

# Smallholder maize-nitrogen response rates, soil fertility, and profitability of inorganic fertilizer use on maize in Tanzania

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25 February 2016

2<sup>nd</sup> Annual Agricultural Policy Conference

Serena Hotel, Dar es Salaam

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# GISAIA/Tanzania project

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- Guiding Investments in Sustainable Agricultural Intensification in Africa
  - Collaborative research & policy outreach by MSU & SUA faculty
  - MSU Ag Policy Advisor (Dr. David Nyange) embedded in DPP/MALF
    - Demand-driven policy analysis, capacity building and policy coordination

# GISAIA/Tanzania MSU/SUA

## research & policy outreach themes

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#1) Informing design/implementation of ag input subsidy programs

- *Ex post* evaluation of NAIVS 2008-2014
- *Ex ante* evaluation of Pilot Ag Credit Subsidy Program

#2) Informing policies/investments to strengthen private sector fertilizer/seed supply chains

- Assess effect of NAIVS on supply chains
- Assess alternative policies to lower unit costs of fertilizer in rural areas

# GISAIA/Tanzania MSU/SUA collaborative research

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#3) Assess profitability of smallholder use of inorganic fertilizer use & improved seed in maize/rice production

- Relevance..?

# Background: Motivation for NAIVS

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- 1) Emergency response to improve household food security
  - Higher maize price environment post 2007/08
  - Poor short season harvest; high regional maize prices
- 2) Address long-term underlying problem: smallholder maize/rice yields are lower than potential yields
  - Partly due to limited use of inorganic fertilizer & improved seed

# Background: Goals of NAIVS

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- 1) Improve smallholder fertilizer/seed access
  - physical access to inputs
  - farmer credit constraints, financial risk
  - 3+ years of voucher receipt helps address lack of smallholder experience with fertilizer use
  - Goal: build sustainable smallholder demand for market-priced inputs
- 2) Strengthen private-sector fertilizer/seed supply chains
  - Provide learning experience & sufficient scale of demand → long-term investments
  - Goal: improved input access for more villages

# Motivation for analysis of profitability of fertilizer use on maize

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- GOT goals for NAIVS were largely met
  - Provided experience for many smallholders to apply fertilizer to maize/rice
  - Provided private sector fertilizer/seed supply chain with increased scale of demand → investments
- Post-subsidy era (?)
  - Gains in access / experience not sustainable unless smallholder use of market-priced fertilizer on maize is profitable
  - If not profitable.. What is appropriate GOT role to increase profitability of fertilizer use on maize?

# Key factors that determine profitability of fertilizer use

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- Marginal Value Cost Ratio (MVCR) =  
(Maize-fertilizer response rate \* Maize price/kg)  
/ Fertilizer price/kg  
  
(Value of additional kg maize produced given an additional kg of Nitrogen) / Nitrogen price/kg
- MVCR = 1.0 means “break even / net returns = 0”
- MVCR  $\geq$  2.0 means “net returns are large enough to be profitable, including production (weather) and market (price) uncertainty”



# What estimates of maize-fertilizer response rates exist for Tanzania..?

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- Most are from zonal research station trials
  - Using researchers' best practices, optimal input rates, etc
- On-farm trials often implemented with 'model / advanced' farmers
- What is the average Maize:N response rate among smallholders..?
  - Malawi, Zambia → 50% or less compared with research stations
  - Smallholder fertilizer use in much of Zambia not profitable – response rates low (soil acidity)

# Motivation / Objective of research

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- Assess how smallholder maize-N response rates compare with those from zonal research centers
  - How do they vary by zone, complementary input use, plot characteristics, etc?
- Assess the extent to which fertilizer use on maize profitable under smallholder conditions
  - Using actual market prices for fertilizer & maize, how profitable is fertilizer use on maize?
  - How does profitability vary by zone, input use, etc?

# What factors determine maize-N response rates?

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- Agro-ecological factors (village):
  - Season rainfall, drought shocks
  - Elevation
- Plot-level factors
  - General soil type, structure (clay, loam, sandy)
  - Plot-specific nutrient levels (N,P), soil organic matter (SOM), soil chemistry --> affected by farmer's plot/soil management practices
    - Phosphorous levels affect uptake of Nitrogen
    - Crop rotation, planting legume → residual N in soil
    - Years since fallow, type of fallow → SOM
    - Crop residues on field after harvest → SOM

# What determines maize-N response rates? (2)

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- Fertilizer type, application rate
  - Use type/rate appropriate for soil characteristics
  - Proper application & timing
- Complementary input use:
  - Use of improved OPV or hybrid seed
  - Seeding rate, seed spacing
  - Timely / frequent weeding
  - Intercropping

# Recent evidence on maize-N response rates, soil fertility, profitability

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- Recent soil sampling & zonal center trials in Tanzania (2010 & 2011)
  - Small subset of districts & trials, but with some dispersion
  - Maize-N response rates of 20 (kg/kg), yet lower than in 1993
  - Fertilizer still improves yields and should be profitable in many areas -- in others, no longer
  - Why? Soil tests show SOM, macro & micronutrients quite low
    - Downward cycle of low fertilizer use, less frequent fallows, lower yields, lower SOM..?

# Data

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## □ National Panel Survey

- National Panel Survey, 3 waves (2008/09, 2010/11, 2012/12)
- Representative at national & zonal levels
  - n=1,591 HHs in each of 3 years
- Plot-level data on plot characteristics, plot-level input use & crop production
  - N=2,787 plots in each of 3 years

## □ Geo-spatial data

- Estimates of seasonal rainfall, elevation

## □ Market price data

- maize & fertilizer retail prices by region

# Methods: OLS-FE of smallholder maize yields (plot-level)

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- Community level
  - Estimated main season rainfall (mm)
  - Elevation (m)
- Plot-level explanatory factors
  - N, P, manure & squared terms (kg/ha)
  - 1=improved OPV or hybrid seed used
  - 1=0 to 6 years since plot was fallowed
  - 1=maize intercropped with legume
  - 1=plot soil is sandy (farmer description)
  - 1=plot soil is loam (clay/other is intercept)

# Methods: OLS-FE of smallholder maize yields, plot level (2)

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## □ Household-level

- # of adults age 15-64 per ha
- Maximum adult education in HH
- Ln(value of livestock & farm equipment)

## □ Other

- Dummies for 2010/11, 2012/13



## Results: Maize-N response rates from OLS regression

Zone	Maize-N Response rate*	Marginal Value Cost Ratio (MVCR) of fertilizer use on maize			
		2008/09	2010/11	2012/13	3yr avg
S.Highlands	9.1	1.44	1.46	1.37	1.42
Northern	9.1	1.66	1.93	2.04	1.88
Eastern	6.9	1.41	1.56	1.45	1.47
Central	6.9	1.36	1.49	1.63	1.49
Lake	6.9	1.31	1.46	1.69	1.49
Western	6.9	1.17	1.30	1.60	1.36

\*Average smallholder Maize-Nitrogen response rate (kg maize/kg N)

## Results: Maize-N response rates from OLS regression

	Maize-N Response rate*	Marginal Value Cost Ratio (MVCR) of fertilizer use on maize			
Input use / cropping / soil		2008/09	2010/11	2012/13	3yr avg
used improved seed	9.6	1.73	1.89	1.99	1.87
did not use improved seed	7.7	1.39	1.52	1.60	1.50
plot fallowed within last 6 yrs	10.6	1.91	2.09	2.20	2.07
plot not fallowed w/last 6 yrs	7.6	1.37	1.50	1.58	1.48
sandy soil	4.3	0.78	0.85	0.89	0.84
clay / other soil	6.0	1.08	1.18	1.25	1.17
loam soil	9.3	1.68	1.83	1.93	1.81

## Maize plots by year

	% maize plots fallowed within last 6 years		
Zone	2008/09	2011/12	2012/13
S.Highlands	18.5	10.9	7.0
Northern	17.5	8.8	7.9
Eastern	20.5	14.8	9.5
Central	21.0	5.3	12.1
Lake	12.1	24.8	8.5
Western	23.9	14.0	3.8
Total	18.8	12.7	7.8

# Policy implications

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What is appropriate role for GOT to help improve profitability of fertilizer use on maize?

- ▣ Considering components of profitability of fertilizer... how to:
  - 1) Improve maize-N response rate
  - 2) Improve expected maize sales price received by smallholders (& reduce uncertainty)
  - 3) Lower the unit cost of fertilizer (in Mbeya, Arusha, Kigoma, etc)

# Policy implications:

## Improve maize-N response rates

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### More holistic approach needed by GOT to improve smallholder maize yields

- NAIVS focused on improving physical access and (temporarily) reducing fertilizer cost
- Yet results show that access to fertilizer not sufficient by itself
- For fertilizer use to be profitable.. farmers need to adopt a package of improved inputs & crop/plot management practices
- Need for increased focus on generation & dissemination of updated knowledge & best practices to increase maize-N response

# Policy implications:

## Improve maize-N response rates

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#1) Urgent need to update knowledge of current soil characteristics in order to update fertilizer recommendations (1993)

- Wide-spread soil sampling
  - TAMASA project (2015, 2016) in “maize” districts
  - Tanzania Soil Information System effort
  - Can GOT & others coordinate to update TZ soil map..?
- Facilitate low-cost soil testing
  - Public-Private initiative to make this available to farmer associations willing to share cost..?
- Yara, ETG are doing soil testing in specific areas
  - Yet soil test information is a ‘public good’

# Policy implications:

## Improve maize-N response rate

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### #2) Need for widespread ag research trials

- Update existing fertilizer recommendations for maize, rice, etc (1993)
  - 2010, 2011 effort updated recs in 11 districts
  - National Soil Service project -- 12 districts
- Evaluate new varieties released
- Evaluate agronomic & economic returns to various forms of Integrated Soil Fertility Management (ISFM)
  - Maize/legume intercropping, crop rotations, improved fallows (MSU/SUA working on this in 3 districts)
- To what extent can existing efforts be coordinated and expanded? (requires funding)

# Policy implications:

## Improve maize-N response rates

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### #3a) Urgent need to disseminate appropriate (updated) fertilizer recommendations

- Tanzania's current district-level fertilizer recommendations do not appear to be disseminated
- Agro-dealers & extension agents
  - NAIVS blanket fertilizer recommendations for maize & rice
- Smallholder maize growers
  - Majority in farmers in most zones & in villages targeted by NAIVS do not know what the 'recommended' application rate is
  - Of those who respond, most give the NAIVS blanket recommendations



# Policy implications:

## Improve maize-N response rates

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#3b) How to disseminate new fertilizer recommendations, best practices, etc?

- Extension efforts (government, NGOs, private sector, farmer field schools, etc)
  - Sufficient funding needed for demo plots..??
  - Expand use of existing IT/mobile phone solutions for extension
- Various on-going efforts to create innovative ag extension methods need to be adopted by public extension
  - Main extension source for smallholder maize farmers
  - More funding not sufficient – also need institutional reform to ensure retraining, strong linkage with ag research system, etc

# Policy implications: Improve maize price levels & reduce their uncertainty

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## #4a) Inherent link between trade policy & sustained technology adoption

- Need for predictable, transparent, rules-based trade & marketing policies to reduce risk/uncertainty in farmer/trader/wholesaler maize price expectations
  - → increase demand for commercial fertilizer
  - → increase incentive for private storage
- Recent trade/marketing decisions (not rules-based)
  - Maize export bans; unexpected removal of rice tariff in 2013; unpredictable NFRA buying/selling
  - Undermining 2008-14 effort to build smallholder demand for commercial fertilizer..??

# Policy implications: Improve maize price levels & reduce their uncertainty

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## #4b) Inherent link between maize market policy & sustained technology adoption

- Warehouse Receipt Systems for maize/rice
  - COWABAMAs are a BRN key investment area
  - Could enable farmers access to much better sales prices & credit
  - Not a silver bullet; need proper investment & management

# Policy implications: Reduce fertilizer costs in interior of country

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#5) Invest in improved port infrastructure

#6) Enable Tanzania Fertilizer Regulatory Authority (TFRA) to be an efficient & effective 'one-stop-shop' for fertilizer importers

#7) Reform of central & TAZARA railways management

- maize and fertilizer are bulk products

# Policy implications: Reduce fertilizer costs in interior of country

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## #8) Invest in rural feeder roads

- Ag input voucher provides benefit for recipients & fertilizer supply chain, for one season
- Improved roads decrease input prices & increase sale prices for all businesses in the area, benefits last many years

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