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

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GISAIA/Tanzania project

- 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
#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

#3) Assess profitability of smallholder use of inorganic fertilizer use & improved seed in maize/rice production
  ■ Relevance..?
Background: Motivation for NAIVS

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

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 \(\rightarrow\) long-term investments
   - Goal: improved input access for more villages
Motivation for analysis of profitability of fertilizer use on maize

- 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

- Marginal Value Cost Ratio (MVCR) =
  \[
  \frac{(\text{Maize-fertilizer response rate} \times \text{Maize price/kg})}{\text{Fertilizer price/kg}}
  \]

  (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 >=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..?

- 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

- 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 profitabiity vary by zone, input use, etc?
What factors determine maize-N response rates?

- **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
    - Phosphorus 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)

- 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

- 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

- National Panel Survey
  - 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)

- 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)

- 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

<table>
<thead>
<tr>
<th>Zone</th>
<th>Maize-N Response rate*</th>
<th>Marginal Value Cost Ratio (MVCR) of fertilizer use on maize</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2008/09</td>
</tr>
<tr>
<td>S.Highlands</td>
<td>9.1</td>
<td>1.44</td>
</tr>
<tr>
<td>Northern</td>
<td>9.1</td>
<td>1.66</td>
</tr>
<tr>
<td>Eastern</td>
<td>6.9</td>
<td>1.41</td>
</tr>
<tr>
<td>Central</td>
<td>6.9</td>
<td>1.36</td>
</tr>
<tr>
<td>Lake</td>
<td>6.9</td>
<td>1.31</td>
</tr>
<tr>
<td>Western</td>
<td>6.9</td>
<td>1.17</td>
</tr>
</tbody>
</table>

*Average smallholder Maize-Nitrogen response rate (kg maize/kg N)
### Results: Maize-N response rates from OLS regression

<table>
<thead>
<tr>
<th>Input use / cropping / soil</th>
<th>Maize-N Response rate*</th>
<th>Marginal Value Cost Ratio (MVCR) of fertilizer use on maize</th>
</tr>
</thead>
<tbody>
<tr>
<td>used improved seed</td>
<td>9.6</td>
<td>1.73 1.89 1.99 1.87</td>
</tr>
<tr>
<td>did not use improved seed</td>
<td>7.7</td>
<td>1.39 1.52 1.60 1.50</td>
</tr>
<tr>
<td>plot fallowed within last 6 yrs</td>
<td>10.6</td>
<td>1.91 2.09 2.20 2.07</td>
</tr>
<tr>
<td>plot not fallowed w/last 6 yrs</td>
<td>7.6</td>
<td>1.37 1.50 1.58 1.48</td>
</tr>
<tr>
<td>sandy soil</td>
<td>4.3</td>
<td>0.78 0.85 0.89 0.84</td>
</tr>
<tr>
<td>clay / other soil</td>
<td>6.0</td>
<td>1.08 1.18 1.25 1.17</td>
</tr>
<tr>
<td>loam soil</td>
<td>9.3</td>
<td>1.68 1.83 1.93 1.81</td>
</tr>
</tbody>
</table>
### Maize plots by year

<table>
<thead>
<tr>
<th>Zone</th>
<th>2008/09</th>
<th>2011/12</th>
<th>2012/13</th>
</tr>
</thead>
<tbody>
<tr>
<td>S.Highlands</td>
<td>18.5</td>
<td>10.9</td>
<td>7.0</td>
</tr>
<tr>
<td>Northern</td>
<td>17.5</td>
<td>8.8</td>
<td>7.9</td>
</tr>
<tr>
<td>Eastern</td>
<td>20.5</td>
<td>14.8</td>
<td>9.5</td>
</tr>
<tr>
<td>Central</td>
<td>21.0</td>
<td>5.3</td>
<td>12.1</td>
</tr>
<tr>
<td>Lake</td>
<td>12.1</td>
<td>24.8</td>
<td>8.5</td>
</tr>
<tr>
<td>Western</td>
<td>23.9</td>
<td>14.0</td>
<td>3.8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>18.8</td>
<td>12.7</td>
<td>7.8</td>
</tr>
</tbody>
</table>
Policy implications

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

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

#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 

#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

#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

#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

#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

#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

#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

#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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