J. Chamberlin, and C. Newman. 2022. “Site-specific agronomic information and technology adoption: A field experiment from Ethiopia.” *Journal of Development Economics* 156: 102788.
- Beg, S., M. Islam, and K. W. Rahman. 2024. “Information and behavior: Evidence from fertilizer quantity recommendations in Bangladesh.” *Journal of Development Economics* 166: 103195.
- Corral, C., X. Giné, A. Mahajan, and E. Seira. 2020. *Appropriate Technology Use and Autonomy: Evidence from Mexico*. Tech. rep., National Bureau of Economic Research.
- De Weerd, J., B. Dillon, E. Hami, B. Van Campenhout, and L. Nabwire. 2024. “Expecting too much, foreseeing too little? Behavioral explanations for the sell low-buy high puzzle in smallholder market participation.” .
- Gars, J., A. Kishore, and P. Ward. 2022. “Confidence and information usage: Evidence from soil testing in India.” *Unpublished Working Paper* .
- Lin, W. 2013. “Agnostic notes on regression adjustments to experimental data: Reexamining Freedman’s critique.” *The Annals of Applied Statistics* 7 (1): 295–318.
- Maertens, M., O. Oyibo, T. Abdoulaye, and J. Chamberlin. 2023. “Sustainable maize intensification through site-specific nutrient management advice: Experimental evidence from Nigeria.” *Food Policy* 121: 102546.
- Oyibo, O., J. Chamberlin, T. Abdoulaye, and M. Maertens. 2022. “Digital extension, price risk, and farm performance: experimental evidence from Nigeria.” *American Journal of Agricultural Economics* 104 (2): 831–852.
- Schut, A. G. and K. E. Giller. 2020. “Soil-based, field-specific fertilizer recommendations are a pipe-dream.” *Geoderma* 380: 114680.
- Sida, T. S., S. Gameda, J. Chamberlin, J. A. Andersson, M. Getnet, L. Woltering, and P. Craufurd. 2023. “Failure to scale in digital agronomy: An analysis of site-specific nutrient management decision-support tools in developing countries.” *Computers and Electronics in Agriculture* 212: 108060.

- Spielman, D., E. Lecoutere, S. Makhija, and B. Van Campenhout. 2021. "Information and communications technology (ICT) and agricultural extension in developing countries." *Annual Review of Resource Economics* 13 (1): 177–201.
- Suri, T. 2011. "Selection and comparative advantage in technology adoption." *Econometrica* 79 (1): 159–209.