What Institutions are Appropriate for Generating and Disseminating Local Agricultural Information?

Evidence from Kenya

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Market for creation of knowledge

- Social planner produces if cost less than sum of benefits to agents (Samuelson 1954).
- Non-rivalry implies decentralized equilibrium may be inefficient (Arrow 1959, Romer 1986).
- Markets for information are also subject to asymmetric information problems.
- Extensive literature on what institutions are best suited to generate and disseminate information (R&D grants, patents, etc.)

LINK TO SLIDE ON PROVIDING INFORMATION TO FARMERS

How should information be delivered?

- Traditional agricultural extension
  - Governments spend considerable amounts on agricultural extension
  - Few farmers report contact/limited evidence of impact
  - Serious governance issues
  - Concerns about two-way flow of information
- Agro-dealers
  - Relying on dealer info is problematic (Cole and Fernando, 2013).
- How well will private markets in agricultural info function?
  - Appropriate regulatory or subsidy policy?
  - Public provision?

Local information

- In US, tractors with GPS devices optimally dose inputs (precision farming).
- In developing countries, information provided at high levels of aggregation.
- Some argue that local variation particularly great in SSA and that this inhibited the spread of the Green Revolution (Otsuka & Larson, 2013).
- Potential technological opportunities
  - Mobile soil analysis technologies
  - Spectroscopy techniques (mid-infrared light)
  - Satellite or drone photographs
  - Mobile phones should allow for cheaper delivery of local information
  - Consideration of temporal (weather) conditions

A database of agricultural information

- Personalized or at least localized recommendations based on agricultural information
  - Geographic info: soil types, weather forecasts, altitude, microclimates
  - Farmer info: demographics, education, cognitive scores, risk aversion, previous farming experience
- Software for personalized recommendations based on kriging, machine learning, and other methods
- Farmers linked to database via phone
  - Access to recommendation by providing own information to the database
  - Recommendation uses own and neighboring information optimally.
- Incentive to provide truthful information
- Returns to scale
  - Fixed costs of software development
  - Data generation and usefulness increases in number of farmers
  - Experimentation and improvement over time

Outline of talk

(1) Motivation
(2) Context
(3) Willingness to pay for information
(4) Failures in the market for information
(5) Potential institutions
(6) Future work

Small-scale maize farming in Western Kenya

- Returns to agricultural inputs
  - Duflo, Kremer & Robinson (2008) argue high average returns to small quantities of fertilizer at top-dressing.
  - Suri (2011): Heterogeneity in costs and benefits of hybrid seeds
  - Marenya & Barrett (2009): Heterogeneity in returns to nitrogen fertilizer associated with variation in soil carbon content

Frictions in information exchange among farmers

- Limited relevant information exchange among farmers (Duflo, Kremer, Robinson, 2008, 2011)
  - Little knowledge about neighbors' farming practices
  - No information spillovers of demonstration plots without explicit invitation to observe
- Source of frictions?
  - Relative status concerns
    - 30% of farmers say they would prefer to live in a world in which their yields were better than their neighbors', even if yields were worse in absolute terms, than a world with lower relative, but higher absolute yields.
  - Farmers don't want to seem to be bragging.
  - Farmers don't want to be blamed if other farmers have a bad experience.
  - Trust

Evidence on Impact of Information

- Duflo, Kremer & Robinson (2008, 2011)
  - Demonstration plots on own land affect fertilizer use for several seasons.
  - Impact on informational contacts only when invited to witness demonstration plot
  - No impact on neighbors
- Duflo, Kremer, Robinson & Schilbach (2013)
  - High take-up for fertilizer measuring spoons ("Bluespoon") at small price
  - Impact of Bluespoon on knowledge and fertilizer use
  - Impact of text message reminders on fertilizer coupon redemption
- Casaburi, Kremer, Mullainathan (2013)
  - Text messages to sugar cane farmers with info and reminders increase yields: 8% ITT, 12% ToT.
  - Hotline to sugar cane company and query calls reduce late and non-delivery of fertilizer.

Soil quality in region

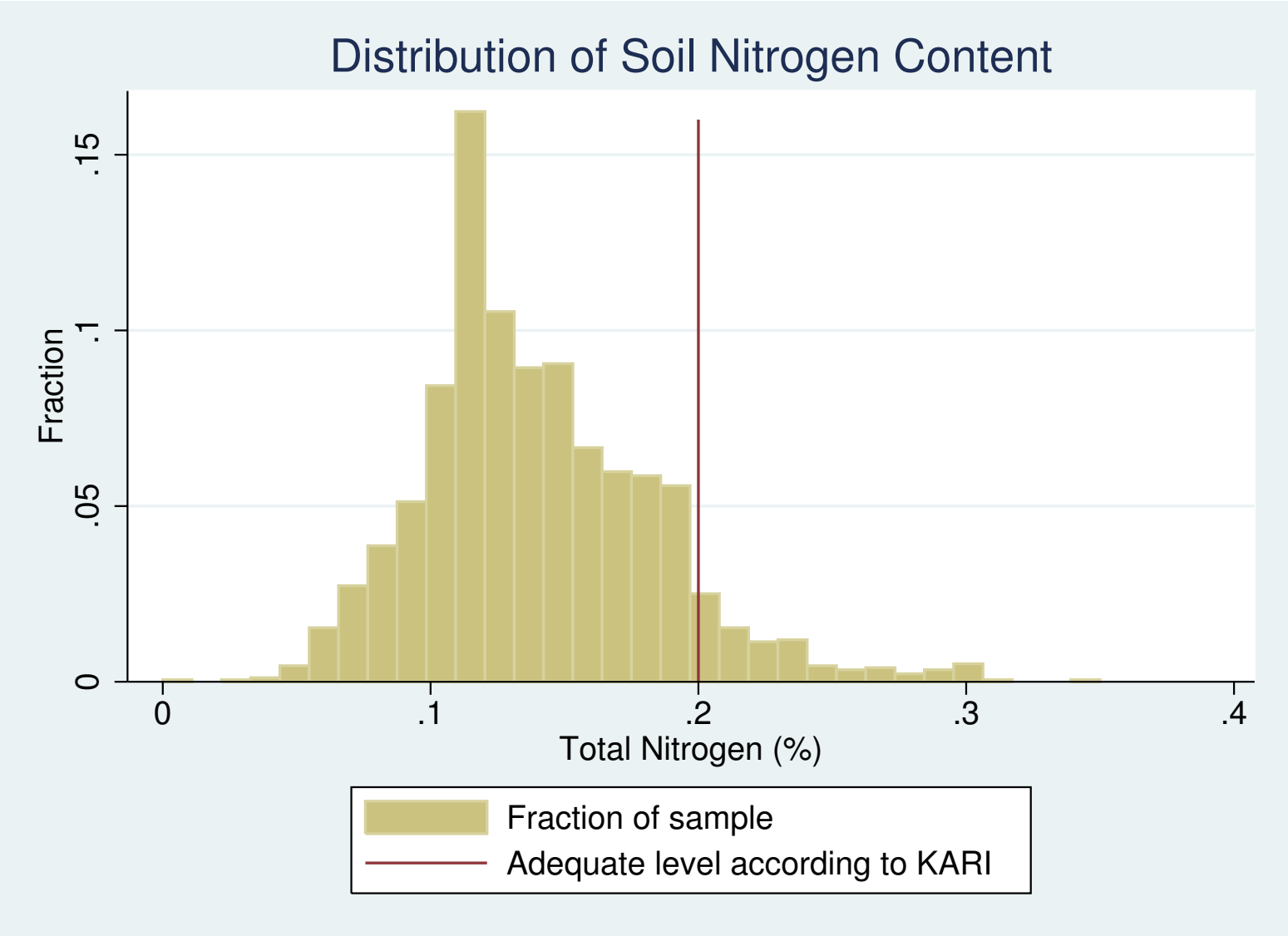
- Previous project: surveys with over 25,000 maize farmers in 2011-2012
  - Sampled parents of students at 186 primary schools in Western Kenya
  - Large meetings with average of 150 farmers per school
  - Detailed home surveys with 5,000 (randomly selected) individuals
- Conducted soil tests in randomly selected subset (1,528 farms)
  - Lab tests performed by KARI in Nairobi (lab costs: $12 per test)
  - Info on micronutrient and macronutrients, pH values, carbon content
  - Input recommendations based on soil characteristics

LINK TO SUMMARY OF KARI RECOMMENDATIONS

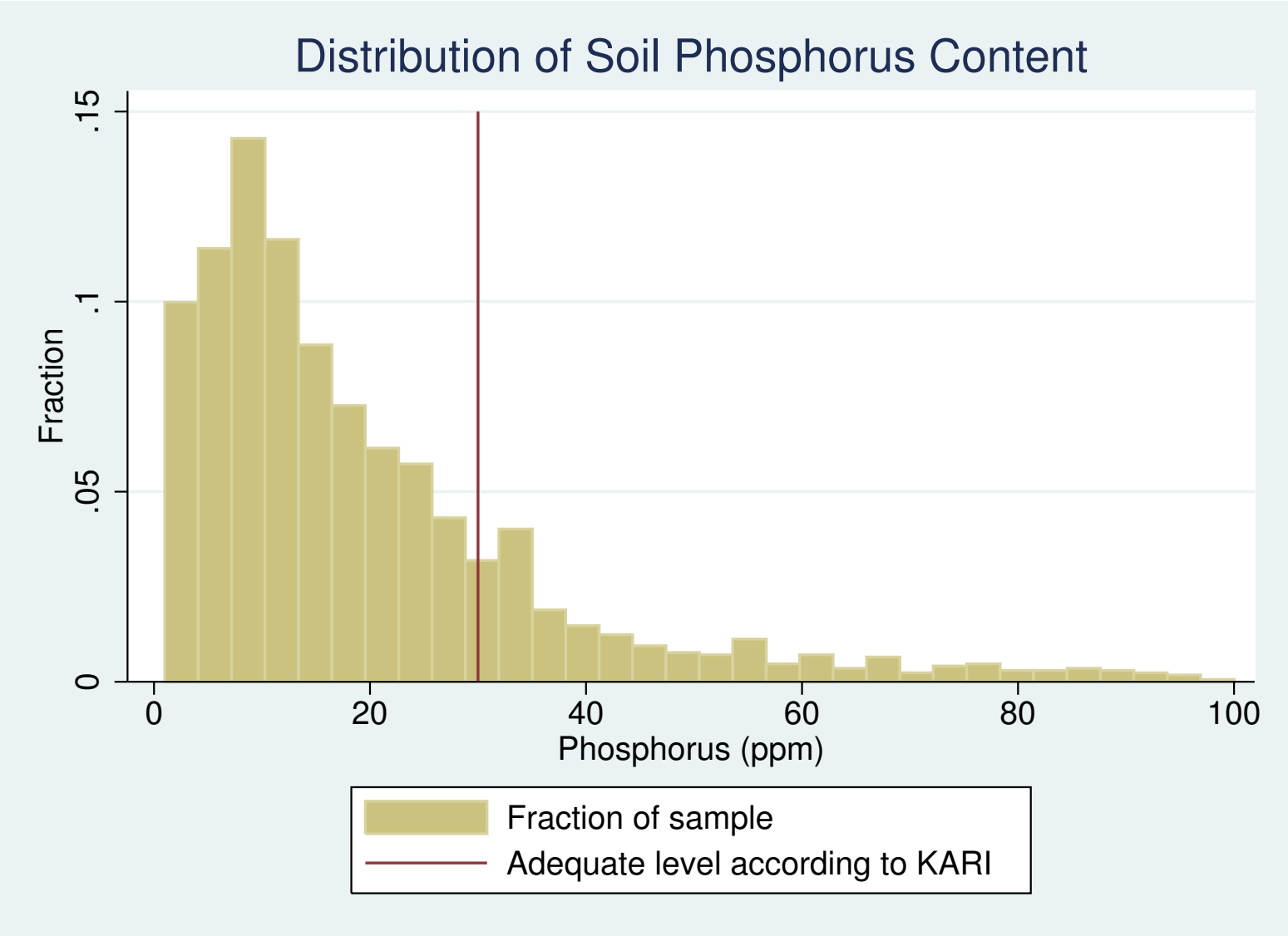
Soil chemistry and fertilizer

- DAP and CAN commonly used types of fertilizer in the area;
  - Calcium ammonium nitrate (CAN) is nitrogen-based fertilizer.
  - Diammonium phosphate (DAP) is a source of phosphorus and nitrogen.
  - Long-term use of DAP makes soil acidic
  - Marenya & Barrett (2009) argue carbon content predicts returns to nitrogen.
- NPK (nitrogen-phosphorus-potassium) and lime as responses to soil acidity
  - Both are little used and largely unknown by farmers in the area.

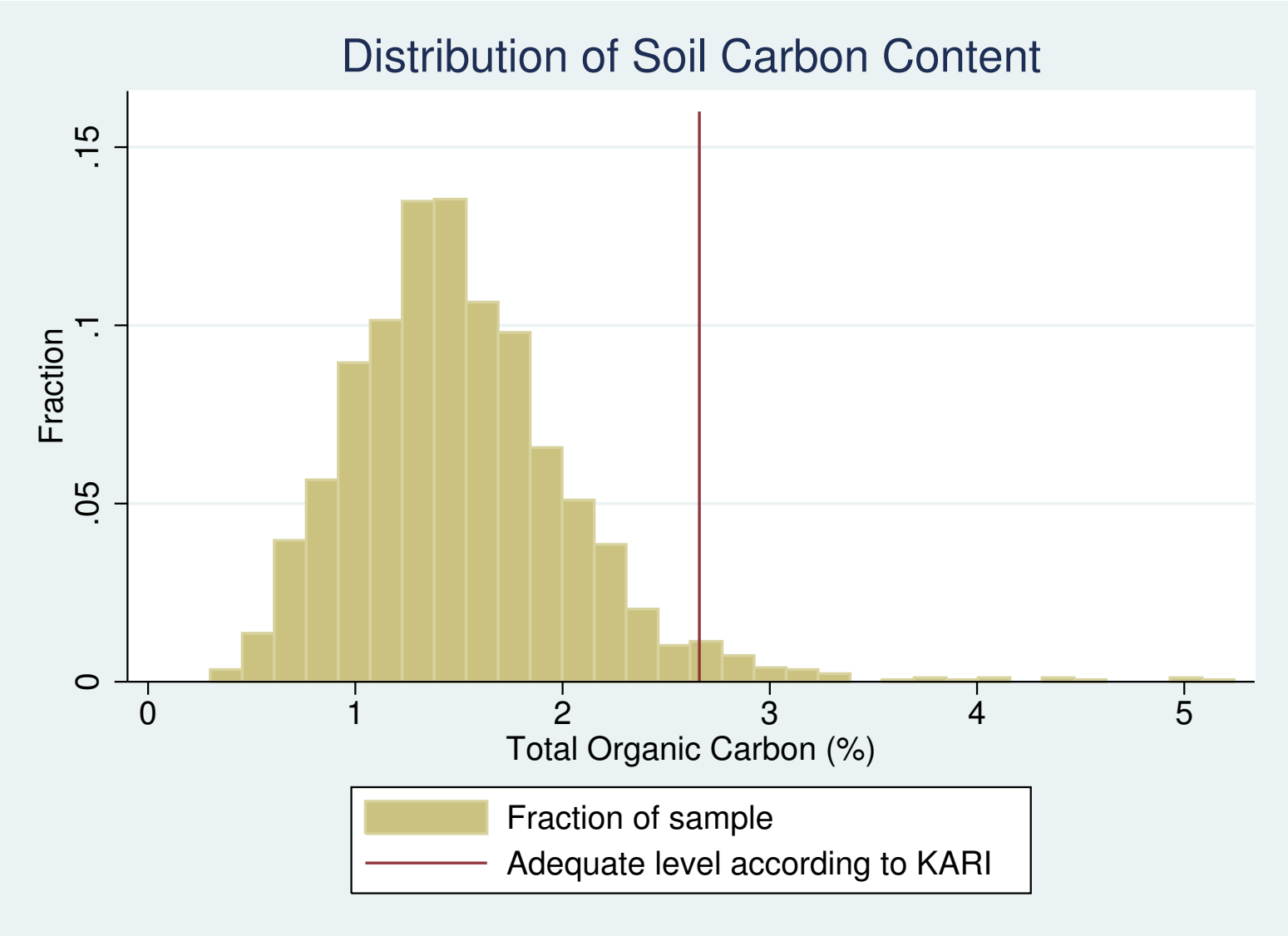
Soil characteristics: nitrogen



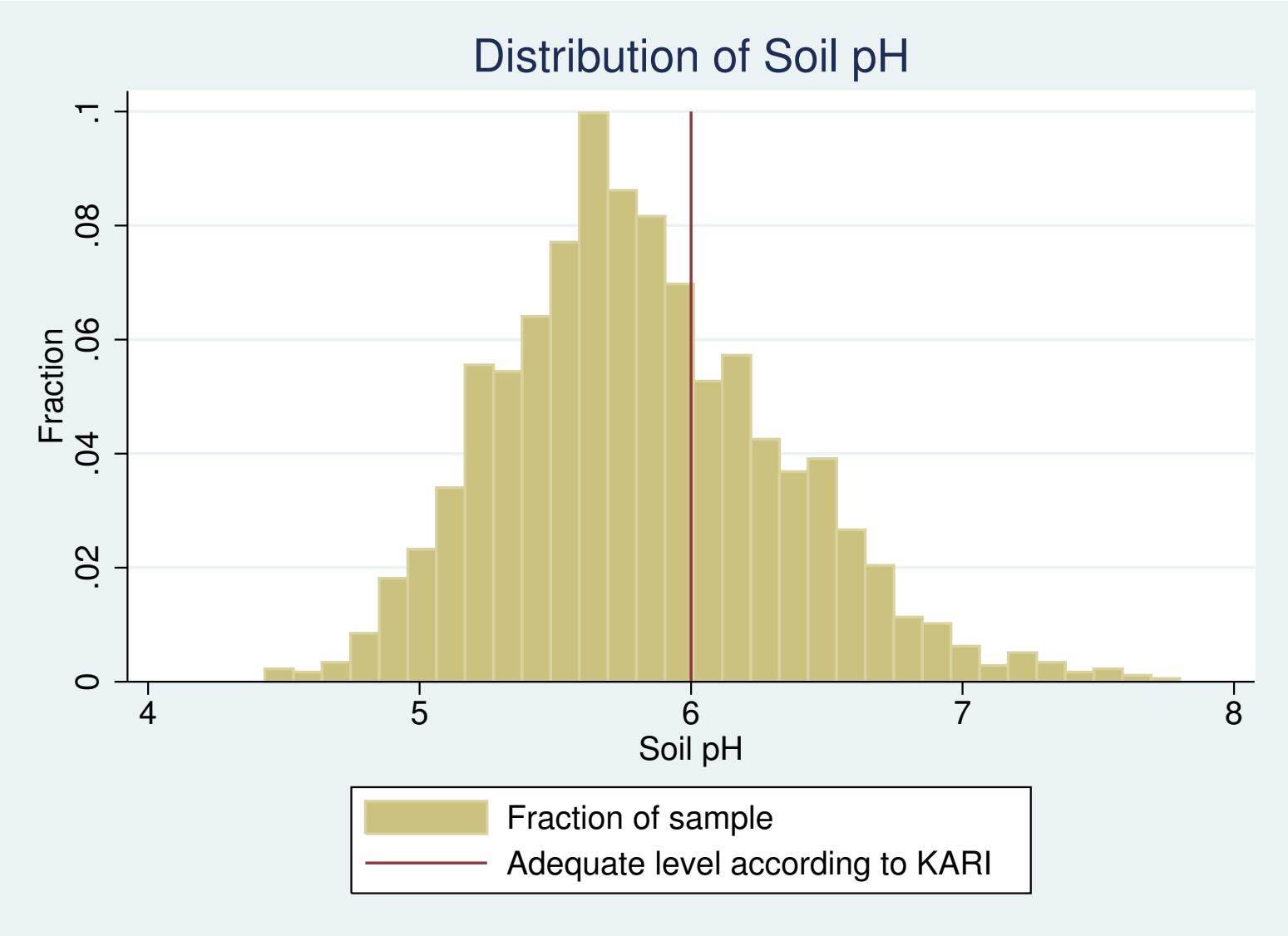
Soil characteristics: phosphorus



Soil characteristics: carbon

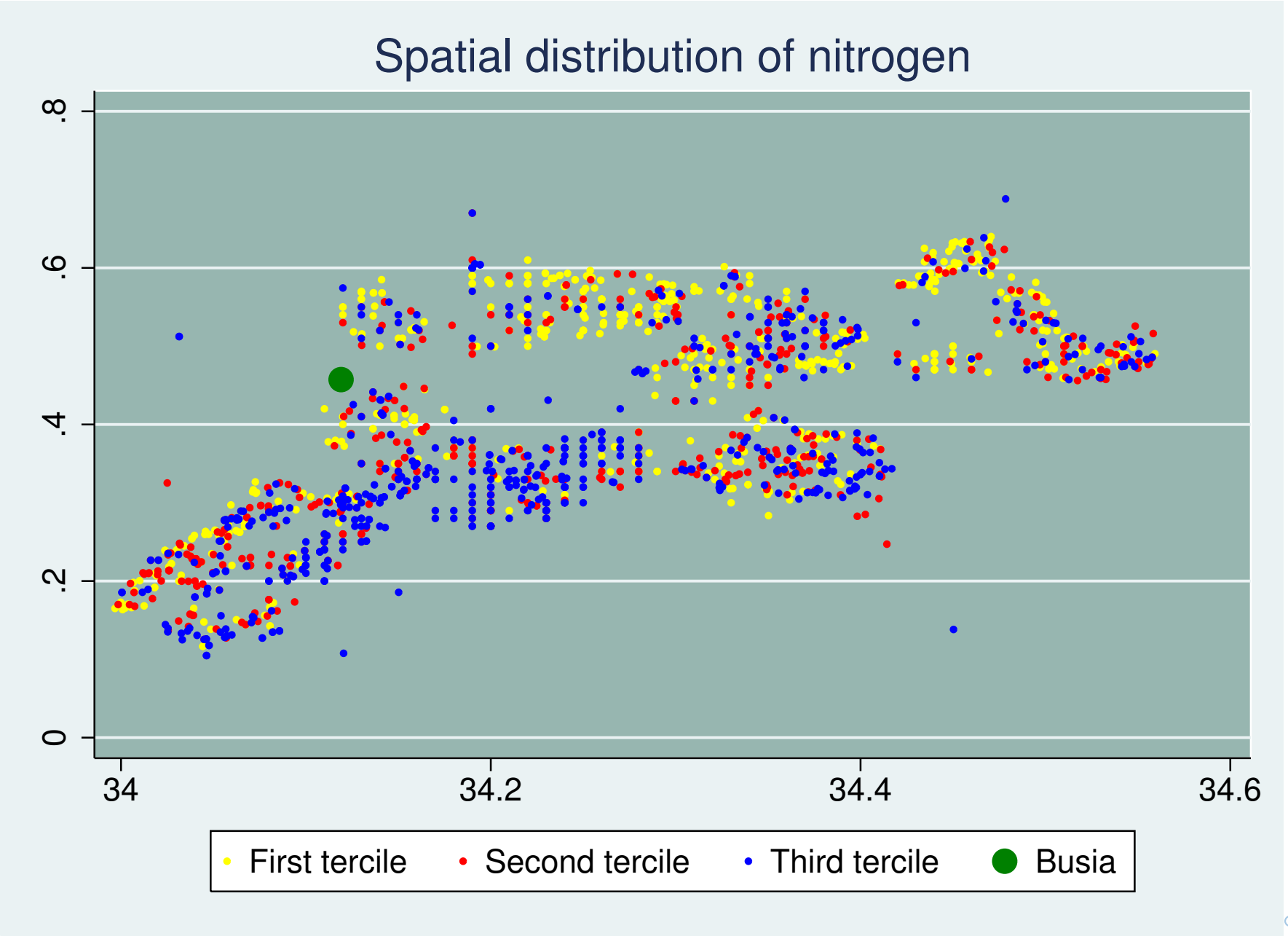


Soil characteristics: pH



Soil characteristics are spatially correlated.

- Visual inspection of maps
- Lower correlation of fertilizer recommendations
- Local means are predictive.
  - ICC of soil characteristics is about 0.25 (cluster: school catchment area).
  - Using local instead of global information for prediction implies tradeoff:
    - Fewer local observations
    - If soil type is spatially correlated, local observations more predictive
  - Using local (school) mean reduces MSE of prediction by about 20% compared to using overall mean.


Spatial distribution of nitrogen
0
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.4
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34
34.2
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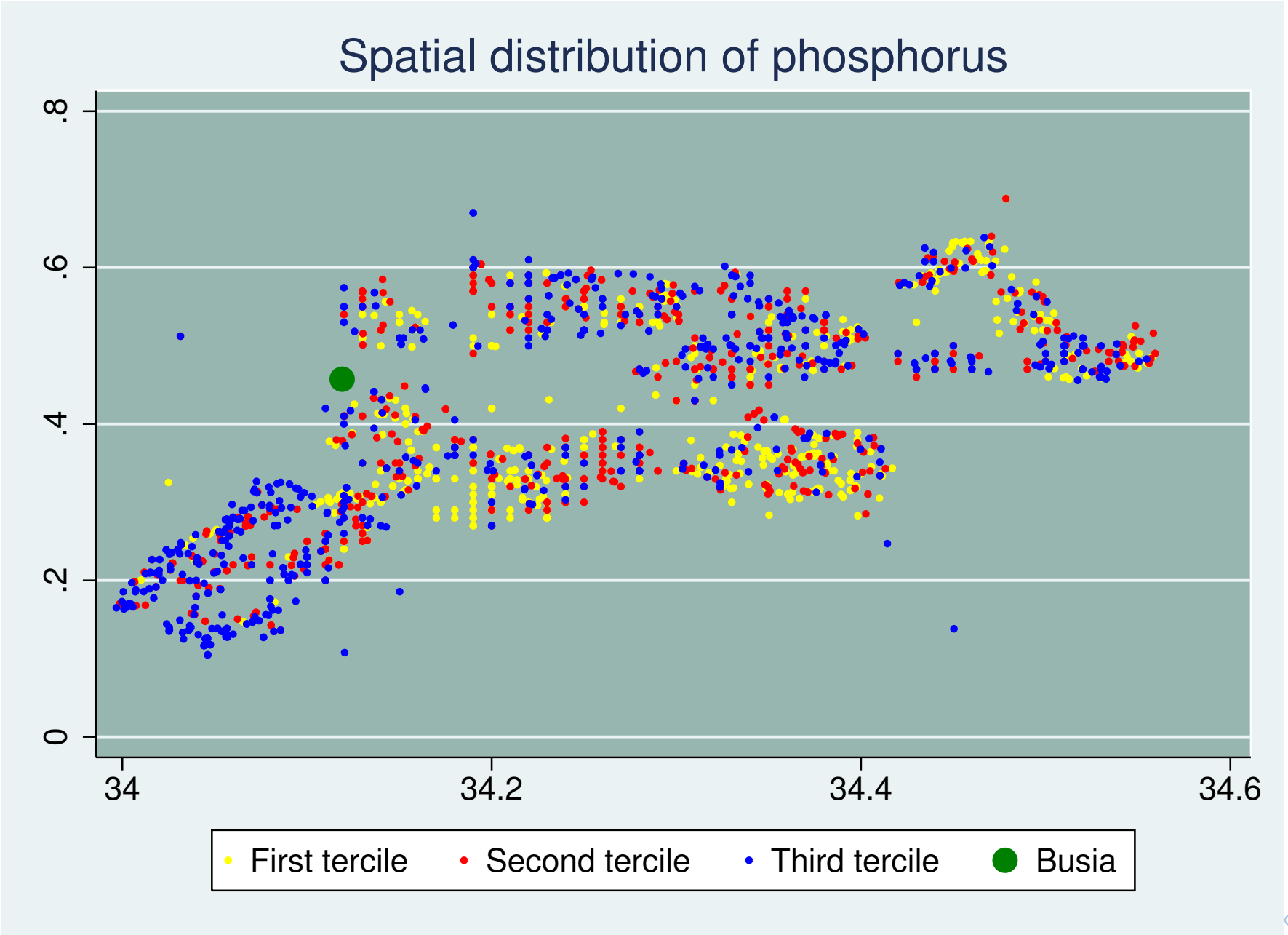
34.6
First tercile
Second tercile
Third tercile
Busia


Spatial distribution of phosphorus
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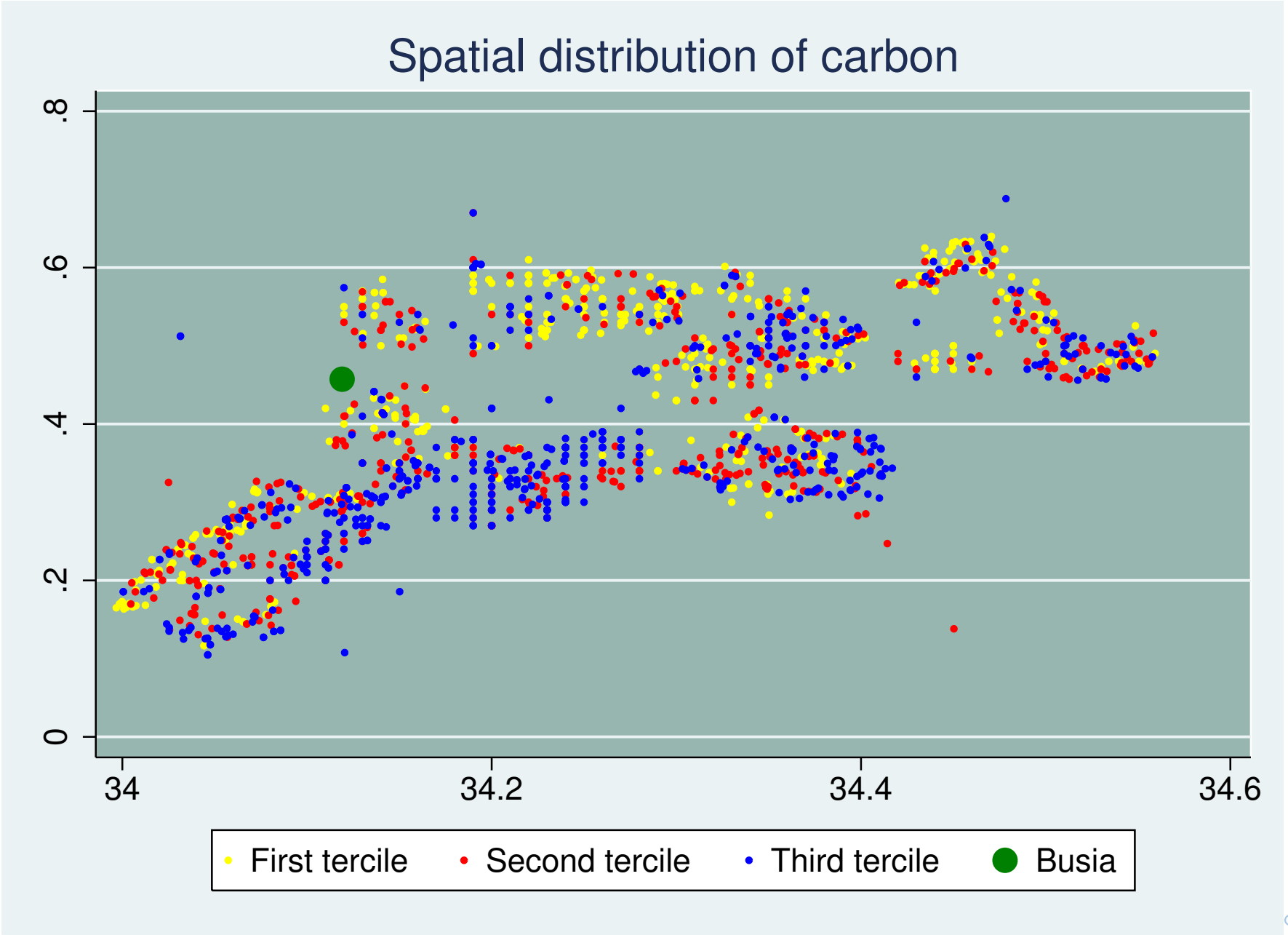
Spatial distribution of carbon
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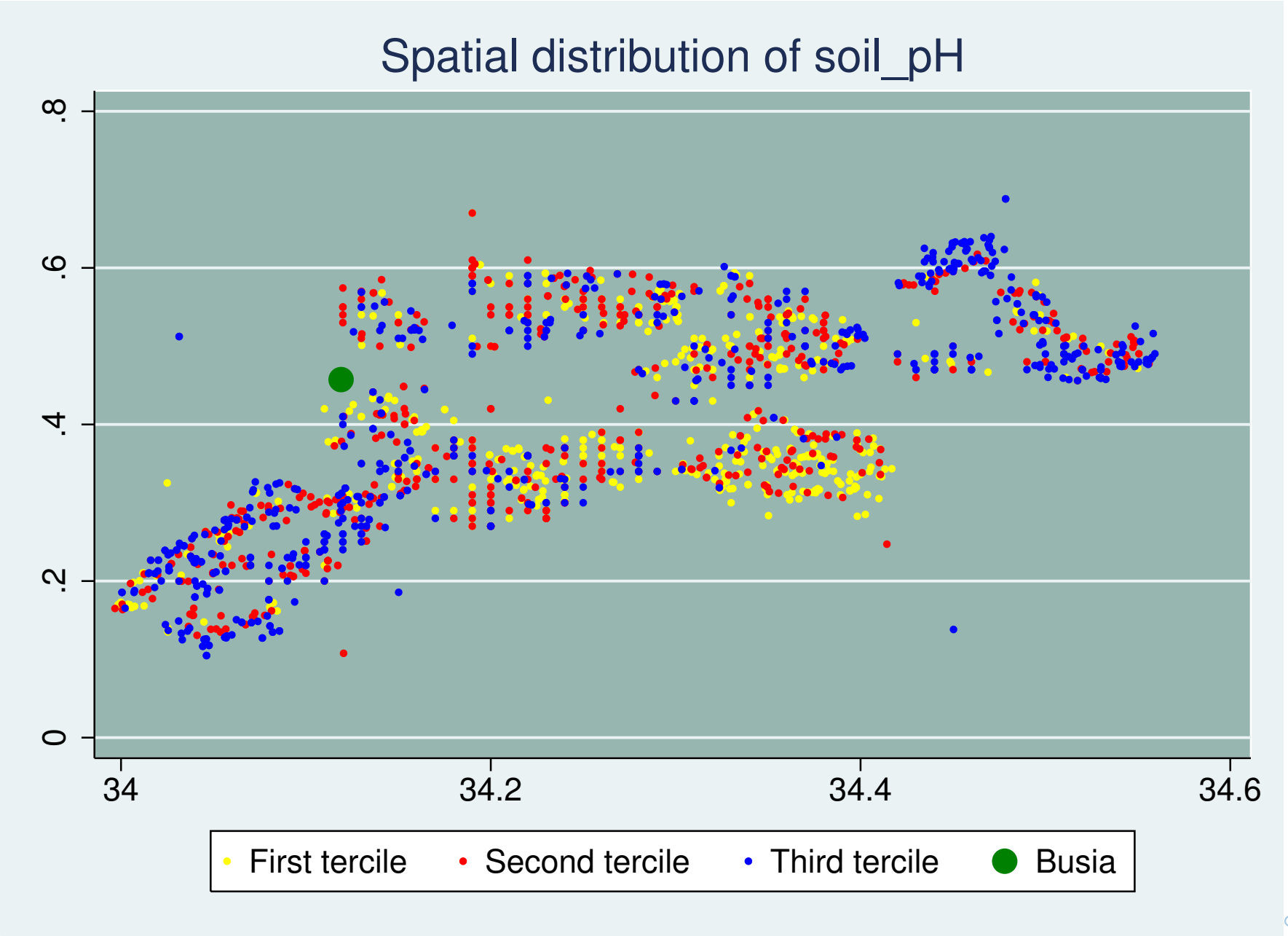
First tercile
Second tercile
Third tercile
Busia


Spatial distribution of soil_pH
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.6
.8
34
34.2
34.4
34.6
First tercile
Second tercile
Third tercile
Busia

Soil characteristics are spatially correlated.

- Visual inspection of maps
- Lower correlation of fertilizer recommendations

LINK TO SPATIAL DISTRIBUTION OF NPK RECOMMENDATIONS

- Local means are predictive.
  - ICC of soil characteristics is about 0.25 (cluster: school catchment area).
  - Using local instead of global information for prediction implies tradeoff:
    - Much fewer local observations
    - If soil type is spatially correlated, local observations more predictive
  - Using local (school) mean reduces MSE of prediction by about 20% compared to using overall mean.
  - Working on more sophisticated spatial prediction methods (kriging)

LINK TO TABLE LINK TO FIGURE

Kriging

- Using local means for prediction does not optimally use spatial information.
- Could use weighted average with inverse of distance as weights instead.
- Sophisticated version: Kriging (Krige, 1951)
  - Geostatistical interpolation method to predict unknown values from data observed at known locations
  - Find optimal weights of own and neighboring information to minimize prediction error.
  - Optimally uses own test result and neighboring test results to give point estimate and standard error.
  - Noise in testing makes neighboring information potentially valuable even for farmers who have own test result.

Costs of soil testing

- At scale, costs mainly depend on number of tests per catchment area and on number of farmers which info is disseminated to.
- With 150 farmers per school (previous project), estimated costs at scale using lab tests are less than $0.50 per farmer whom one soil test info is disseminated to.
  - $0.48 to return info in a meeting
  - Much less if use cell phone

On-farm experimental plots

- Data from 1,030 fertilizer test plots (6m by 6m) with 230 farmers in 2013
- Three types of chemical fertilizer: DAP, CAN, NPK, and comparison plots
- Calculated rates of return using data on inputs, prices and harvest weights

Value of soil information

- Is collecting (additional) tests in local area socially & privately optimal?
- Does aggregate value of soil information exceed cost (Samuelson rule)?
- Is it privately profitable to pay for soil test info?
- Our data is on farmers' willingness to pay for soil tests and test plot info.
  (1) If subjects expect no info transfer, $\sum$ WTP = aggregate social value of info
  (2) If subjects expect to receive some info from others, $\sum$ WTP $<$ social value
  (3) If subjects expect to sell information, possible that $\sum$ WTP $>$ social value
- Existing evidence on information diffusion suggests that information transfer is limited, unpriced. Therefore focus on case (1).
- Will collect more evidence on this issue.

This project

- Three trials to elicit WTP for information based on soil tests and test plots
- Sample: maize farmers in same study area (Western Kenya)
  - 54% used any type of chemical fertilizer over previous season.
  - 91% of these applied the same type of fertilizer (DAP).
  - 15% report having experimented with new fertilizer in the past.
  - Little own formal on-farm experimentation or use of soil tests

Information sheets

- Soil test information ▸ LINK TO SOIL TEST INFO SHEET
  - Fertilizer recommendations based on soil characteristics
    - Diammonium phosphate (DAP)
    - Calcium ammonium nitrate (CAN)
    - Nitrogen-Phosphorus-Potassium (NPK)
  - Application during planting and top-dressing
  - Amounts expressed as total per acre and per planting hole
- Test plot information ▸ LINK TO TEST PLOT INFO SHEET
  - Rates of return for 3 types of fertilizer (percentage along with explanation)
  - Yields with and without fertilizer
  - Amounts of fertilizer applied
  - Local maize and fertilizer prices
  - Caveats: explain that info may not be accurate, soils may be different, etc.

    ▸ LINK TO TEST PLOT INFO CAVEATS

Ways of eliciting WTP for information in three different trials

- Different ways of eliciting willingness to pay for information
  (1) Random Lottery Incentive System (RLIS)
    - Variant of BDM (1964)
  (2) Take-it-or-leave-it (TIOLI)
    - Provided farmers with cash and sold info at different prices
- BDM, TIOLI relationship
  - Berry et al. (2012): BDM understates WTP relative to TIOLI
  - Cole & Fernando (2013): BDM and TIOLI yield similar WTP
- Willingness To Pay vs. Willingness To Accept

LINK TO WTP VS WTA SLIDE

Ways of eliciting WTP for information in three different trials

- Different settings
  (1) Home: Surveys conducted at participants' homes
  (2) Public: Individual surveys conducted at school meetings (facilitates info transfer)
- Explanation of information before eliciting WTP
  (1) Only limited information ex ante given to farmers during first trial
  (2) Much improved explanation in remaining two trials
    - Information sheet templates & explanation before eliciting WTP
    - Explained choice does not affect future participation
    - Shown diagrams with test plot set-up, distances, etc.
    - Played practice round (matchbox)

Eliciting WTP: Random Lottery Incentive System (RLIS)

- Procedure
  - Sequence of choices between monetary amounts or information
  - Elicited WTP for several types of information (WTP modules)
  - Randomize order of modules and order of questions within modules
  - Randomly select one question for which choices are actually implemented
  - WTP := highest amount at which info is preferred over money
  - Maximum amount Ksh 200 in trial 1, increased to Ksh 500 ($5.8) in trial 3.
  - Binning and maximum amount both lead to underestimation of WTP.
- RLIS example (with WTP = Ksh 150):

[W5a.] Which would you prefer: information based on 1 soil test within 10 km or 20 Ksh?	[X] information	[ ] 20 Ksh
[W5b.] Information or 50 Ksh?	[X] Information	[ ] 50 Ksh
[W5c.] Information or 100 Ksh?	[X] Information	[ ] 100 Ksh
[W5d.] Information or 150 Ksh?	[X] Information	[ ] 150 Ksh
[W5e.] Information or 200 Ksh?	[ ] Information	[X] 200 Ksh
[W5f.] Information or 300 Ksh?	[ ] Information	[X] 300 Ksh
[W5g.] Information or 400 Ksh?	[ ] Information	[X] 400 Ksh
[W5h.] Information or 500 Ksh?	[ ] Information	[X] 500 Ksh

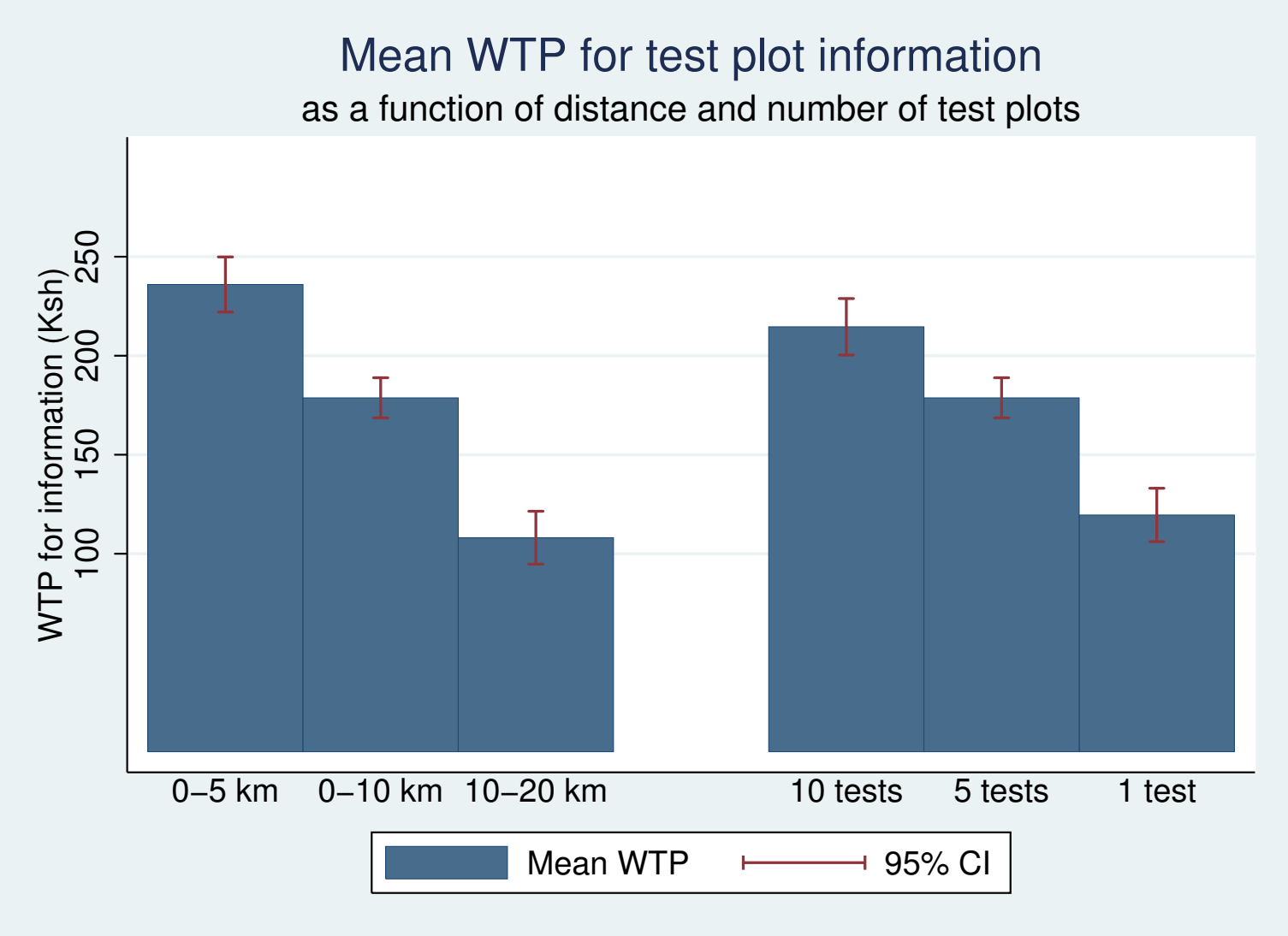
WTP for info in three trials: overview

	Trial 1 (Feb '12)	Trial 2 (Jul '12)	Trial 3 (Jul '13)
Number of farmers	459	251	697
Schools	50	67	34
Method	RLIS	TIOLI	RLIS
Setting	Home	Public	Home
Explanation of info	Limited	Detailed	Detailed
Maximum amount	Ksh 200	Ksh 100	Ksh 200/500
Soil test info	2 nearest plots in sample	1 randomly chosen result from area	1 randomly chosen result from area
Mean WTP	Ksh 156 ($1.8)	Ksh 27 ($0.3)	Ksh 217 ($2.6)
Test plot info	—	—	5 randomly chosen within 10 km
Mean WTP	—	—	Ksh 190 ($2.3)

What affects WTP?

- Evidence from WTP for test plot info in trial 3
  (1) WTP higher for info from closer plots and from higher number of plots
  (2) WTP for info from own plots higher than for info from others' plots
  (3) WTP lower for information from comparison plots only

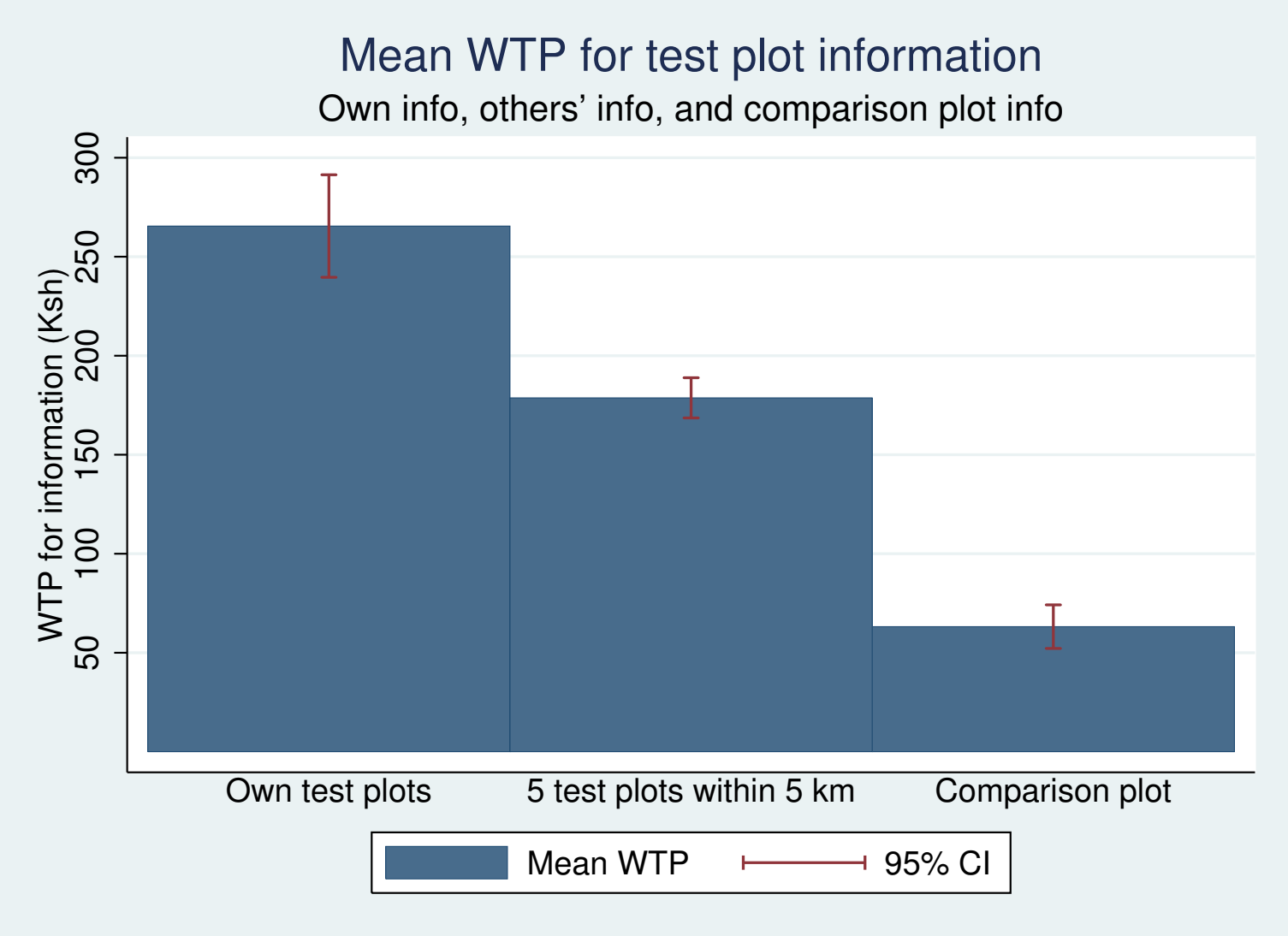
WTP is higher for more precise info.



What affects WTP?

- Evidence from WTP for test plot info in trial 3:
  (1) WTP higher for info from closer plots and from higher number of plots
  (2) WTP for info from own plots higher than for info from others' plots
  (3) WTP lower for information from comparison plots only

Own info, others' info, and comparison plots



WTP for comparison plot information

- 25% of farmers are willing to pay for comparison plot info.
- WTP for comparison plot info correlated with WTP for test plot info

LINK TO SCATTER PLOT OF WTP FOR TEST PLOT INFO VS WTP FOR COMPARISON PLOT INFO

- If comparison plot info is treated as valueless, then two alternative approaches to calculating WTP (for 5 test plot results within 5 km)
  (i) Exclude individuals with positive WTP for comparison plot info
    - Avg. WTP for farmers with 0 WTP for comparison plot info: Ksh 171 ($2.02)
  (ii) Subtract WTP for comparison plot info
    - Avg. WTP once WTP for comparison plot info is subtracted: Ksh 122 ($1.44)
- Average WTP remains high for both approaches.

LINK TO GRAPH WITH WTP FOR DIFFERENT DISTANCES BY WTP FOR COMPARISON PLOT INFO

Other correlates of WTP

- So far: within-individual comparisons
- Now: Across individual comparisons
- Covariates

  (+) Education
  (+) Wealth
  (+) Land size
  (−) Knowledge of other person who got test plots
  (−) Perceived differences of soils in the village
  (−) Past fertilizer use
  (+) Gender (male)

Other correlates of WTP

VARIABLES	(1) WTP	(2) WTP	(3) WTP	(4) WTP	(5) WTP	(6) WTP	(7) WTP	(8) WTP
Years of education	6.22***							5.25***
	(1.779)							(1.899)
Wears shoes		43.43**						26.72
		(15.949)						(15.936)
Land owned			6.10					4.87
			(4.630)					(4.587)
Knows of other IPA plots				-46.25***				-40.89***
				(11.222)				(12.114)
Other land different					-60.10***			-57.34***
					(15.296)			(14.943)
Used fert last season						-44.62**		-49.01**
						(20.573)		(19.638)
Male							42.46***	16.24
							(13.895)	(13.262)
Observations	808	808	808	808	808	808	808	808
R-squared	0.018	0.014	0.003	0.014	0.025	0.015	0.011	0.083
Mean WTP	183.6	183.6	183.6	183.6	183.6	183.6	183.6	183.6

Robust standard errors clustered by school. Dependent variable: WTP for results from 5 test plots within 10 km

Cost of information: Types of costs

(I) Costs per soil test in school catchment area

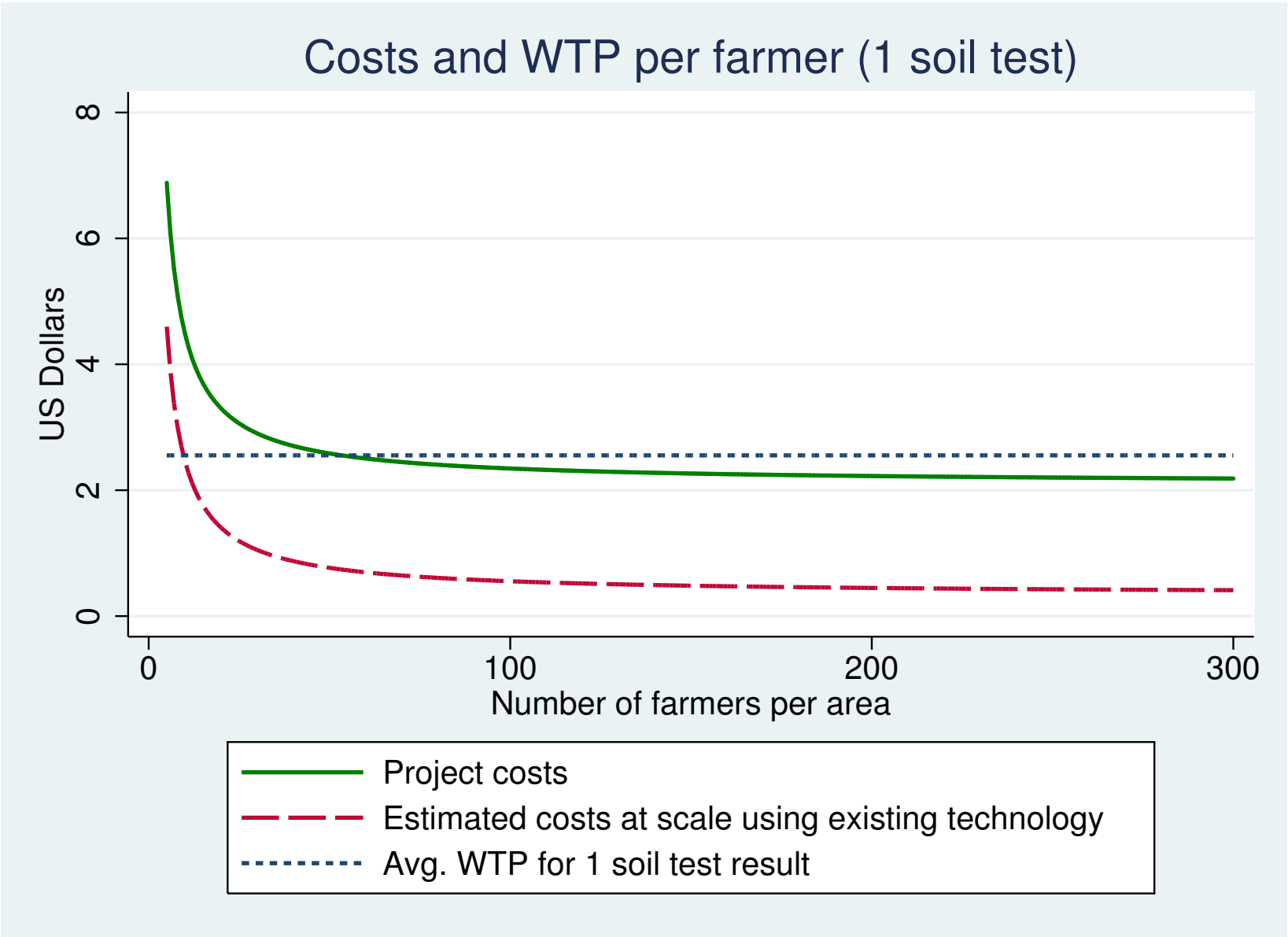
- Staff and farmers' time
- Transportation
- Lab costs and materials

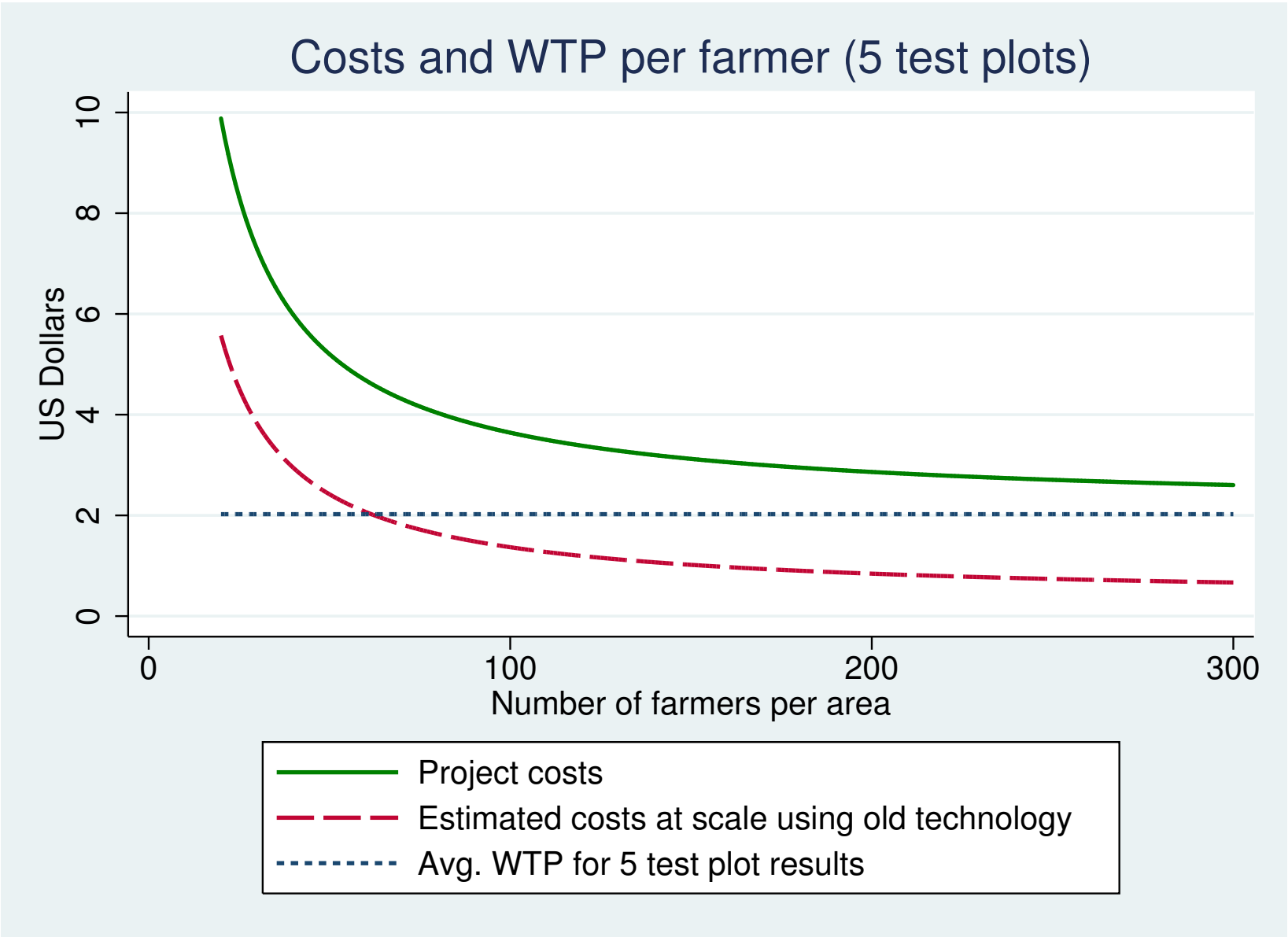
(III) Costs of disseminating information per additional farmer

- Staff and farmers' time
- Transportation
- Home visits vs. large meetings
- Alternatives: mobile phones

Cost calculations today

- Fix number of results per school catchment area
  - 1 soil test
  - 5 test plots
- Costs as a function of number of farmers in school catchment area
  - Actual implementation costs
  - Cheaper methods
    - Generation of info: Cheaper salaries
    - Dissemination of info: Large meetings
  - Costs may come down much further over time.
    - Mobile phones for dissemination: marginal costs of text messages virtually zero
    - Mobile testing units


Costs and WTP per farmer (1 soil test)
US Dollars
0
2
4
6
8
0
100
200
300
Number of farmers per area
Project costs
Estimated costs at scale using existing technology
Avg. WTP for 1 soil test result


Costs and WTP per farmer (5 test plots)
US Dollars
0
2
4
6
8
10
0
100
200
300
Number of farmers per area
Project costs
Estimated costs at scale using old technology
Avg. WTP for 5 test plot results

Are there failures in the market for information?

- Social value of soil tests exceeds costs of providing it.
- Costs of soil tests exceed private benefit for single individual.
- Situation less clear for test plots
- Kriging could should increase predictiveness of information significantly.
  - So far use local info only
  - Want to optimally combine local and overall info.
  - Want to also include other information (weather, demographics, etc.)

Potential institutions

(I) Exchange of information among farmers
(II) Commercial firm/NGO with interactive database, personalization software
(III) Contract farming
(IV) Full public model
(V) Public core, private add ons

Effect of Frictions in Information Exchange on Incentives to Collect Info

- Perfect spatial correlation within villages
- N identical farmers with information valuation v.
- Friction in information transmission
- Fraction of info transmitted is $\alpha \in [0, 1]$.
  - Value of info depreciates by $1 - \alpha$ each time transmitted.
  - Treat as exogenous, not as outcome of asymmetric info game.
- Cost of information generation c
- Bertrand competition when multiple sellers
- Not possible to commit to future pricing

Equilibrium

- Suppose farmer A generates information, then sells it to farmer B.
- If B resells info, value of information is $\alpha^2 v$ to each potential buyer.
- A can therefore sell at price $(\alpha - \alpha^2)v$.
- A invests if $c < v + (N-1)(\alpha - \alpha^2)v$.
- Iff $\alpha < 1/2$, increased transmission raises incentives to generate information.
  - If $\alpha = 0$ or $\alpha = 1$, then private value of info is v.
  - Private value maximized for $\alpha = 1/2$.
  - Social value of information delivered to farmers

$$V^s = \begin{cases} v + (N-1)(1-\alpha)v & \text{if } c < v + (N-1)(\alpha - \alpha^2)v, \\ 0 & \text{otherwise.} \end{cases}$$

  - If v is random variable with low enough support, $\mathbb{E}[V^s]$ is maximized for $\alpha \in (1/2, 1]$.

Interactive database and personalization software

- Even individuals who have own soil tests may value info from others.
  - Noise in any one estimate
  - Local correlation
  - Kriging optimally uses own test result and neighboring test results to give point estimate and standard error.
  - Could also provide other information relevant to agricultural decisions that interacts with own info and demographics, weather, altitude, prices, etc.
- Personalized recommendation
  - Even if $\alpha = 1$, can sell for positive price or require farmers to provide own information.

Public vs private provision

- Netflix model: farmers buy kriging estimate, but in doing so provide own data.
  - There is likely to be an interior optimum on data collection. Not worth it to collect soil test from every farmer.
  - Incorporation of information from other clients provided Netflix with first-mover advantage, barrier to entry.
  - Monopolist will not achieve first best unless can perfectly price discriminate among consumers with heterogenous valuations.

LINK TO GRAPH ON BIMODAL DISTRIBUTION OF WTP

- Potential need for regulation of private markets
  - Suggestive evidence of mistakes: 25% of farmers purchase comparison plot information

Contract farming

- Very relevant in area (sugar cane farming, One Acre Fund, dairy cooperatives)
- If contracted price $<$ MRP, then firm has incentive to promote R&D and extension to boost yields.
- This may be welfare-improving, but since firm only captures partial value of info, first best will not be reached.
- Evidence on impact of mobile extension in sugar cane (Casaburi, Kremer & Mullainathan, 2013)
- Time-limited "patent" restricting competition in purchases for introduction of new cash crops?
  - Contingent on investment in R&D and extension?
  - Allow local farmers to vote to restrict competition?
  - Allow farmer cooperatives to restrict competition?

What type of subsidies and regulation are appropriate?

- Strong prima facie case for public subsidies
- Exclusive government ownership could potentially stifle innovation for incentive and political economy reasons.
- Potential hybrid solutions?
  - Some aspects could be kept public and open access (e.g. weather information, soil test information).
  - Experimentation could be allowed with other elements (e.g. interfaces).

Future work I: WTP

- Questions
  - Will farmers pay for information using their own money (at home)?
  - Will farmers purchase information at shops?
- Address social desirability concerns and test potentially scalable policies
- Different offers at stores (all for sale)
  - Info sheets
  - Combination of info sheets and Bluespoon
  - Starter kits
- Potential resale of information
  - One individual could purchase info and sell to everyone
  - Generate and sell personalized information
  - Need GPS coordinates to personalize info
  - Could map out entire areas in advance
  - Other characteristics (e.g. previous fertilizer use) may improve prediction
- Incentivize subset of farmers to go to shop (e.g. via coupon for free soap)?
- Cell phone collection/distribution of info?

Future work II: Do farmers pay for additional precision equally across various dimensions?

- Above: gradients of WTP for test plot results
  - How does WTP vary with increase in precision of information?
  - Within-person comparisons (several modules per person)
  - Gradients wrt number of tests & distance from nearby landmark
- Will collect gradients of WTP for soil test info wrt different characteristics
  - Number of soil test result
  - Distance from nearby landmark
  - Other dimensions of proximity: "good" farmers, rich farmers, etc.
  - Collection time of soil information
- Test whether farmers pay for additional precision equally across these dimensions

LINK TO DETAILS ON EMPIRICAL TESTS

Future work III: Extent and source of frictions

- Return to farmers and their (ex ante collected) friends and neighbors
  - (i) How well do farmers remember information given to them?
    - Did farmers understand the information correctly?
    - Potential memory problems (especially difficult for illiterate farmers)
  - (ii) Do neighbors and friends know the information that was provided?
    - Does knowledge vary with treatment status of original respondent?
  - (iii) Do neighbors and friends pay for the information that was provided?
    - Does WTP vary with treatment status of original respondent?

Future work IV: predictiveness of local information

- Does local information predict current and future rates of return to different types of fertilizer?
- Predictiveness of different types of information
  - Local soil characteristics
  - Local recommendations
  - Own vs nearby information
- Interact soil characteristics with farmer characteristics (education, age, psychometrics, etc.)?
- Plans forward
  - Explore predictiveness of local information (work in progress)
  - Conduct soil tests & test plots with same farmers (only limited overlap so far)
  - Standard errors of measured soil characteristics and recommendations (test-retest correlation)

Future work V: Impact of info on fertilizer use and agricultural practices

- Provide randomized subset of farmers with information as described above
- Measure impact of information using coupon redemption technique
  - All farmers receive coupons redeemable at local shop
  - Three coupons: each valid for either bar of soap or one type fertilizer
  - Does information provision affect coupon redemption?
  - Reaction to info depends on priors.

Conclusion

- Potentially huge scope for using cheaper data collection and dissemination to improve agriculture
- Interactive database, personalization software
- Fixed costs, then scalable
- How best to design institutions to encourage this?