Improving Yields with Improved Recommendations: Evidence from Mexico Midline Results

Carolina Corral (QFD)
Xavier Giné (World Bank)
Aprajit Mahajan (UC Berkeley)
Enrique Seira (ITAM)

FERDI workshop on learning for adopting

May 31, 2016

Improving Small Farmer Productivity

- Improving agricultural productivity often seen as key to reducing poverty.
- Technology adoption an important mechanism for improving productivity.
- However, adoption of technologies remains uneven particularly among small farmers in developing countries (Foster and Rosenzweig (2010) and Jack (2013)).
- Yields in Mexico remain low and variable – comparable to poorer countries. ▸ Yield Summary

Diverse Explanations for Observed Adoption

- Missing Markets
  - Credit: Croppenstedt et al (2003), Crepon et al (2011).
  - Risk: Cole, Gine and Vickery (2013), Bryan, Chowdhary and Mobarak (2014), Karlan et al (2012).
  - Output: Ashraf, Gine and Karlan (2009).
  - Information: Foster and Rosenzweig (1995), Bandiera and Rasul (2006), Ben Yishay and Mobarak (2015)
- Behavioral Biases: Duflo, Kremer and Robinson (2011)
- Essential Heterogeneity : Suri (2011), Barrett, Marenya and Barrett (2009).
- Important since different explanations suggest different interventions.

This Project

- Better understand (certain kinds of) heterogeneity.
  - Focus on Soil quality. Cited as central to understanding fertilizer adoption (Jayne and Rashid (2013)).
  - Develop interventions based on improved understanding of heterogeneity.
- Variation in soil characteristics.
  - Cation Exchange Capacity: CEC
  - Macronutrients (N, P, K): NPK
  - Variation within and across clusters: Soil Quality ANOVA
- Considerable variation in Soil Quality within and across clusters.
- $\text{Var(Soil Quality)} \implies \text{Var(Yield Maximizing Inputs)}$
- Devise interventions based on soil quality.

Experimental Interventions

- Three Interventions
  - Soil analysis and recommendations (Individual and Averaged)
  - In-kind grant (Flexible and Inflexible)
  - Agricultural Extension Services.
- Combined these into 4 treatment arms (+ control arm).
- First describe each intervention in detail and then the treatment arms.

Soil Analysis

- Soil Analysis and Recommendations (Fertilab).
- Detailed information about
  - Physical characteristics (e.g. slope, texture, density)
  - Nutrient content (e.g, 14 macro– and micro– nutrients).
  - Capacity of soil to retain and transfer nutrients (e.g. electrical conductivity, pH levels, cationic exchange capacity).

SA Document SA Document 2

- Analysis carried out on 1 hectare sub-plot chosen by farmer.
  - Farmers unwilling to try new method on entire plot (focus groups). Use sub-plot as demonstration plot.
  - All interventions restricted to sub-plot but keep track of practices in non-program plots as well.
  - Control sub-plots were tested but results were not provided to farmers.

Input Recommendations

- Used soil analysis to generate input recommendations for target yield of 4.5 to/ha under normal weather conditions.
  - Recommendations from Fertilab (proprietary) calibrated model based on Leontief (Liebig) production functions.
  - Recommended dosages of (a) Urea (b) Diammonium Phosphate (DAP), (c) Potassium Chloride (KCl) + micro-nutrients.
- Recommendations:
  - Fertilizer Dosage
    - Quantities and prices
  - Timing of fertilizer application – at sowing and 30 days after depending on plant growth.
    - Dealer mixed fertilizers as per localized recommendations. Provided in two packages.
  - Precision sowing-drill – optimal spacing and fertilizer. Drill
  - Timing of herbicide use (2 and 40 days after sowing)

Input Recommendations: Logistics

- Recommendations provided in document to farmer and explained by research team and during AEW sessions.
- Provided prices, quantities and total costs for each recommended input – “Shopping List”. ▸ Costs
  - Compared costs to farmer’s 2014 input costs.
- Provided location of agro-dealer for fertilizer package pick-up (ave. distance 17 km).
- Coordinated logistics for precision sowing drill. Aggregated demand and hired drills from large farmers locally.

Nutrient and Fertilizer Recommendations

- Nutrient recommendations show substantial variation (corresponding to variation in soil quality).
  - Substantial within and across cluster variation: ANOVA
- Nutrient recommendations were translated into fertilizer recommendations.
- Recommendations differed from usual practices
  - Farmers typically used more fertilizer overall (particularly Urea) and much less KCl and no micro-nutrients.

Fertilizer Recommendations: Invidividualized

Variable[a]	Mean	2014	p-value[b]
DAP	33.70	46.53	0.9894
	(27.87)	(59.88)	
KCl	35.30	9.23	0.6881
	(28.23)	(25.84)	
Urea	150.42	253.14	0.4374
	(34.75)	(140.17)	
Micronutrients	19.97	2.05	0.5063
	(2.01)	(20.83)	
Total	238.61	318.78	0.6671
	(54.32)	(168.61)	

Per-hectare recommendations (T1 and Control) $n = 322$. Means presented for Control farmers.

[a] All quantities in Kilograms.

[b] p-value for testing the null that the coefficient on T1 is zero.

Average Soil Analysis and Recommendations

- Random subset of farmers received averaged soil analysis and recommendations. Averages were taken over all farmers in the same region.
- Still localized (but not individualized) analyses and recommendations.
- Average recommendations cheaper to generate and blend so (if outcome differences are small) may be more cost-effective.

Fertilizer Recommendations: Averaged

Variable[a]	Mean	p-value[b]
DAP	18.10 (15.91)	0.8939
KCl	28.80 (18.11)	0.8135
Urea	139.68 (13.06)	0.9939
Micronutrients	20.41 (0)	
Total Fertilizer	207.00 (24.84)	0.7601

Comparing T2,T3,T4 to Control ($n = 656$).
[a] All quantities in Kilograms.
[b] p-value for testing the null hypothesis that the coefficients on T2,T3 and T4 are zero.

In-Kind Grants

- Provided 2000 pesos ($\approx$ U.S \$150) worth of inputs to sub-set of farmers.
- Cover half of average per-hectare cost (using last year costs).
- Some farmers could only purchase items on shopping list.
  - Grant applied sequentially starting with Sowing drill (800 pesos) and then towards fertilizer packages.
- Other farmers could purchase any inputs in dealer store (no govt. permission to do cash grants).
- If total shopping list cost more than 2000 pesos, farmer responsible for paying the difference (enforced all-or-nothing payment).

Cost of Averaged Recommendations

Input	Mean (Pesos)	p-value[a]
Precision Sowing	800 (–)	
Sowing Fertilizer Package	845.29 (143.22)	0.7988
Second Fertilizer Package	815.47 (78.17)	0.7761
Farmer Cost[b]	460.76 (211.21)	0.7722

[a] p-value for testing the null hypothesis that the coefficients on T2,T3 and T4 are zero (n=656).
[b] Farmer Cost is equal to the sum of the inputs (precision sowing and the two fertilizer packages) less the 2000 Peso in-kind grant.

Cost of Personalized Recommendations

Input	Mean (Pesos)	p-value[a]
Precision Sowing	800 (–)	
Sowing Fertilizer Package	1,009.72 (255.20)	0.8641
Second Fertilizer Package	921.33 (195.19)	0.6806
Farmer Cost[b]	726.34 (422.22)	0.8227

[a] p-value for testing the null hypothesis that the coefficients on T1 is zero (n=322).

[b] Farmer Cost is equal to the sum of the inputs (precision sowing and the two fertilizer packages) less the 2000 Peso in-kind grant.

Agricultural Extension Services

- Contracted with private firm IPAMPA to offer extension services (at no cost to farmers).
- Previous RCT in Tlaxcala and focus groups suggested complementarities between recommendations and AES.
- Extension service consisted of 3 plot visits by AEWs along with 3 group training sessions (at sowing, 40 days after sowing and pre-harvest).
- AEWs assist in precision sowing, emphasize farmer recognition of signs of nutrient deficiencies (N, P, K) and following plant development and fertilizer timing.

Experimental Design

T1 : Treatment Arm 1

1. Agricultural extension services
2. *Individualized* soil analysis and recommendations
3. *Inflexible* in-kind grant

T2 : Treatment Arm 2

1. Agricultural extension services
2. *Averaged* soil analysis and recommendations
3. *Inflexible* in-kind grant

T3 : Treatment Arm 3

1. Agricultural extension services
2. *Averaged* soil analysis and recommendations
3. *Flexible* in-kind grant

T4 : Treatment Arm 4

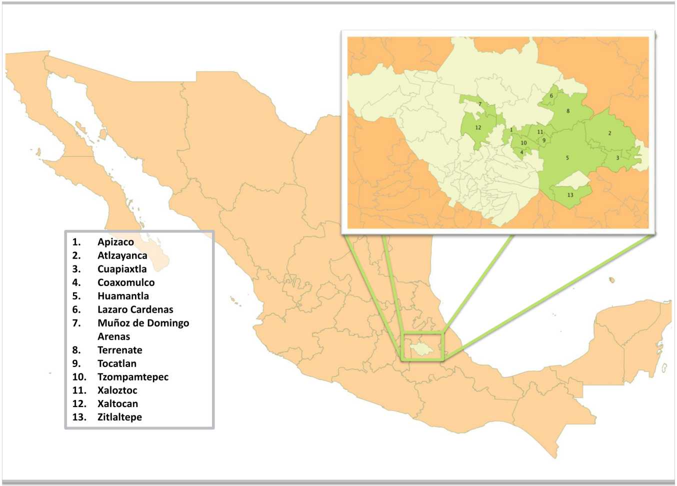
1. Agricultural extension services
2. *Averaged* soil analysis and recommendations

T5 : Control arm

Treatment Arm Rationale

- Budget constraints → No full factorial design.
- Past RCT work suggested pairing recommendation with AES. Threfore, all non-control arms had AES & recommendations.
- Past work also suggested supply-side constraints to implement recommendations. Paired with private agro-dealer to prepare tailored packages for farmers. All arms had access to dealer.
- Finally, want to directly test (a) effect of average vs. individual recommendations and (b) effect of flexible vs inflexible in-kind grant and (c) effect of grant.

Tlaxcala (Mexico)



- 13 municipalities of Tlaxcala with large population of small maize farmers.
- One of Mexico's poorest states. 88% of agriculture rain-fall dependent.

Sampling

- 34 promotional meetings in Jan. 2015. Widely advertised program in all municipalities.
- Eligibility restricted to farmers with land $\leq$ 15 ha., 18 $\leq$ age $\leq$ 70 and planned to sow maize.
- 981 farmers eligible. Randomized into program in February 2015.
- Census (INEGI) Comparison
- Study farmers have on average lower yields than Mexican average, less likely to use hybrid seeds and more likely be rainfed. More likely to use fertilizers and herbicides.
- Sample selection likely different if program were run by other organization. Summary Statistics

Attrition

- Of 981 randomized farmers , 911 actually sowed maize in 2015 and of these 819 remained in program past baseline.
- Differential Attrition: T4 and Control maize-sowers much more likely to attrit.
    - Attrition Table
- Dealing with Attrition: Use entire randomized sample (981 farmers) and
    - Strategy 1: Assign 0 to all attriters – for binary take-up choices (Horowitz and Manski (2000)).
    - Strategy 2: Construct Lee Bounds (Lee (2009), Zhang and Rubin (2003)).

Take-Up ITT: Sowing Machinery and Fertilizer

	QFD sowing	1^{st} Package	2^{nd} Package	Farmer Payment
T1	0.6684***	0.7306***	0.5440***	288.8049***
	(0.0404)	(0.0385)	(0.0408)	(29.3767)
T2	0.7784***	0.8247***	0.7165***	283.0573***
	(0.0303)	(0.0312)	(0.0364)	(28.8657)
T3	0.6482***	0.8844***	0.7035***	189.8980***
	(0.0423)	(0.0390)	(0.0462)	(25.8816)
T4	0.0600***	0.0550***	0.0250**	18.0528**
	(0.0171)	(0.0167)	(0.0102)	(7.3672)
R-squared	0.6843	0.8017	0.6564	0.4179
p-value T1=T2=T3=0	0.0000	0.0000	0.0000	0.0000
p-value T1=T2=T3=T4	0.0000	0.0000	0.0000	0.0000
p-value T1=T2=T3	0.0109	0.0029	0.0001	0.0004
p-value T1=T2	0.0124	0.0230	0.0000	0.8738
p-value T2=T3	0.0098	0.1086	0.7485	0.0005

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.
Using complete initial sample with 0 assigned to all attriters ($n = 786$).

- Take-up rates significantly higher in T1-T3.
- Fertilizer take up similar for T2 & T3
- T1 take-up somewhat lower than T2.

Take-Up: Extension Services

	1st training course	2nd training course	3rd training course
T1	0.6943***	0.6632***	0.3679***
	(0.0349)	(0.0419)	(0.0537)
T2	0.7474***	0.7165***	0.3866***
	(0.0357)	(0.0328)	(0.0547)
T3	0.8342***	0.7538***	0.4422***
	(0.0336)	(0.0368)	(0.0563)
T4	0.2250***	0.2500***	0.1200***
	(0.0359)	(0.0377)	(0.0316)
R-squared	0.7143	0.6639	0.3756
p-value T1=T2=T3=0	0.0000	0.0000	0.0000
p-value T1=T2=T3=T4	0.0000	0.0000	0.0000
p-value T1=T2=T3	0.0041	0.1088	0.2186
p-value T1=T2	0.3047	0.2718	0.6874
p-value T2=T3	0.0219	0.3554	0.1466

Robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.
Using complete initial sample with 0 assigned to all attriters ($n = 786$).

- T1-T3 have similar take-up rates.
- T4 significantly lower (recall free extension services)

Uncertainty about soil quality

	Quality (0-10)	Certainty (1=Yes)
T1	-0.29	0.13***
	(0.18)	(0.04)
T2	-0.38**	0.08*
	(0.18)	(0.04)
T3	-0.30*	0.13***
	(0.18)	(0.04)
T4	-0.35*	0.09**
	(0.18)	(0.04)
Y_0	0.36***	0.42***
	(0.13)	(0.03)
Constant	6.93***	0.10***
	(0.13)	(0.03)
R-squared	0.01	0.19
Mean (control)	6.99	0.18
p-value T1=T2=T3=T4=0	0.24	0.03
p-value T1=T2=T3=T4	0.95	0.61
p-value T1=T2	0.60	0.27
p-value T1=T3	0.94	0.95
p-value T2=T3	0.64	0.29

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.
Using complete initial sample ($n = 911$).

- T1-T4 appear more certain about soil quality after recommendations.

Expectations of Yield Volatility

	Mean	sd	CV
T1	0.290**	0.114***	0.010
	(0.121)	(0.043)	(0.017)
T2	0.374***	0.186***	0.040*
	(0.123)	(0.045)	(0.021)
T3	0.497***	0.221***	0.042**
	(0.120)	(0.044)	(0.020)
T4	0.456***	0.153***	-0.001
	(0.115)	(0.044)	(0.016)
Post	-0.382***	-0.146***	0.072**
	(0.106)	(0.034)	(0.030)
Post * T1	0.185	-0.017	-0.085**
	(0.156)	(0.053)	(0.038)
Post * T2	0.137	-0.037	-0.082**
	(0.156)	(0.055)	(0.040)
Post * T3	0.170	-0.094*	-0.127***
	(0.155)	(0.053)	(0.037)
Post * T4	-0.641***	-0.186***	-0.011
	(0.149)	(0.054)	(0.040)
Constant	2.054***	0.616***	0.324***
	(0.084)	(0.027)	(0.012)
R-squared	0.064	0.072	0.009
Mean	2.102	0.609	0.349

Robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

- T1-T3 have lower CV of yields after recommendations.

Investment in Inputs

	Seeds	Machinery	Labor total	Fertilizers*	Total Inv.
T1	15.80	347.53***	-84.14	742.17***	1,161.34***
	(32.22)	(32.30)	(65.73)	(98.10)	(164.99)
T2	49.90	408.24***	-163.52**	530.64***	975.96***
	(29.90)	(23.65)	(70.60)	(85.46)	(146.81)
T3	126.12***	328.68***	6.94	443.98***	1,063.62***
	(42.43)	(28.85)	(77.17)	(89.27)	(176.49)
T4	89.71**	42.71	-55.97	9.88	106.34
	(36.54)	(27.17)	(77.80)	(103.48)	(171.64)
Constant	92.58***	313.25***	518.23***	1,315.92***	3,502.62***
	(20.10)	(27.03)	(60.56)	(81.20)	(181.60)
Observations	822	822	822	822	822
R-squared	0.02	0.30	0.01	0.10	0.09
Control mean	92.58	313.25	518.23	1315.92	3502.62
p-value T1=T2=T3==T4=0	0.03	0.00	0.24	0.00	0.00
p-value T1=T2=T3=T4	0.15	0.00	0.14	0.00	0.00
p-value T1=T2	0.50	0.05	0.09	0.01	0.07
p-value T1=T3	0.04	0.52	0.45	0.00	0.31
p-value T2=T3	0.07	0.02	0.03	0.10	0.49

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.
Comments: *Computed with YARA's packages costs
Using sample of individuals that remained in program past baseline ($n = 819$).

- T1-T3 have invested more, but received in-kind grant as well.
- Need to do Lee Bounds.

Fertilizer Usage

	Urea total (kg)	DAP total (kg)	KCl total (kg)
T1	-25.7177**	-0.8764	15.8174***
	(12.1635)	(5.1459)	(3.4390)
T2	-31.9490**	-15.0892***	14.8095***
	(13.1591)	(5.5515)	(3.8430)
T3	-32.5253***	-13.7192**	20.2700***
	(10.9923)	(5.8380)	(3.6954)
T4	3.1980	4.0002	5.6455
	(14.5540)	(5.7378)	(3.4546)
Constant	192.4910***	38.4231***	12.6250***
	(10.4575)	(5.0737)	(2.6892)
Observations	819	819	819
R-squared	0.0272	0.0334	0.0605
Lee Bounds [T1 v C]	[-39.038, -18.676]	[-5.744, 1.808]	[11.785, 17.666]
95% CI	[-61.756; 3.664]	[-29.329; -3.478]	[8.453; 30.073]
Lee Bounds [T2 v C]	[-46.207, -22.855]	[-20.923, -12.595]	[12.271, 16.919]
95% CI	[-65.802; -3.050]	[-15.387; 11.473]	[-3.876; 26.173]
Lee Bounds [T3 v C]	[-48.278, -22.712]	[-18.639, -10.049]	[14.371, 23.757]
95% CI	[-67.267; -4.041]	[-11.729; 30.236]	[6.293; 23.262]
Lee Bounds [T4 v C]	[-15.295, 21.548]	[0.132, 11.529]	[4.241, 7.692]
95% CI	[-46.542; 52.051]	[-27.028; -1.415]	[4.506; 24.270]

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

- T1-T3 less Urea, DAP; More KCl.
- $T1 \approx T2 \approx T3$

Fertilizer Usage

	Total Used (Kgs)	|Rec-Used|
T1	-3.7658	-87.8428***
	(14.5788)	(9.9955)
T2	-22.9028	-96.1506***
	(14.9336)	(9.9029)
T3	-17.1600	-89.2421***
	(14.7468)	(10.6810)
T4	9.0473	-2.1020
	(18.0665)	(11.7260)
Constant	253.2506***	131.8965***
	(14.0748)	(8.7631)
Observations	819	819
R-squared	0.0092	0.2006
Lee Bounds [T1 v C]	[-19.037, 7.344]	[-100.474, -85.036]
95% CI	[-48.309; 34.784]	[-36.960; 47.698]
Lee Bounds [T2 v C]	[-38.645, -14.359]	[-110.551, -93.865]
95% CI	[-63.805; 22.143]	[-121.109; -72.150]
Lee Bounds [T3 v C]	[-39.316, -2.932]	[-110.600, -83.318]
95% CI	[-62.999; 10.393]	[-128.261; -76.729]
Lee Bounds [T4 v C]	[-15.000, 28.750]	[-12.028, 10.189]
95% CI	[-53.717; 76.916]	[-121.690; -66.789]

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

- T1-T3 much closer to recommendations.

Intermediate Outcome: Plant Density

- Measured plant density in July 2015.
- Measured # plants (and cobs) in 10 linear meters at 10-30 different parts of the sub-plot.
- Multiple measures of plant density for the same sub-plot.
- Mechanized sowing led to more uniform plant spacing, less competition for nutrients.

Results: Plant Density

	#Plants/10m	Extrapolation
T1	4.434***	5,936***
	(0.875)	(1,090)
T2	4.078***	5,408***
	(0.832)	(1,034)
T3	3.693***	5,139***
	(0.830)	(1,024)
T4	1.790*	2,342**
	(0.928)	(1,150)
Control (mean)	24.50	30219
n	23,608	23,571
R-squared	0.188	0.182
p-val T1=T2=T3=T4	0.0224	0.00920
p-val T1=T2=T3	0.657	0.728
p-val T1=T2	0.660	0.602
p-val T2=T3	0.617	0.778

Standard errors are clustered at the sub-plot level.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

- T1-T3 ITT effects $\approx 15 - 18\%$
- Need to do Lee Bounds.

Weather Shock: Drought

- Rains failed in all municipalities in study area after July. ▸ News Report
- Rains failed during critical period for plant development – flowering period and maturation period (Sinclair et al. 1990)
- In November, 77% of farmers reported at least one rainless spell on program plot with median spell of 31 days.
  - Plot level measures of rainfall
  - Drought non-differential across arms.
- Elicited yield expectations from farmers twice during the growing season (July and November).
  - On average farmers incidence of a drought was associated with a downward revision of expected yields by about .18 tonnes.
  - Every additional day in the rainless spell associated with 4 Kg. drop in expected yields.

Yields: Measurement

- Aimed for mechanized measurement of yields but not always possible. Four possibilities.
  1. Farmers had not harvested and harvester to cut plants, shell corn and place grains in truck for weighing (465 farmers).
  2. Farmers had not harvested but harvester was not used on plot. Cobs were removed by hand, shelled using portable shelling machines and grain weighed on plot (32 farmers).
  3. Farmers had harvested and program plot harvest grain was clearly identifiable. Grain weighed using portable weighing machines (84)
  4. Farmers had harvested but program sub-plot grain was not identifiable or no maize was produced. No weighing was done (220 farmers).
- Measurement method differential across arms – $\sim 50\%$ mechanized harvested in T4 & C; $\sim 70\%$ in T1-T3.

Predicting Missing Machine Yields

	(1) No Mech. Measure	(2) No Mech. Measure
T1	-0.1506***	-0.1355**
	(0.0397)	(0.0523)
T2	-0.2296***	-0.2035***
	(0.0390)	(0.0390)
T3	-0.1752***	-0.1195**
	(0.0533)	(0.0581)
T4	0.0333	-0.0374
	(0.0374)	(0.0446)
2014 SR Yield (t/ha)		-0.0153
		(0.0130)
Plant Density ($/m^2$)		-0.0302*
		(0.0162)
Finished primary school		-0.0001
		(0.0327)
Constant	0.4667***	0.4783***
	(0.0381)	(0.0709)
Observations	981	807
R-squared	0.0457	0.0424
p-value T1=T2=T3=T4	0.0000	0.0000
p-value T1=T2=T3	0.1469	0.1469

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
$n = 808$ in Col (2) since plant density only measured at Follow Up

Other Yield Measures

- Farmers also self-reported yields
  - For machine measured plots farmers self-reported yields before measurement.
  - For remaining plots, farmers self-reported yields (at different time).
- Use July plant density to predict machine yields and use fitted values to replace missing data.
  - Need relationship between density (P) and yields(Y) to be constant across sample selection(S) – $Y](P,T)[S$ (Untestable)
  - Can check $P]T[S$ – e.g within control arm, plant density in August is uncorrelated with whether plot has machine measurement in December.

Yield Results

	Yield[a]	Yield (SR)[a,b]	Predicted Machine Yields[a,c]
T1	408.1722**	243.4055	189.9922***
	(199.6873)	(166.2819)	(61.2488)
T2	293.8714**	178.0060	154.3075***
	(140.3609)	(157.9114)	(43.7949)
T3	550.1912***	245.7767	149.2523***
	(190.5384)	(147.2822)	(44.6375)
T4	425.4531**	84.9087	64.4631*
	(207.9147)	(185.6127)	(37.6206)
Constant	2,078.4571***	2,155.3750***	2,107.2250***
	(214.3861)	(174.3770)	(33.7666)
Observations	625	811	813
R-squared	0.0132	0.0049	0.0337
Lee Bounds [T1 v C]	[-170.712, 921.857]	[189.472, 325.941]	[147.786, 240.691]
95% CI	[-549.144, 1317.576]	[-567.201, 758.299]	[63.387, 334.332]
Lee Bounds [T2 v C]	[-478.074, 1036.946]	[28.811, 308.723]	[84.477, 249.185]
95% CI	[-836.117, 1448.513]	[-301.989, 621.583]	[7.901, 330.780]
Lee Bounds [T3 v C]	[-79.476, 1046.340]	[33.131, 400.790]	[68.610, 236.287]
95% CI	[-467.578, 1467.232]	[-240.186, 689.366]	[-95.945, 205.102]
Lee Bounds [T4 v C]	[279.513, 530.617]	[-230.769, 437.597]	[-11.114, 127.199]
95% CI	[-280.584, 1383.807]	[-141.617, 650.418]	[-6.227, 310.493]

[a] Measured in Kgs..
[b] Self-Reported Yields
[c] Predicted yields based on plant density measured in July.
Robust standard errors in parentheses.
*** $p<0.01$, ** $p<0.05$, * $p<0.1$.

- Bounds generally tighter for $T1$

Yield Results

- Machine Measured yields: Selected sample – plots more likely to be from T1-T3. Lee bounds wide suggesting weak treatment effects.
- Self-Reported yields: Selection problem weaker. Lee bounds suggest positive effects for T1-T3.
- Predicted Machine Yields: Untestable assumption. Lee bounds suggest positive effects for T1-T3.

Conclusions

- Provided farmers with localized recommendations and AEW services, agro-dealer coordination and in-kind grants to help implementation.
- High take-up in grant receiving arms. Level of localization seems to not matter for take-up or plant density.
- Variance within higher than variance across clusters.
  - For soil characteristics, input recommendations, plant density.
- Providing in-kind grants appears important.
  - Uncertainty about new recommendations.
- Take-up high and pre-drought plant density higher in treatment sub-plots. Severe drought likely affected yields.
- Following farmers in 2016 to see if any practices stick.

Soil Analysis: Fertilab Document

Fertilab®
Fertilidad de Suelos S. de R.L.

Análisis que ***Rinden Frutos***

DIAGNOSTICO DE LA FERTILIDAD DEL SUELO

INFORMACIÓN GENERAL

Cliente	Ismael Zacamolpa Cerbani		
No. de Registro	SU-35440	Cultivo Anterior	Ninguno
Fecha de Recepción	09/03/2015	Cultivo a Establecer	Maiz
Fecha de Entrega	11/03/2015	Tipo de Abono Organico	N/A
Rancho o Empresa	Cuaxomulco	Tipo de Agricultura	Temporal
Municipio	Cuaxomulco	Manejo de Residuos	Retirados
Estado	Tlaxcala	Meta de Rendimiento	5 Ton/Ha Ton/Ha
Identificación	.23.01.10.01	Prof. Muestra	0-30 cm

Propiedades Físicas del Suelo

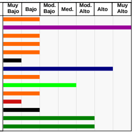
Clase Textural	Franco Arcillo Arenoso		
Punto de Saturación	31.6	%	Mediano
Capacidad de Campo	16.7	%	Mediano
Punto March. Perm.	9.94	%	Mediano
Cond. Hidráulica	6.00	cm/hr	Mod. Alto
Dens. Aparente	1.35	g/cm3	

Reacción del Suelo Necesidades de Yeso y Cal Agrícola

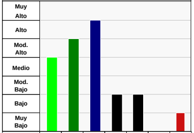
pH (1.2 agua)	5.12		Acido
pH Buffer	6.90		
Carbonatos Totales (%)	0.01	%	Libre
Salinidad (CE Extracto)	0.30	ds/m	Muy Bajo
Requerimientos de Yeso	No Requiere		
Requerimientos de Cal	0.00		

Fertilidad del Suelo

Det	Result	Unid
MO	1.11	%
P-Bray	61.2	ppm
K	121	ppm
Ca	633	ppm
Mg	90.0	ppm
Na *	19.5	ppm
Fe	34.3	ppm
Zn	0.42	ppm
Mn	7.70	ppm
Cu	0.45	ppm
B	0.13	ppm
Al *	12.2	ppm
S	13.8	ppm
N-NO3	22.7	ppm



Cationes Intercambiables
Gráfico Basado en % de Saturación



% Sat	71.3	16.7	7.00	1.81	3.16	ND	——
meq/100g	3.16	0.74	0.31	0.08	0.14	0.00	4.43
Catión	Ca	Mg	K	Na*	Al*	H*	CIC

Relacion Entre Cationes (Basadas en me/100g)

Relación	Ca/K	Mg/K	Ca+Mg/K	Ca/Mg
Resultados	10.2	2.39	12.6	4.27
Interpretación	Mediano	Mediano	Bajo	Mediano

* Es deseable que estos elementos tengan un bajo contenido

Interpretación Resumida del Diagnostico de la Fertilidad del Suelo

Suelo con pH acido. Suelo de textura media. Libre de carbonatos. Libre de sales. Bajo nivel de materia organica, es recomendable su aportacion. Bajo nivel de calcio. Muy alto suministro de fosforo disponible.Contenido bajo de potasio. Bajo nivel de magnesio. Suministro moderado en nitratos.

En cuanto a la disponibilidad de micronutrientes: Pobre en zinc. Bajo contenido de cobre. Muy pobre en boro.

Poniente 6. No. 200 Ciudad industrial
Celaya, Gto. C.P. 38010
Tel. (461) 614 5238, 614 7951
www.fertilab.com.mx

Supervisor de Análisis de Suelos
Ing. José Trinidad Guzmán M.

▸ Return to Soil Analysis

Soil Analysis: Farmer Document

Return to Soil Analysis

Fertilab ipampa Qfd

ID. .23.01.09.

RECOMENDACIÓN PARA FEDERICO SERRANO HERNANDEZ

CUAXOMULCO, CUAXOMULCO

Municipio:	CUAXOMULCO
Localidad:	CUAXOMULCO
Parcela:	CUAXILCA
Análisis de suelo:	35455

1. *Diagnóstico de su PARCELA* CUAXILCA

El laboratorio Fertilab, especialista en suelos analizó la muestra de su parcela y encontró que existen los siguientes niveles de nutrientes:

Propiedades Físicas del Suelo		Reacción del Suelo		
Clase Textural:	Franco Arcillo Arenoso	pH (1:2 agua):	6,69	Neutro
Densidad Aparente	1,1 g/cm3	Materia Orgánica:	0,56	
Punto de Saturación:	30 %	Carbonatos Totales	0,01%	
Cond. Hidráulica:	6,7 cm/hr			

Elementos en el suelo	Ideal para 4.5ton/ha	Cantidad en su parcela (ppm)	
Nitrógeno	**71**	5,44	✗
Fósforo	**30**	4,86	✗
Potasio	**300**	246	✗
Magnesio	**200**	423	✓
Hierro	**9**	10,2	✓
Zinc	**1.2**	0,46	✗
Manganeso	**4**	10,2	✓
Cobre	**.5**	0,99	✓
Boro	**.8**	0,02	✗

ppm = partes por millón

Return to Soil Analysis

Fertilab ipampa Qfd

ID. .23.01.09.

RECOMENDACIÓN PARA FEDERICO SERRANO HERNANDEZ

CUAXOMULCO, CUAXOMULCO

Municipio:	CUAXOMULCO
Localidad:	CUAXOMULCO
Parcela:	CUAXILCA
Análisis de suelo:	35455

1. ***Diagnóstico de su PARCELA*** **CUAXILCA**

El laboratorio Fertilab, especialista en suelos analizó la muestra de su parcela y encontró que existen los siguientes niveles de nutrientes:

Propiedades Físicas del Suelo		Reacción del Suelo		
Clase Textural:	Franco Arcillo Arenoso	pH (1:2 agua):	6,69	Neutro
Densidad Aparente	1,1 g/cm3	Materia Orgánica:	0,56	
Punto de Saturación:	30 %	Carbonatos Totales	0,01%	
Cond. Hidráulica:	6,7 cm/hr			

Elementos en el suelo	Ideal para 4.5ton/ha	Cantidad en su parcela (ppm)	
Nitrógeno	**71**	5,44	✗
Fósforo	**30**	4,86	✗
Potasio	**300**	246	✗
Magnesio	**200**	423	✓
Hierro	**9**	10,2	✓
Zinc	**1.2**	0,46	✗
Manganeso	**4**	10,2	✓
Cobre	**.5**	0,99	✓
Boro	**.8**	0,02	✗

ppm = partes por millón

Precision Sowing Drill

Return to Input Recommendations

Return to Input Recommendations

Fertilab ipampa Qfd **ID.** .23.01.10.

3. Paquete de fertilización con productividad mayor según los análisis de suelo de su parcela

Según el análisis de suelo de su parcela, Ud. podría alcanzar una productividad de **4.5 toneladas** en su parcela de prueba si en 2015 sigue los siguientes pasos:

1. Fertilizar a la siembra y a los 30 días después de la siembra con un paquete de fertilizantes diversificado.
2. Sembrar 20 kilogramos de semillas criollas o 60,000 de semillas híbridas por hectárea, utilizando una sembradora de precisión para asegurar que las semillas no compiten entre ellas por nutrientes, y que los fertilizantes no quemen sus semillas.
3. Aplicar un herbicida sellador a los 2 días de la siembra y volver a aplicar un herbicida a los 40 días de siembra para que sus plantas no compitan por nutrientes con malezas.

Le proponemos **diversificar el uso de fertilizantes** como se explica abajo para llegar a una productividad de hasta 4.5 toneladas por un costo total de **$2512,04**

Dosis de fertilizantes en kg/ha [2]	MOMENTO DE APLICACIÓN		
	Siembra Kg aplicados por ha	**1era fertilización** Kg aplicados por ha	**Kg totales**
Urea (Blanco)	40,21	163,29	203,5
DAP (Negro)	76,09	0	76,09
Cloruro de Potasio	4,17	4,17	8,33
Minab R	20,41	0	20,41
Costo por aplicación	**$1354,49**	**$1157,55**	**308,33**

PRODUCCION MAXIMA ESPERADA [3]	**4.5 tn por ha**
Precio de Venta promedio (esperado)	2762,45$ por ton
Valor de la producción	**12431,04$ por ha**
1. Gastos en fertilizantes	**2512,04$ por ha**
2. Gastos en otros insumos y actividades	**1,200 $ por ha****
Semillas (20 kg por ha)	0 $ por ha
Sembradora	800 $ por ha
Herbicida sellador (2 días después de la siembra)	200 $ por ha
Herbicidas	200 $ por ha
Costo de la producción	**3712,04$ por ha**

[2] Los precios son establecidos según la casa de fertilizantes YARA HUAMANTLA al 31/3 por kg de producto: Urea Yara: $6.90, DAP Yara $9.70, Cloruro de Potasio YARA: $7.40; Agroquímica Minab-R $15.10

[3] Las metas de producción están basadas en la calidad de su terreno son **aproximadas** y pueden variar dependiendo de factores externos como la cantidad de lluvia y la ocurrencia de eventos adversos como heladas o plagas. Los actividades agrícolas incluyen: sembradora de precisión (1200 pesos), 2 aplicaciones de herbicidas (400 pesos) y 5 jornales de mano de obra para herbicidas, fertilización y otras labores y cosecha (2000 pesos)

Anova Assumptions

- Assumes $\mathbf{Y}_c \equiv \{Y_{ic}\}_{i=1}^{n}$ is i.i.d. across clusters.
- Assumes $Y_{ic} = \mu + \alpha_c + \epsilon_{ic}$ and that $\{\epsilon_{ic}\}_{i=1}^{n}$ are i.i.d across individuals within a cluster.
- Therefore,

$$\text{Corr}(Y_{ic}, Y_{jc}) = \frac{\sigma_\alpha^2}{\sigma_\alpha^2 + \sigma_\epsilon^2}$$

- Each cluster is about 2.7 km^2 (We sample approx .15 km^2 or about 5%)
- QQ plots indicate non-normality

Return to Individual SA Anova

Comparing Study Farmers to Census

	Mexico		Study sample	
Variable	Mean	Sd	Mean	Sd
Rain-fed agriculture[a]	0.87	0.213	1.000	0.000
Chemical fertilizers[a]	0.74	0.282	0.973	0.160
Organic fertilizers[a]	0.06	0.114	0.390	0.488
Hybrid seeds[a]	0.23	0.265	0.064	0.245
Herbicides[a]	0.34	0.301	0.858	0.348
Insecticides[a]	0.20	0.237	0.116	0.320
Technical assistance[a]	0.03	0.061	0.106	0.308
Maize Yields (ton/ha)	2.73	2.500	1.96	1.118
% pop. working < twice min wages	61.76	19.53	74.9	04.33

Source:INEGI. VIII Agricultural, Livestock and Forestry Census 2007.
[a] Fraction of plots with given characteristic.

▸ Sampling

Return to Drought Slide

RECONOCE SAGARPA 22 MIL HECTÁREAS DE CULTIVO SINIESTRADO POR SEQUÍA EN TLAXCALA

Los más afectados son los cultivos de maíz, trigo, amaranto y cebada

Tlaxcala, Tlax; a 1 de septiembre de 2015: Por Pedro Morales

El delegado en Tlaxcala de Sagarpa, Javier Garza Elizondo, informó que en la entidad existen 22 mil hectáreas de diversos cultivos afectados por la sequía, por lo que se ha notificado al gobierno del estado y a la Secretaría de Fomento Agropecuario.

El funcionario federal dijo que ya se tienen los contactos con las aseguradoras para que los técnicos supervisen los daños en los cultivos de maíz, trigo, amaranto y cebada.

Mientras se reúnen con los productores, de los comisariados ejidales y autoridades de comunidad para realizar una evaluación.

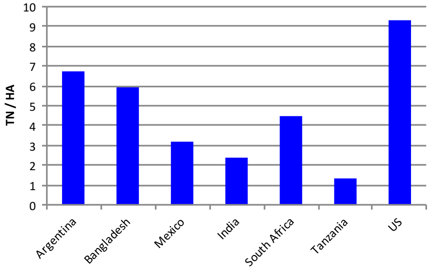
El funcionario federal aseguró que las condiciones están dadas para que se activen los seguros y las empresas, a través del estado, paguen el recurso a los productores de las zonas de Huamantla, Tlaxco, Calpulalpan y Cuapiaxtla.

Garza Elizondo, manifestó que en el caso del cultivo del trigo, se tiene un plan emergente para atender a las afectaciones provocadas por una plaga llamada “la roya” la cual es común es este cultivo, pero en esta ocasión afectó de manera importante los sembradíos del cereal.

Reconoció que aún no se tiene la fecha para que los técnicos de las aseguradoras realicen las supervisiones, pero que a más tardar será en el transcurso de estos días cuando se avance en el diagnóstico de daños.

Return to Introduction

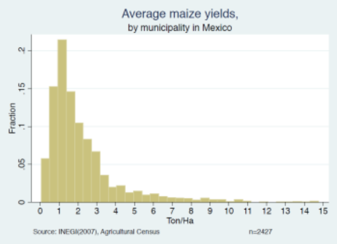
Average Maize Productivity 2008-2012



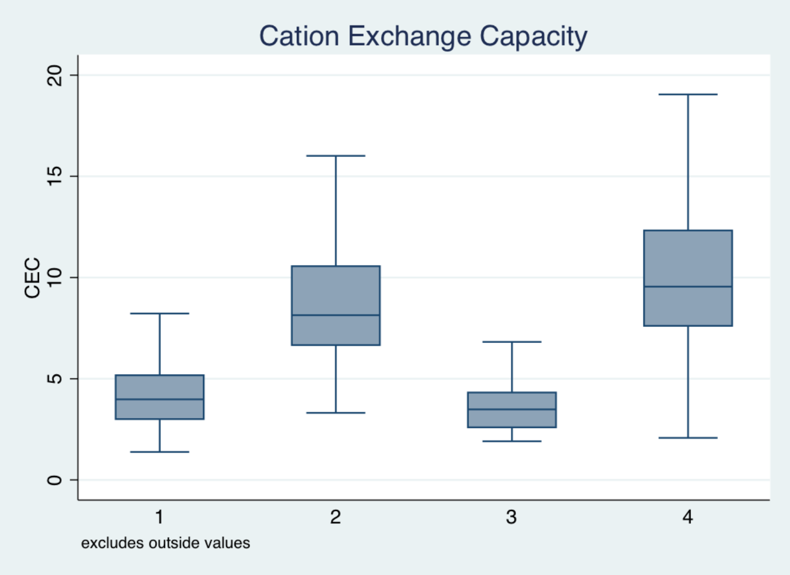
*** Includes irrigated and non irrigated plots**

Source: FAO STATISTICS http://faostat3.fao.org/faostat-gateway/go/to/home/E

Although yields have been improving in Mexico since the 1980's, they are as low as those in much poorer countries, particularly among small land holders.

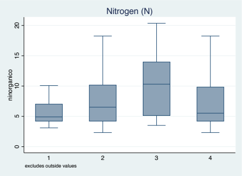


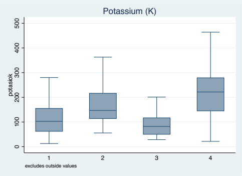
Return to Project Intro

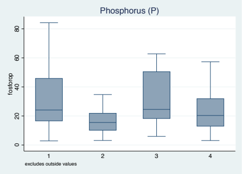


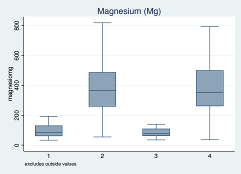
Return to Project Intro

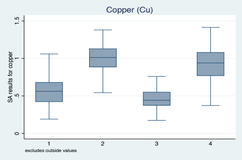
Variation: Macronutrients











Variation in Soil Quality

- Considerable heterogeneity in soil quality.
- ANOVA: Sub-plot i in cluster (localidad) c

$$Y_{ic} = \mu + \alpha_c + \epsilon_{ic}$$

Characteristics	$\frac{\sigma_\alpha^2}{\sigma_\alpha^2 + \sigma_\epsilon^2}$	σ_ϵ	σ_α
Sand (%)	0.426272	8.029361	6.921045
Clay (%)	0.326779	4.692272	3.269121
Slit (%)	0.372773	4.939243	3.807766
Nitrogen (N)	0.112593	6.9907	2.490083
Phosphorus (P)	0.188448	23.32174	11.23826
Potassium (K)	0.220409	102.0539	54.26382
Calcium (Ca)	0.143122	1314.204	537.1018
Magnesium (Mg)	0.404289	98.36461	81.0339
Cation Exchange Capacity, CEC	0.186664	6.881082	3.296493
pH (1:2)	0.392394	0.507053	0.407477

$n = 817$.

- Within variation > Across variation. Anova
- Soil Sampling Scheme (Key to Soil Sampling)
- Project Intro

Attrition

	Attrition 0[a]	Attrition 1[b]
T1	0.0160	-0.0498
	(0.0154)	(0.0345)
T2	0.0002	-0.0763**
	(0.0195)	(0.0327)
T3	-0.0060	-0.1044***
	(0.0164)	(0.0274)
T4	-0.0012	0.0701**
	(0.0172)	(0.0328)
Constant	0.0462***	0.1949***
	(0.0124)	(0.0363)
Observations	981	981
R-squared	0.0012	0.0282
p-value T1=T2=T3=T4	0.6462	0.0001
p-value T1=T2=T3	0.4665	0.2969

[a] Attrited after Randomization but before knowing Treatment Assigment.
[b] Attrited after Treatment Assignment was known.
[c] No mechanized yield measurement available.
Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

▸ Attrition Discussion

Summary Statistics and Balance

Variable	Mean[a]	p-value[b]
Male	0.8269 (0.3795)	0.4673
Age	56.7179 (14.0192)	0.3432
Years as farmer	35.0449 (16.9482)	0.3491
Finished primary school	0.6218 (0.4865)	0.1168
Self-Reported Yield (t/ha)[c]	1.9657 (1.0782)	0.9959
Total ha worked[c]	5.8899 (5.1306)	0.5193
Used sowing precision machinery[c]	0.1154 (0.3205)	0.8989
Number of fertilizations[c]	1.6 (0.5296)	0.994
Total Fertilizer (Kgs./ha)[c]	333.766 (162.4325)	0.8924
Ever done soil analysis	0.1538 (0.3620)	0.8911
Ever fertilized at sowing	0.1677 (0.3748)	0.6281
Ever had AEW	0.1026 (0.3044)	0.7412
Used hybrid seeds[c]	0.0387 (0.1935)	0.228
Total self-reported income[c]	28271.3462 (32968.9182)	0.3955

[a] $n = 817$. S.E.s in parentheses.
[b] p-value for treatment coefficients jointly equal to zero.
[c] In 2014.

▸ Sampling

Individual Nutrient Recommendations: ANOVA

- Soil quality Heterogeneity $\implies$ Recommendation Heterogeneity.
- ANOVA: Sub-plot i in cluster (localidad) c

$$Y_{ic} = \mu + \alpha_c + \epsilon_{ic}$$

Nutrient	$\frac{\sigma_\alpha^2}{\sigma_\alpha^2+\sigma_\epsilon^2}$	σ_ϵ	σ_α
Nitrogen (N)	0.133353	15.55322	6.101006
Phosphorus (P)	0.182385	11.62552	5.490764
Potassium (K)	0.249569	14.47331	8.346572
Magnesium (Mg)	0.250801	0.812977	0.470375

$n = 817$.

- Within variation > Across variation

Recommendations