BASIS AMA Research Program

Proposal Full Title: A Multiple Interventions Approach to Increasing Technology Adoption, Kenya Pilot
Acronym: MITA - Kenya

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Abstract

The Multiple Interventions Approach to Increasing Technology Adoption Project (MITA) is a multi-year project that started in 2013 in Tlaxcala, Mexico. All the interventions within the MITA program are targeted at smallholding maize farmers.

Our research aims to answer the following questions:

1. *Does providing plot specific information to farmers about their soil characteristics and corresponding recommendations about the timing and use of fertilizers, affect their behavior and ultimately yields and earnings?*
2. *To what extent does providing individually "tailored" vs local "average" recommendations of fertilizers can increase yields? We hypothesize that one reason for the heterogeneity in returns to inputs documented by previous researchers (e.g Bellon and Taylor, 1993; Suri, 2011) is that these inputs are used without accounting for the heterogeneity in plot characteristics.*

The results from the 2013 interventions showed that providing farmers with individualized soil analyses led to a 10% increase in yields (although this effect was imprecisely estimated). Soil analyses combined with agricultural extension services significantly increased yields by 15% relative to a control group without cash grant. Preliminary results from the 2015 interventions show promising take-up rates for different agricultural technologies for farmers receiving both soil analysis information and agricultural extension services.

We propose to leverage the lessons learned in Mexico to design and pilot an Agricultural Extension Service program that would replicate our already tested model but that could be implemented in the context of Western Kenya. The work will be undertaken in association with Precision Agriculture for Development (PAD). PAD is a US-based non-for-profit organization with the mission to improve the livelihoods of smallholder farmers by adapting precision agriculture technologies for developing countries using mobile phones and other low-cost technologies. PAD is planning to start an evaluation of their mobile-based extension service during Summer 2016. We will design and pilot the complementarities between the delivery of local soil analysis information through mobile phones and the provision of information through Agricultural Extension Workers (AEW). We are requesting funding from BASIS to support these activities.

1. MITA Mexico

1.1 Background and motivation

A majority of the world's poor live in rural areas and most of them depend on income from agriculture. Agricultural growth has been shown to about two times more effective in reducing poverty than growth originating in non-agricultural sectors (WDR, 2008). Policies that foster agricultural productivity not only can have a substantial impact on food security, but also on poverty reduction.

The Green Revolution introduced high-yield crop varieties, chemical fertilizer and other modern cultivation practices, yet the impact of these new technologies on farming practices and output has been uneven (Hazell, 2009). In many areas, traditional farming practices still predominate, and the take-up of new agricultural technologies and practices remains limited (e.g. Byerlee and de Polanco, 1986; Bellon and Taylor, 1993 and Foster and Rosenzweig, 2010).

According to statistics from Food and Agriculture Organization, maize yields range from 1.4 tons per hectare (t/ha) in Kenya to more than 9 t/ha in the US. In Mexico, despite growth in yields since the 1980s, yields are still around 3 t/ha, and lower still among small landholders. There has been considerable debate in academic and policy circles about whether the observed variation in yields reflects inherent (and unobserved) differences across farmers (e.g. Suri (2011), Marenya and Barrett (2009)) or differentiated access to improved inputs and practices. Increasing our understanding of the drivers of yields remains a first order question for policy-makers, as different drivers suggest different interventions to improve agricultural yields.

The Multiple Interventions Approach to Increasing Technology Adoption Project (MITA) is a multi-year project that started in 2013 in Tlaxcala, Mexico. All the interventions within the MITA program are targeted at small maize farmers (1-15 hectares of holdings and producing less than 3 tons of maize per hectare) who work in regions with agro-climatic conditions favourable for maize cultivation. The target population is representative of approximately 13% of the Mexican population and is characterized by low incomes and poor living standards. We work with farmers situated in many agro-ecological regions of the state to broaden external validity. We focus only on maize production since it is a staple crop central to the Mexican diet and also a staple worldwide.

Our research aimed to answer the following research questions:

3. Does providing plot specific information to farmers about their soil content as well as about recommended fertilizer usage and timing affect farmer behavior and ultimately yields and earnings?
4. To what extent does providing plot specific "tailored" vs "average" recommendations of fertilizers increase yields? We hypothesize that one reason for the heterogeneity in returns to inputs documented by previous researchers (e.g Bellon and Taylor, 1993; Suri, 2011) is that these inputs are used without accounting for heterogeneity in plot characteristics.

We began with the hypothesis that there was considerable variation in individual plot characteristics and that this heterogeneity of endowments in turn implies corresponding variation in the optimal inputs required to maximize yields. We tested this hypothesis using data collected on soil quality from a sample of smallholder farmers. Next, we tested the hypothesis that recommended input doses, based on soil tests, did in fact improve yields for smallholder farmers in field situations (as opposed to agricultural efficacy trials in experimental stations).

1.2 MITA Designs and Lessons Learned

In the first year of the program (2013) we implemented an RCT with four arms:

1. Control Arm
2. Soil Analysis Arm (SA)
3. SA with Best Practice Extension Services (SA+ES)
4. (SA+ES) + targeted Foliar Fertilizer Offers

We followed 419 farmers and 1,192 plots during 5 surveys in 2 month intervals. 146 farmers were assigned to the control group while 273 farmers were in one of the three treatment groups. Farmers in the study are broadly representative of smallholder farmers in Mexico

The soil analyses were a comprehensive set of tests carried out on farmer plot soil samples by a highly reputed local laboratory (Fertilab) recommended by the International Maize and Wheat Improvement Center (CIMMYT). The soil analysis provided detailed information on a range of plot characteristics including acidity levels (pH levels), electric conductivity, soil saturation points, cationic interchange, organic matter as well as nutrient levels of N, P, K, Ca, Mg, Mn, Fe and Zn among others.

In addition to the soil analysis, the lab also provided a set of individualized recommendations for obtaining a target maize yield of 5 t/ha – this choice was driven by our partner Fertilab's recommendation calibrations. The soil analysis and the recommendations were explained to farmers in a 90 minute one-on-one session. The session provided the farmer with general information on the importance of each nutrient and its place and timing in the plant's growth process and hence the importance of following the recommendations in the soil analysis.

In addition to the soil analysis and information session, farmers in the Soil Analysis and Best Practice Extension Services (SA+ES) group were frequently visited by extension workers for a total of over 6 visits during the agricultural cycle. The agricultural extension workers (AEWs) were graduates from Mexico's best agricultural universities who had further been trained in a set of CIMMYT's best practices conservation agriculture protocols. AEWs were equipped with tablets that were used to both record plot level information on activities carried out by the farmer (a sort of checklist) as well as monitor AEW visits using the tablets' GPS technology.

The main aim of the first year was to examine whether the provision of pure information and advice (arms 2 and 3) led to any changes in farmer behavior and yields. A secondary aim (arm 4) was to test whether targeted fertilizer offers in conjunction with improved information let to increased up-take and yields. Farmers assigned to that treatment arm either received a free package of foliar fertilizers with a market price of 44 USD, or a subsidy for the same package at different prices ranging from 25% to 100% of market price.

Analysis of the first year of data suggests the following findings (see appendix 2 MITA 2013 Results, BASIS Technical Committee 2014):

1. There is considerable variation in soil quality even with relatively homogenous agro-climactic zones
2. There is considerable variation in the recommended kinds and doses of fertilizer across different soil plots. Farmers, however, appear to use standardized amounts of a limited set of fertilizers irrespective of their soil characteristics
3. The provision of the individualized soil analysis led to a 10% increase in yields although the impact is imprecisely estimated. Soil analyses and the visits by AEWs significantly increase yields by 15% relative to the control group. There are, however, no detectable differences between farmers in the completely or partially subsidized foliar fertilizer arms relative to those not offered foliar fertilizer. We note that foliar fertilizer is applied to correct for nutrient imbalances in the application of basal and top-dressing fertilizer. As a result, the impact of foliar fertilizer tends to be low thus requiring larger samples to detect those effects.

Based on information collected during these surveys, it appeared that the following were potentially important constraints to the farmers' ability to follow recommendations:

(a) Absence of appropriate fertilizer packages in the market. Most fertilizer dealers stocked a standard set of fertilizer packages with limited ability at this point to cater to farmer-specific fertilizer packages.

(b) Absence of resources to purchase inputs. First year data indicate sub-optimal use of basal and top dressing fertilizer, suggesting that liquidity constraints may be important.

In Year 2 of the project, we aimed to relax those constraints on farmers' abilities to follow individualized plot recommendations. First, we worked with a high-quality international agricultural dealer, YARA, to provide a set of tailored fertilizer packages based on the results of almost 1000 soil analyses. Second, we issued in-kind grants for sowing to smallholder producers. The amount of the grant is USD 138 per hectare (2,000 Mexican pesos), corresponding to 30% of production costs and 50% of input costs in our previous surveys.

The arms in Year 2 of the project were:

- T1: Individualized soil analysis and recommendations and an inflexible in-kind grant along with agricultural extension services.
- T2: Average soil analysis and recommendations and an inflexible in-kind grant along with agricultural extension services.
- T3: Average soil analysis and recommendations and a flexible in-kind grant along with agricultural extension services.
- T4: Average soil analysis and recommendations and no grant along with agricultural extension services.
- T5: Control arm

We discussed each component (or sub-intervention) of the project in turn and the rationale for the particular combinations of the components chosen in each treatment arm in Appendix 1.

Preliminary results of soil analysis, program take up the first follow up survey and plant density estimations presented at the 2015 Basis Steering Committee on October 2015 shows that:

Soil Analysis Results

- There is considerable heterogeneity in soil quality within and across localities in the program, with the former of the same order as the latter.
- Nutrient and fertilizer recommendations also show substantial variation (corresponding to variation in soil quality).
- Recommendations differed from farmers' usual practices: farmers typically used more fertilizer overall than the recommended amount (particularly Urea) but less DAP and KCl and no micro-nutrients.

Take-Up: Sowing Machinery and Fertilizer

- Take-up rates were significantly higher for the treatment groups with 2,000 pesos grants (T1-T3). The group with no subsidies had lower, but still reasonable, take-up rates for some of the interventions.

Take-Up: Extension Services

- T1, T2 and T3 have similar take-up rates in the neighborhood of about 80%.
- Although T4 was also offered free extension services, training assistance in this arm was much lower, at about 35%.

Measured plant density in July 2015

- We measured the number of plants (and cobs) in 10 linear meters at 30 different parts of the sub-plot.
- Mechanized sowing led to much more uniform plant spacing, less competition for nutrients. T1-T3 ITT effects are between 15 - 18%, while for T4 farmers are 5.92%

Conclusions

- The use of localized recommendations seems promising. Take-up was high and the plant density was higher in the treatment sub-plots (1 hectare).
- Level of localization (individual vs. locality average) seems to not matter for take-up or plant density.
- Variance within a given localized area is often of the same order as variance across areas. That is true for soil characteristics, input recommendations, and plant density.
- Relaxing resource constraints appears important, also for take up of Agricultural Extension Services. T4 take-up rates were much lower than T1-T3. There seemed to be a fair amount of uncertainty about the new production methods and AEWs seemed to be more valuable in this

context. By contrast, there was no perceived need for AEWs under “business-as-usual" production.

We now propose to replicate a version of this program in Western Kenya. This will be done in partnership with a research team, led by Prof. Michael Kremer (Harvard) who has years of experience working with maize farmers in that region. Their team already has plans to evaluate the impacts of a service that would provide context-specific agricultural recommendations to smallholder farmers via mobile phones. The proposed project would complement those efforts and help gain additional insights on the importance of local information for farmer decision making. More details about PAD can be found in section 2.7.

2. Replication Pilot 2016-17, Western Kenya

Preliminary evidence from the work in Mexico suggests positive impacts of delivering context-specific agricultural information to smallholder farmers based on their soil characteristics, We propose to pilot a an intervention that would extend the lessons learned from Mexico to a very different setting: Western Kenya.

2.1 The problem and context

The high diversity of agroclimatic conditions and soil characteristics in Africa makes the suitability of agricultural inputs and management practices highly variable even across relatively small areas (Voortman et al. 2000; Tittonell et al. 2005, Vanlauwe et al. 2010). Various scholars have argued that this variability has specially hindered the African continent’s ability to reap the benefits of the Green Revolution in ways comparable to Asia and Latin America (Otsuka and Larson 2013, Evenson and Gollin 2003). This heterogeneity in local conditions – including soil chemistry, altitude, microclimates, or the market environment – can also lead to substantial differences in the profitability and suitability of different inputs across space, such as chemical fertilizer or hybrid seeds (Marenya and Barrett 2009, Suri 2011).

In Kenya, as in many parts of Africa, smallholder crop yields have remained very low partly because of issues around soil degradation: small land holdings are continuously cultivated without adequate nutrient replenishment, soil acidity is prevalent and the adoption of productivity-enhancing inputs is low. In Western Kenya, where this additional work would take place, previous research has documented that farmers exhibit low levels of fertilizer use, and among those who use fertilizer, many tend to systematically overuse it or use fertilizer types not recommended for their soil characteristics (Duflo, Kremer and Robinson, 2011). These behaviors are likely to exacerbate problems of soil acidity, which are widespread in the area. High soil acidity reduces crop yields and the yield response of fertilizers.

2.2 Proposed Activities

We plan to use the lessons from the work that has already taken place in Mexico and apply them in a different context. The proposed activities would build upon planned work by the Precision Agriculture for Development (PAD) project and its evaluation (more information in Appendix 4) but the requested funding would cover additional data collection activities that would help disentangle the potential for impact from different information delivery methods.

We propose to assess the effectiveness of providing soil analysis information on the adoption of locally appropriate agricultural inputs, in particular agricultural lime and a more diverse set of fertilizers (urea, dap, potassium chloride and micro-nutrients), by smallholder maize farmers in Western Kenya. The main research questions that this work will seek to answer are:

1. Do smallholder maize farmers choose to adopt locally-appropriate agricultural inputs (i.e., appropriate fertilizer blends and agricultural lime) when provided with information from local soil tests?
2. What are cost-effective channels to deliver this information and are there complementarities between these methods? We seek understand the relative effectiveness of disseminating agricultural information to farmers through in person delivery through extension workers and through PAD’s mobile phone system.

We propose to pilot these activities starting in summer 2016, in time for the short rains planting later in 2016, then more extensively with the long rains in early 2017. The following sub-sections provide more details on how we arrived at these research questions.

2.2.1 SMS versus in-person delivery of information

The proliferation of mobile phones in developing countries – including Kenya – renders information and communication technology (ICT)-based approaches particularly attractive since they offer the ability to inexpensively collect and deliver information to a large number of users. But, to date, evidence is limited and mixed regarding whether delivering agricultural information to farmers via their phones is effective.

In India, Cole and Fernando (2016) show that farmers who receive frequent reminders to use a mobile phone-based agricultural consulting service experienced increases in yields for cumin (26%) and cotton (up to 3.5%). They calculate a 1:10 cost-to-benefit ratio. In another project in Western Kenya, from which we derive lessons for the proposed intervention, Casaburi et al. (2014) working in partnership with the Mumias Sugar Company (MSC), the largest sugar producer in Kenya, conduct two trials of mobile agriculture extension services with contract farmers. While one trial found no significant gains, the other increased sugar-cane yields by 11.5% relative to a control group. Others offer more pessimistic evidence:

The proposed mobile system in Kenya will request information from farmers through SMS (e.g. location, basic demographics, etc.) and will then provide targeted recommendations for quantities and types of fertilizer and agricultural lime targeted at their local area (the content of this information may be refined as the database of agricultural information is finalized). This information will follow relevant application dates during the agricultural season.

There may be reason to believe, however, that the evidence of no or little impact is mixing the delivery method with the quality of the underlying content. For the purposes of this pilot we will nest our work within PAD's plans to evaluate a mobile-based extension service. The plan is to pilot the complementarities between in-person and mobile-based delivery methods. This will not only help us assess the importance of in-person delivery of local agricultural recommendations and the external validity of the work in Mexico, but also, we plan to use the extension workers to directly collect information from farmers which will be relevant for shaping PAD operations in the region.

The PAD team has secured funding for evaluating the non-AEW farmers and finance the development and deployment of the mobile phone platform. Our proposed pilot will be launched with farmers from the same sample frame but we are requesting additional funding to undertake these activities. We will carefully track the costs of our implementation in order to inform a proper benefit/cost analysis.

We will rely heavily on lessons-learned in Mexico about how to deliver the messages in-person. The Mexico team expects to learn if it is possible to replicate some of our previous findings in alternative contexts. In particular, we will use the results (if successful) to promote improvements in agricultural extension service programs elsewhere in Africa and Asia and share the lessons from our work internationally.

Farmer Trainings and Agricultural Extension Services

We will pilot two different scenarios that can help the PAD team understand how they could improve the program in case that they need to reinforce their treatments for the large season (March 2017): a) Farmers Group Trainings and b) Agricultural Extension Services. The first is less costly and scalable however they might not be as effective as providing personalized information through extension agents.

Groups of interested farmers will receive expert trainings right before each main stage of growth of the plants: soil preparation, sowing, and crop development. Trainings will be adapted to the local context and are subject to further refinement, but they are expected to cover the following topics:

1. Locally appropriate lime and fertilizers recommendations (as defined by soil tests). The trainings will practically show how much to apply and the correct method.
2. Top-dressing fertilization and efficient weed and pests controls. For instance: determining when the plant needs fertilizers using the number of adult leaves as guidance, how to detect nutrient deficiencies observing the color of the leaves and the importance of weeds control.

Agricultural Extension Workers (AEW) plot visits

In order to verify the farmer´s understanding of the trainings and remind him of the importance of the recommendations, the AEW will be visit the plot in three opportunities with the farmer: 1) *Soil preparations using lime*, 2) *Sowing and first fertilization verification* (15 days after sowing), and 3) *Crop development*: (45 days after sowing).

The AEW will verify plant density, sowing technique, amount and type of seeds, amount and type of fertilizers, nutrient deficiencies, presence of plagues and weeds, size of the plants and provide recommendations accordingly of how to improve their yields. The AEW will record all the measurements, recommendations, and the questions posted by the farmer using tablets.

2.2.2 Creating locally-appropriate input recommendations

The impact of providing local information hinges on our ability to create the best possible context-specific knowledge. While there may be value to understanding the soil and climate conditions on every farm or even plot within a farm, the costs of doing so are currently prohibitive in a context like Western Kenya. Grouping farmers into local "clusters" with relatively similar conditions, therefore, may be a critical first step in identifying and providing locally appropriate information. But, the optimal methods for doing this grouping are not well understood.

There are a range of existing efforts to update soil maps and generate more reliable and context-dependent recommendations to farmers. The combination of reductions in the cost of soil chemistry assessment, better statistical techniques for prediction of soil chemistry using available of data, and inexpensive information delivery methods has the potential to give farmers much better information on the appropriate types of inputs for their farms and the potential profitability of input use.

For the purposes of this evaluation, information on local soil characteristics will be generated using an extensive set of individual soil test data that exists for the area. Then, kriging techniques (geospatial interpolation), which optimally combine available soil information to predict soil characteristics for a particular location, will be used to "map" that information onto a larger area. From that full map, we will experiment with different methods of creating "clusters" of farmers and median soil characteristics for the group.

2.3 Target Population

The interventions are targeted at small maize farmers in Western Kenya (approximately 1-2 acres farms). Since the impacts of information are likely to be heterogeneous and might only affect those who are able and willing to engage with the system and access relevant inputs, we plan to study the impacts of this intervention on a sample of farmers who have already shown interest to receive this information. While those could be considered a set of "early--adopters", The lessons from this project are likely to be relevant for a variety of settings in Africa. .

2.4 Evaluation Design and Treatments

This evaluation proposal builds upon planned work by the RCT evaluation design of PAD. They are planning to work with several thousand farmers in the region, and recruit at least 5,000 farmers interested in enrolling in the mobile-based extension. Currently, the PAD research team plans to follow up with 2,500 farmers for an endline, half of which will be randomized into individualized recommendations, and half will remain as control group to evaluate their cell phone program.

We are currently requesting funding to expand the sample to 3000 farmers. We propose to pilot and test the impact of in-person delivery on a subset of 500 farmers, using the following design:

PAC Original Evaluation Design

Intensive Mobile Program	1250
Comparison – Mobile	1250
Total	2500

PAC + MITA treatments

Mobile	1250
Mobile + group trainings	250
Mobile + group trainings + Plots Visits	250
Comparison Group	1250
	3000

To recruit farmers, we plan to work together with PAD's team. PAD is piloting different recruitment methods, including working with agrodealers clientele and with farmers that they have been enrolled in other local programs and who have shown interest in extension.

All the 500 farmers assigned to the MITA AEW intervention will be invited to attend the trainings sessions and 250 will also receive the visit to their plots where the AEW will observe the soil preparations and development of the plant, record using tablets the issues observed, farmer practices before the visit, the recommendations provided to the farmer, as well as the questions the farmer posed to better understand what topics were not clear through the phone messages or the training sessions.

Finally, we plan to complete two endlines with this group of 500 farmers. During the first endline we will estimate plant density estimation before harvest. For the second endline, we will collect a household-based survey after the harvest. We will use these questionnaires to obtain more careful self-reported measures of input adoption, measure changes in farmers' knowledge and beliefs and ultimately collect self-reported information on yields. As part of their planned activities, PAD will collect information for their control group and the mobile phone treatment arm. Teams will share data collected.

2.5 Partners and collaborators

Precision Agriculture for Development (PAD) was recently awarded funds in order to further develop the technology and platform to provide advice at scale, build organizational capacity, launch 2-3 demonstrations (two in Africa and one in India) which would lead to rigorous impact evaluations and set the stage for further expansion. Initially, the Global Development Incubator (GDI) is incubating PAD global but they anticipate independent operations by mid- 2016. In Kenya, operations will be hosted by Innovations for Poverty Action for the first couple of years as the project is initially implemented and evaluated.

The proposed evaluation will be concurrent to the first formal demonstration of PAD in Africa. However, PAD builds upon services that PAD team members have been developing and studying for several years and they plan to draw general lessons from these past experiences in India and in Kenya.

PAD is led by a team with experience in software development, developing and testing solutions to address agricultural constraints in developing countries and scaling innovations. PAD Leadership includes Prof. Michael Kremer (Harvard), Prof. Shawn Cole (Harvard), Prof. Daniel Bjorkgren (Brown) and Heiner Baumann. The PAD Team in Kenya also includes, Megan Sheahan who has several years of experience working on agricultural development and Raissa Fabregas who has been conducting research on extension services in the region. For more information about this organization here: www.precisionag.org.

IPAK is the Kenyan branch of Innovations for Poverty Action (IPA). IPA is a research organization committed to performing high-quality randomized evaluations throughout the developing world. IPA-Kenya was created in 2005 and has extensive experience managing the day-to-day field operations of randomized evaluations. IPAK currently hosts PAD activities in Kenya.

Fertilab is the top-tier soil laboratory in Mexico who analyse the soil samples and developed the recommendations for the MITA project will work as a consultants to verify the recommendations of the Kenya soil lab. Fertilab is the only Mexican lab approved by the North American Proficiency Testing Program (NAPT) and is highly recommended by CIMMYT. Fertilab provided the soil analyses to construct the tailored recommendations for each of the plots in the 2013-2015 (www.fertilab.com.mx).

Carolina Corral is one of the Principal Investigators of the MITA and will responsible of hiring and training the Kenyan AEWs, as well as of overseeing the launch and deployment of the program and its evaluation. Carolina holds a M.Sc. in Economics from Université de Montréal. Since 2013, she is the Research Director of Qué Funciona para Desarrollo a Mexican non-profit organization funded that unites prominent national and international academics with the purpose of doing rigorous research that is useful and pertinent to further development. Carolina is the former Deputy Country Director Innovations for Poverty Action (IPA) Ghana where she supervised 12 RCTs of health, education, food security, savings and agriculture programs as well as managing an annual budget of USD 1,444,000 and annual surveys of 22,000 households and 8,000 children.

2.6 Project Calendar

MITA, Replication Pilot 2016-17, Western Kenya

Implementation Activity (orange)

Evaluation Activity (blue)

		2016							2017							
Activity	Res.	Jun	jul	ago	sep	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	Ago
Focus Groups with Farmers	IPA/MITA/PAC	Eval.														
Analysis of soil data and local recommendations	PAC/QFD/Fertilab	Impl.														
Hire and Train extension Workers	IPA / QFD	Impl.														
Promotion of the program and Registration Survey	IPA / QFD		Eval.													
Randomization	PIs			Eval.												
Baseline 1, and marking of plots	IPA			Eval.												
1st Farmers' training - Soil Preparations (Lime/Fertilizers) and sowing	AEW				Impl.											
1st AEW plot visits - Sowing	AEW				Impl.											
2nd Farmers' training - first fertilization and weed/plague control	AEW					Impl.										
AEW plot visits - first fertilization and weed/plague control	AEW					Impl.										
2nd Farmers' training - first fertilization and weed/plague control	AEW						Impl.									
AEW plot visits - first fertilization and weed/plague control	AEW						Impl.									
Harvest	Farmers							Impl.								
Data Cleaning and Analysis: Baseline	IPA				Eval.											
Pilot of Plant density Estimation Methods	IPA					Eval.										
Plant density estimation	IPA						Eval.									
Yield Measurement and Expectations Surveys	IPA								Eval.							
Data Cleaning and Analysis: Yield Estimations and Harvest	IPA									Eval.	Eval.					
Paper and non-academic publications	PIs										Eval.	Eval.	Eval.	Eval.	Eval.	Eval.

Appendix 1: MITA Mexico 2015 Interventions

Agricultural Extension Services

Farmers were offered extension services from IPAMPA a local private extension service company. There were at least two reasons for considering such services. First, in a past study done in the same region we found some suggestive evidence that agricultural extension services were useful. Second, in focus group discussions farmers were keen to try out the new set of recommendations but only in conjunction with advice from extension workers on the precise implementation of the recommendations to their plots.

The extension services package consisted of three group training sessions and 2 plot visits by the AEWs to interested farmers. The first group meeting introduced farmers to the precision sowing drill and covered the sowing phase. The second group meeting covered the application of fertilizer post-sowing and emphasized instructing farmers on the recognition of nutrient deficiencies and how to address them. The final meeting was held pre-harvest and emphasized field preparation. In addition to these group meetings, AEWs also visited individual sub-plots twice, once just before and once just after sowing.

We next discuss the rationale for the particular combination of these sub-interventions into four treatment arms. First, a limited budget meant that we could not implement a full factorial design. Second, past experimental work in the region along with focus groups suggested pairing the recommendations with extension services. In particular, past work suggested that providing soil analyses and recommendations in themselves had only limited effects on outcomes while pairing them with extension services improved yields. For this reason, arms T1-T4 all combined recommendations with extension services. Arms T1-T3 also provided in-kind grants with the interventions. We can isolate the effect of the in-kind grant by comparing arms T1-T3 individually with T4 although as noted above all arms T1-T4 received the recommendations as well as extension services.

Individual Soil Analysis and Recommendations

The soil analysis was carried out by Mexico's leading soil testing laboratory and one specifically recommended to us by CIMMYT, Fertilab. Fertilab provided a detailed analysis of the nutrient content in the soil samples as well as information about the plot's capacity to retain and transfer nutrients (e.g. soil type, density, electrical conductivity). In addition, the laboratory also provided the nutrient levels required in the sub-plot to generate maize yields of 4.5 tons per hectare under normal rain and temperature conditions. These recommendations were based on calibration style models that are the norm in agronomy. Fertilizer was to be applied at two time-points: (a) at sowing, (b) approximately 30-60 days after sowing, depending on the plant's development.

In addition, Fertilab as well as the local agronomists at IPAMPA (the extension service company we worked with and which we describe in greater detail below) recommended modifying certain sowing practices. In particular, they recommended (a) the use of a precision sowing drill at planting to enable both the optimal use of fertilizer as well as achieve optimal plant spacing, (b) the use of herbicides two days after sowing to reduce nutrient diversion by other plants. These additional sowing recommendations were also included in the advice provided to farmers.

Based on focus group discussions (in December 2014) we developed a template for delivering the soil analysis and recommendations that was divided into three parts:

> *1. Soil Analysis Diagnostic*: Provides the main soil characteristics in a relatively easy to read format. The soil analysis measured a range of factors that measured the soil's ability of retain and transfer nutrients (pH levels, electrical conductivity, sand and lime concentrations, saturation points, cationic exchange capacity) as well as the levels of 14 key nutrients {the primary macro-nutrients (N, P, K), the secondary macro-nutrients (Ca, Mg, S) and selected micronutrients (Na, Fe, Zn, Mn, Cu, B).
>
> *2. A set of required nutrient quantities in order to achieve a yield of 4.5 tonnes* per hectare under normal weather conditions according to Fertilab calculations. The recommendations used the levels of the 11 nutrients to compute needed quantities for the following fertilizers {Urea (CO(NH2)2), Monoammonium Phosphate (MAP), Potassium Chloride (KCl), Magnesium Sulphate (MgSO4), Zinc Sulphate(ZnSO4), Iron Sulphate (FeSO4), Granubor (Sodium Tetraborate Pentahydrate) and Manganese Sufate (MnSO43H2O).The recommendations also

specified the timing of application which could be (a) at sowing (first fertilizer package), (b) between the fourth and sixth adult leave (the second fertilizer package) appearing which generally occurred between 30 and 60 days of sowing. In addition farmers were also advised to use the sowing drill as well as herbicide two days after sowing.

3. *A one-page cost report* that contains (a) prices per unit (and total cost) for the fertilizer, machinery and herbicide required to implement the recommendations. We refer to this as a shopping list. (b) A statement of the farmer's fertilizer input use in the past year (based on the baseline survey) in quantities and costs. The purpose of this was to provide farmers with an easy comparison between the costs of their past input use and the cost of the shopping list.

Soil samples were collected from farmers in all treatment arms during the baseline (February and March 2015). The surveyors divided up the sub-plot into a number of internally homogenous regions and took 15 soil samples (from a depth of 30 cm.). These 15 samples were then mixed and collected in bags following standard soil analysis protocols. These bags were then sent to Fertilab for analysis.

The analysis, recommendations and shopping list were provided to farmers in T1-T4 in the last week of March and first week of April. Control farmers did not receive the analysis or recommendations but were told that they would receive their soil analysis in the next agricultural season. Farmers who chose to use the sowing drill informed QFD by the second week of April. Following this, QFD and Ipampa contracted with larger farmers in the region to rent tractors and sowing drills and coordinated the use of tractors and drills across the experimental farmers.

We contracted with a commercial fertilizer dealer, Agropecuaria Amozoc, to produce the tailored fertilizer packages to farmers. The dealer was selected among 8 large agrodealers in Tlaxcala because he was the only one with the capacity to blend fertilizers on-site and this was an important reason for using their services. Packages were available for pick-up from the dealer store (which was on average 17:2 km. (s.d. 6.7) away from the average farmer). We discuss the payment scheme below in the section on grants.

Average Soil Analysis and Recommendations

This sub-intervention was exactly the same as the individual sub-intervention outlined above (on p. 3) except that the soil diagnostic (item 1) and the fertilizer recommendations (in item 2) were based on an average of the soil analyses carried out in the farmer's cluster[1] rather than being based on the farmer's own sub-plot. The rationale for this intervention was to assess the differences in outcomes from using localized but not individualized fertilizer recommendations. Localized recommendations are cheaper to create and are also easier for the deliver to provide so that if outcome differences between the two are small, localized recommendations may be a more cost-effective method to improve yields. The optimal level of aggregation however remains unclear. See Table 5 for details on the averaged recommendations.

Inflexible In-Kind Grants

We provided inflexible in-kind grants worth 2000 pesos to farmers in T1 and T2. The amount would cover approximately one-half of the per-hectare input costs based on costs from the last growing season for the average farmer. In arm T1 and T2 the grant was inflexible in the sense that farmers could only use it to purchase items on their shopping list and also had to follow the recommended timing of the input application. This meant that the grant would be used to cover sowing costs (i.e. the cost of the machinery, the initial fertilizer package and the herbicide) and only then subsequent fertilizer packages. For the typical farmer the grant would cover the cost of the sowing machinery, the first fertilizer package, the cost of herbicide and approximately one-third (???) of the second fertilizer package. The in-kind grant was used for two reasons. First, fertilizer dealers did not typically stock the fertilizers in the blends that were required by the recommendations (either individualized or average) and were only willing to do so if we could guarantee a certain modicum of sales. Providing in-kind grants to farmers for the purchased of the recommended packages was one way to ensure the dealers of some demand. Second, the in-kind grant was an incentive to farmers to try out the new set of recommendations since these were quite different from their usual practices.

1 Plots were classified into 19 clusters based geographic proximity, similarity of height and type of soil to other plots in the area

Farmers who opted to receive the inflexible in-kind grants had to go to the local dealer to pick up their tailored fertilizer packages. As mentioned earlier, there were three packages and the farmers were required to make two visits the dealership to pick up the packages. See Table 6 for the cost of the various inputs.

Flexible In-Kind Grants

In arm T3 farmers were not required to purchase items on the shopping list or to follow the timing of input application. Instead, they could use the 2000 pesos to purchase any inputs of their own choosing from the fertilizer dealer. They could, if they chose, use the grant to purchase items on the shopping list but were under no obligation to do so and this was made explicit in all discussions between the research team and the farmers. This intervention was developed to examine the role of rigidity of the inflexible grants which attempted to enforce strict adherence to the agronomists' recommendations. Ideally, we would have like to add another arm that received an untied cash transfer of 2000 pesos but unfortunately we could not obtain permission from the Mexican government to carry out this intervention.

Appendix 2: MITA 2013 Results, BASIS Technical Committee 2014

See attached

Appendix 3: MITA 2015 Midline Results, BASIS Technical Committee 2015

See attached

Appendix 4: Precision Agriculture for Development

See attached