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
  - Funded by BMGF
  - Collaborative research between MSU or Purdue & local universities in 7 African countries

- GISAIA/Tanzania
  - Collaborative research & policy outreach by MSU & SUA faculty
  - MSU Ag Policy Advisor (Dr. David Nyange) embedded in DPP/MAFC
    - Demand-driven policy analysis, capacity building and policy coordination
**GISAIA/Tanzania MSU/SUA collaborative research themes**

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

- *Ex post* evaluation of NAIVS 2008-2014
- *Ex ante* evaluation of 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
#3) Assess profitability of inorganic fertilizer use on maize/rice among smallholders

- Importance / relevance ??
  - NAIVS designed to provide smallholders & fertilizer supply chain with multi-year experiment
  - Smallholders’ returns to fertilizer must be > additional cost (including margin for risk) or NAIVS will not stimulate long-term increase in smallholder commercial fertilizer use
Key factors that determine profitability of fertilizer use

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

(Value of additional kg maize produced given an additional kg of Nitrogen) / N price/kg

- MVCR > 1 means “net returns > 0”
- MVCR >=2 means “net returns are large enough to be profitable, including risk”
Sources of estimates of maize-fertilizer response rates

- Most maize-fertilizer response estimates from research station trials
  - Best practices, optimal input rates, etc
- On-farm trials often implemented with ‘model / advanced’ farmers
- What is the average smallholder Maize:N response rate..?
  - Malawi, Zambia → 50% or less compared with research stations
  - Smallholder fertilizer use in much of Zambia not profitable – response rates low (soil acidity)
Determinants of maize-N response rates

- Agro-ecological factors (village):
  - Season rainfall (rainfed production)
  - Drought shocks
  - Elevation

- Plot-level factors
  - General soil type, characteristics
  - Plot-specific nutrient levels, soil organic matter, soil chemistry --> plot/soil management practices
  - Years since fallow, type of fallow
  - Crop rotation, planting legume
  - Biomass left on field after harvest (forage?), etc
Determinants of maize-N response rates (2)

- Fertilizer type, dosage, application
  - Type and dosage optimal for soil characteristics
  - Proper application & timing

- Complementary input use:
  - Use of improved OPV or hybrid seed
  - Seeding rate, seed spacing
  - Timely / frequent weeding
  - Intercropping
Background: 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 response rates lower than in 1993; many areas now need more fertilizer
  - Fertilizer still improves yields and is profitable in some areas -- in others, no longer
  - Why? Tests show soil organic matter (SOM), macro & micronutrients quite low
    - Downward cycle of low fertilizer use, less frequent fallows, lower yields, lower SOM..?
Background: Design of Accelerated Food Security Program (AFSP)

1) NAIVS = targeted fertilizer/seed voucher subsidy program to address some key constraints
   - Improve smallholder physical access to inputs
   - Subsidy reduces farmer credit constraints, risk
   - 3+ years of voucher receipt helps address lack of smallholder experience with fertilizer use

2) Included technical training of agro-dealers
   - Fertilizer/seed types, rates; business mngt
   - Yet blanket NAIVS-specific recommendations were taught, despite district-level recommendations (1993)
3) Improve extension

- $30 million for extension (ASDP) extension
- W. Bank provided $US 30mil for ISFM research, extension .. Was it used..??
Motivation / Objective: Test key assumptions of GOT strategy

- We test assumption that fertilizer use on maize is profitable under smallholder conditions
  - What are average maize-N response rates?
  - How do they vary by zone, complementary input use, plot characteristics, etc?
  - How profitable is fertilizer on maize?
  - GOT main emphasis to improve access, reduce credit constraint & providing experience.. Is that sufficient to build sustainable demand for fertilizer at commercial prices?
Data

- **National Panel Survey**
  - Representative at national & zonal levels
    - n=1,591 HHs in each of 3 years, n=310 HHs 2 years
  - Plot-level data on plot characteristics, plot-level input use & crop production
    - N=2,787 plots in each of 3 years; n=511 plots 2 years

- **Geo-spatial data**
  - Estimates of seasonal rainfall, elevation
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
  - Years since fallow (or 1=plot was fallowed)
  - 1=maize intercropped with legume
  - 1=maize intercropped with non-legume
  - 1=plot soil is sandy
  - 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
<table>
<thead>
<tr>
<th>Zone</th>
<th>2008/09</th>
<th>2010/11</th>
<th>2012/13</th>
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<tbody>
<tr>
<td></td>
<td>% report fallow</td>
<td>Yrs since fallow (median)</td>
<td>% mono-crop</td>
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<tr>
<td>Southwest</td>
<td>10.1</td>
<td>18.8</td>
<td>43.6</td>
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<td>North</td>
<td>7.4</td>
<td>21.0</td>
<td>19.0</td>
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<td>6.3</td>
<td>15.0</td>
<td>30.3</td>
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<tr>
<td>Western</td>
<td>7.1</td>
<td>16.0</td>
<td>15.4</td>
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<tr>
<td>Total</td>
<td>9.6</td>
<td>17.0</td>
<td>33.3</td>
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<tr>
<td>Southwest</td>
<td>8.0</td>
<td>18.5</td>
<td>44.2</td>
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<tr>
<td>North</td>
<td>5.3</td>
<td>23.5</td>
<td>23.6</td>
</tr>
<tr>
<td>Eastern</td>
<td>9.3</td>
<td>16.6</td>
<td>31.8</td>
</tr>
<tr>
<td>Western</td>
<td>2.3</td>
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<tr>
<td>Total</td>
<td>7.8</td>
<td>17.5</td>
<td>37.8</td>
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<tr>
<td>Southwest</td>
<td>2.1</td>
<td>23.0</td>
<td>41.1</td>
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<tr>
<td>North</td>
<td>1.5</td>
<td>26.0</td>
<td>26.0</td>
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<tr>
<td>Eastern</td>
<td>1.5</td>
<td>18.5</td>
<td>33.9</td>
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<tr>
<td>Western</td>
<td>2.7</td>
<td>23.0</td>
<td>35.4</td>
</tr>
<tr>
<td>Total</td>
<td>2.6</td>
<td>21.0</td>
<td>36.4</td>
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<tr>
<td>Maize-N response rates (kg maize/kg N)</td>
<td>S.West</td>
<td>MVCR</td>
<td>MVCR</td>
</tr>
<tr>
<td>----------------------------------------</td>
<td>--------</td>
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<td>maize-N response rate</td>
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<td></td>
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<td>1.47</td>
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<td>Eastern</td>
<td>7.2</td>
<td>1.05</td>
<td>1.32</td>
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<td>1.52</td>
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<tr>
<td>West</td>
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<td>1.27</td>
<td>1.49</td>
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<tr>
<td>southwest &amp; northern highlands</td>
<td>9.6</td>
<td>1.72</td>
<td>1.48</td>
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<td>medium/lower potential zones</td>
<td>7.2</td>
<td>1.23</td>
<td>1.44</td>
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<td>did not use improved OPV/hybrid</td>
<td>8.2</td>
<td>1.43</td>
<td>1.45</td>
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<td>used improved OPV or hybrid</td>
<td>9.2</td>
<td>1.61</td>
<td>1.63</td>
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<td>plot fallowed within 1-6 yrs</td>
<td>10.2</td>
<td>1.78</td>
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<td>9.9</td>
<td>1.73</td>
<td>1.75</td>
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<td>plot fallowed within 13-18 yrs</td>
<td>9.2</td>
<td>1.61</td>
<td>1.63</td>
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<td>plot fallowed within 19-25 yrs</td>
<td>7.7</td>
<td>1.34</td>
<td>1.36</td>
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<td>plot fallowed within 26+ yrs</td>
<td>6.8</td>
<td>1.19</td>
<td>1.20</td>
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<td>sandy soil</td>
<td>3.6</td>
<td>0.63</td>
<td>0.64</td>
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<tr>
<td>clay / other soil</td>
<td>6.0</td>
<td>1.05</td>
<td>1.06</td>
</tr>
<tr>
<td>loam soil</td>
<td>10.2</td>
<td>1.78</td>
<td>1.81</td>
</tr>
</tbody>
</table>
Policy implications

#1) Urgent need to update knowledge of current soil characteristics and fertilizer recommendations

- Wide-spread soil sampling
- Update fertilizer recommendations by crop, zone
- Update improved variety assemelements (given new releases) together with fertilizer (or not)
- Discuss results with fertilizer importers & distributors, then communicate new recs to extensionists & agro-dealers --
- Run trials with ‘researcher’ and ‘typical farmer’ input levels & management
Policy implications (2)

#2) Is there sufficient focus from GOT on research/extension (knowledge generation & transfer) to improve smallholder maize yields..?? More holistic approach needed..?

- # of extension workers increased.. But do they have the proper recommendations..?
- Substantial donor funding for ISFM extension efforts available.. Was it used..?
- Fallowing rates are very low, SOM is low
- Agro-dealer training used blanket recs
- Many farmers are using fertilizer but not improved varieties (why?)
Policy implications (3)

#3) There is a vital link between output market policy & sustained technology adoption

- Need for predictable, transparent, **rules-based** trade & marketing policies to **reduce** risk/uncertainty in farmer/trader/etc maize price expectations → increase demand for commercial fertilizer

- Recent trade/marketing decisions (not rules-based) are undermining 2008-14 effort to build demand for commercial fertilizer
  - Maize export bans (several times); unpredictable NFRA buying price / time; unexpected rice tariff removal
Research gaps

- More analysis of existing data
  - Analysis of how profitability varies within a zone given market access differentials

- Need to add many more ISFM measures to plot-level survey work
  - Plot-level soil testing
  - Recall data on plot use between survey waves (types of fallows, cropping, etc)
  - Plot preparation methods
  - Use of improved fallows, simultaneous fallows..?
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