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# Guiding Investments in Sustainable Agricultural Intensification in Africa (GISAIA/Tanzania)

## Policy Research Brief #2 -- December 2016

### The profitability of inorganic fertilizer use in smallholder maize production in Tanzania: Implications for alternative and complementary strategies to improve smallholder maize productivity

David Mather, Isaac Minde, Betty Waized, Daniel Ndyetabula, and Anna Temu  
Michigan State University & Sokoine University of Agriculture

We use plot-level data from the National Panel Survey to estimate maize-N response rates and the profitability of inorganic fertilizer use. We find that average smallholder maize-N response rates are not even 50% of those from zonal center trials, implying that there is a considerable gap between actual and potential returns from fertilizer use. Fertilizer use on maize is only marginally profitable for farmers with average response rates, even in higher potential zones. Farmers who used improved maize seed, fallowed a plot more recently and/or received an extension visit have higher response rates and more profitable fertilizer use, yet fallowing is infrequent and extension does not reach most farmers. These results strongly suggest that farmers need more than just improved access to fertilizer, they need to adopt a package of improved inputs and crop/plot management practices. Thus, regardless of whether NAIVS continues or not, these results imply that government must consider complementary strategies (beyond NAIVS) to help increase the profitability of fertilizer use on maize. Otherwise, it is doubtful if the gains in farmer use of fertilizer on maize under NAIVS will be sustained when an increasing number of farmers must pay the market price for fertilizer (as NAIVS continues to scale down or stops). We provide a number of strategies that can help improve the profitability of fertilizer use on maize by (i) improving smallholders' knowledge of fertilizer use and plot management practices that can enable them to get the most out of fertilizer applied to maize; (ii) improving maize price levels and their predictability; and (iii) reducing fertilizer costs from the port to rural villages.

#### INTRODUCTION

As has been recognized by both African governments and donors in recent years, one of the keys to reducing rural poverty and improving the nutritional status of rural households in Tanzania will be to achieve wide-spread improvements in food crop productivity among smallholder farmers. Prior to the international food price crisis of 2007/08, maize yields in Tanzania remained low, averaging between 800-900 tons/ha nation-wide, despite Tanzania's favorable agro-ecological potential. While there are a range of factors which determine maize yields, an obvious constraint in Tanzania is the fact that as of 2007/08, only 14.3% of smallholder maize producers applied inorganic fertilizer to maize, though this varied considerably by agro-ecological zone from a low of 0.9% in the Lake zone to 21% in the Southern highlands (Mather *et al*, 2016a). In addition, only 23% of smallholder maize growers used improved maize seed (either OPVs or hybrids) in 2007/08.

In 2008/09, the Government of Tanzania (GoT), with financial support from the World Bank, began to rapidly scale up the National Agricultural Input Voucher Scheme (NAIVS) in order to address the longer-term challenge of improving smallholder demand for and access to

inorganic fertilizer and improved seed for maize production. By 2012/13, NAIVS had provided up to 2.5 million smallholders with access to a limited quantity of inorganic fertilizer and improved maize or rice seed at subsidized prices (50% of the market price for fertilizer, 100% subsidy for seed). The initial goal and design of NAIVS was not to provide an unending subsidy to lower the price of fertilizer for targeted farmers but to provide a lower-risk 'experimentation period' for both smallholders and private sector fertilizer/seed supply chain firms. This was expected to lead to both an increase in smallholder demand for *market-* priced fertilizer and improved seed, and an increase in supply chain investments in physical infrastructure, human capital, and exchange relationships so as to 'jump-start' the development of market-driven agricultural input distribution system that reached more villages and thus more smallholders. However, whether or not smallholder experimentation with subsidized fertilizer and improved seed during NAIVS leads to an increase in their demand for market-priced fertilizer for use on maize is largely a function of the extent to which actual smallholder use of inorganic fertilizer is profitable under typical market-based fertilizer and maize prices.

In this brief, we summarize results from a paper (Mather et al, 2015b) in which we analyze plot-level data from the National Panel Survey (NPS) to address that question. We first use regression analysis of this data to estimate average smallholder maize-nitrogen response rates and how they vary by zone, complementary input use and plot management practices and soil type. We then assess the extent to which smallholder fertilizer use on maize is profitable and how it varies by zone and complementary input use. Finally, we discuss implications for GoT strategies to sustainably improve smallholder maize productivity.

## DATA & METHODS

We use data from three main sources: (i) village, household and plot-level data from the National Panel Survey that covered the main seasons of 2008/09, 2010/11, and 2012/13; (ii) village-level data on estimated rainfall and elevation matched to NPS village spatial coordinates; (iii) monthly wholesale maize prices by region from the Ministry of Industry and Trade.

We first use regression analysis of this data to estimate the determinants of smallholder maize yields. Explanatory variables include controls for agro-ecological potential (estimated main season rainfall, elevation), plot-level input decisions (nitrogen, phosphorous and manure per hectare; use of improved seed; years since plot was fallowed; education level of plot manager, plot soil type (sandy, loam, clay/other)), household-level factors (adults per hectare, total landholding, total farm asset value, and household received an extension visit that year related to crop production (or in a previous panel year)).<sup>1</sup> From this regression, we obtain an estimate of the average smallholder maize-nitrogen response rate, and how it varies by zone, complementary input use and plot management practices. We also use the regression results to compute the Average Product (AP) of Nitrogen as the gain in gain in maize yield (kg/ha) for a given household with observed fertilizer use, relative to a counter-factual scenario in which that household had not used any fertilizer.<sup>2</sup> We then compute the average value cost ratio (AVCR) as [AP of Nitrogen (kg maize/kg

N) \* Maize price (Tsh/kg)] / Fertilizer price (TSh/kg). An AVCR>1.0 means that the net returns to fertilizer use are positive (profitable), but unless it is >=2.0, the expected net returns may not be high enough to compensate farmers for the high risk of maize production (weather) and post-harvest prices (market uncertainty).

## RESULTS

**Finding #1 -- Average smallholder maize-N response rates are not even 50% of those from zonal research center trials**, thus there is a large gap between actual and potential smallholder maize yields when using fertilizer. The implication of low smallholder maize-N response rates (and low AP of Nitrogen) is that while smallholders who apply fertilizer to maize are doing better than breaking-even (on average), their returns are still marginally profitable (i.e. AVCR<2.0). That is, their net returns to fertilizer use are not high enough to compensate for significant production and/or market price risks.<sup>3</sup>

**Table 1. Maize-nitrogen response rates and average value cost ratios (net returns) to fertilizer use by zone**

	Mean across survey years given observed quantity of Nitrogen (N) applied			
Zone	Maize-N response rate (MPP)	Average Product of N (APP)	MVCR	AVCR
S.Highlands	7.0	8.2	1.00	1.17
Northern	7.1	9.9	1.33	1.86
Eastern	7.8	11.8	1.40	2.12
Central	7.8	11.8	1.49	2.26
Lake	7.8	11.8	1.33	2.01
West	7.8	11.8	1.22	1.85
South	7.8	11.8	1.44	2.18

However, our other results demonstrate that there are ways to improve maize-N response rates and achieve higher profitability, but it requires a more holistic approach to productivity which focus not simply on improving farmer access to and use of fertilizer, but recognizes that farmer knowledge of appropriate fertilizer use needs to be improved and that fertilizer use

<sup>1</sup> Key factors that we do not observe include: planting date, seeding density, actual levels of macro/micro-nutrients in a given plot's soil, timing of weeding and plot-manager technical knowledge. However, our use of OLS with correlated random effects at the household level controls for potential bias to our estimated partial effects from any of these unobserved factors, which are constant over the panel waves.

<sup>2</sup> See Mather et al (2016b) for details.

<sup>3</sup> AVCR in the Southern highlands is lower than that of other regions in part because average annual maize prices are lowest in that zone. The reason for this is likely due to poorer road infrastructure relative to other regions and considerably further distance from major areas of demand.

should be combined with plot management practices that maintain soil health.

**Table 2. Maize-nitrogen response rates and average value cost ratios (net returns) to fertilizer use**

Complementary plot input use & soil type	Mean across survey years		
	MPP	APP	AVCR
used improved seed	10.2	11.2	1.90
did not use improved seed	7.1	8.0	1.36
HH had extension visit (GoT)	8.1	10.0	1.70
HH had extension visit (other)	9.6	10.0	1.70
HH did not have extension visit	7.2	7.9	1.34
HH has title to plot	8.6	10.9	1.85
HH does not have title to plot	6.7	7.4	1.26
plot fallowed within last 6 yrs	9.1	8.9	1.51
plot last fallowed within 7-12 yrs	8.5	10.9	1.85
plot last fallowed within 13-18 yrs	7.7	9.6	1.63
plot last fallowed within 19-25 yrs	7.0	7.9	1.34
plot last fallowed within 26+ yrs	6.1	7.4	1.26

**Finding #2: Use of improved maize seed (OPV or hybrid) generates a considerably higher maize-N response** of 10.2 as compared with the 7.1 achieved by fertilizer users who do not use an improved variety (Table 2). In addition, the net returns of fertilizer use for improved seed users (AVCR=1.9) is considerably higher than those of others (AVCR=1.36).

**Finding #3: There is a very clear negative effect on maize-N rates of years since the plot was last fallowed.**

The implication for profitability of fertilizer use is dramatic, as those who fallowed within the last 12 years have higher net returns (AVCR) to fertilizer use relative to other households (Table 2). Unfortunately, most maize plots were not fallowed recently. For example, in 2008/09, only 9.6% of smallholder plots were fallowed in the year before, and this dropped to only 2.8% in 2012/13. Subsequently, the average number of years since the plot was last fallowed increases from 2008/09 to 2012/13. These low fallowing rates and long duration between fallows on maize plots are worrying because unless a farmer employs sufficient cropping, plot management and/or fertilizer use to maintain soil nutrient levels, then continuous cropping (especially with maize) can mine micro and macro nutrients from the soil over time. This results in lower soil fertility, which reduces the effectiveness of fertilizer use, and thus its profitability. For example, recent research from Kenya has found that soils low in soil organic matter (SOM) have considerably lower grain to fertilizer response rates

(Marennya and Barrett, 2009). In fact, recent soil tests in various regions of Tanzania found low levels of SOM and other micro-and macro-nutrients, and note that maize-N response rates at these sites were lower than they were in 1995 (MAFC, 2013). The authors of this report attribute the low soil fertility they found to a downward cycle of soil fertilizer due to continuous cropping, low inorganic/organic fertilizer use, less frequent fallows.

**Finding #4: Households that received an extension visit from GoT (private sector, NGO, or coop) related to crop production have a maize-N response rate of 8.1 (9.6) relative to 7.2 for those that did not receive a visit.** One potential explanation for the large positive effect of an extension visit on response rates is that, among households in higher potential southern highlands and northern zones that apply fertilizer, those which received an extension visit applied a median of 243 kg/ha of fertilizer compared with 171 kg/ha for those who did not. Thus, extension recipients were more likely to apply the blanket NAIVS recommended fertilizer application rate for maize of 247 kg/ha and to have used both basal and top-dressing fertilizer, while those without an extension visit apply less than the recommended fertilizer rate and often only apply top-dressing (urea). Because phosphorous levels affect the uptake of nitrogen by a maize plant, using a fertilizer without phosphorous (urea) by itself could also explain lower nitrogen response rates (if existing P levels in the soil are too low).

## POLICY IMPLICATIONS

The GoT's main agricultural growth strategy since 2008 has been to use a large-scale fertilizer subsidy program (NAIVS) to improve smallholder access to fertilizer and improved seed for maize production, and to do so in a way that builds longer-term and sustainable smallholder demand for market-priced fertilizer/seed in maize production. The GoT succeeded in primarily targeting vouchers to farmers who had not previously used fertilizer on maize, thus NAIVS provided very valuable experience for voucher recipients to experiment with fertilizer on their own plots at lower financial risk (Mather et al, 2016a). However, the results from our analysis show that fertilizer use on maize is only marginally profitable in all regions of the country – even in high potential zones -- thus it is doubtful if the gains in farmer use of fertilizer on maize under NAIVS will be sustained when an increasing number of farmers must pay the market price for fertilizer (as NAIVS continues to scale down or stop).

In summary, our analysis thus strongly suggests that regardless of whether NAIVS continues or not, the GoT must consider alternative and/or complementary strategies at this point in time (beyond NAIVS) that can help to improve the profitability of fertilizer use on maize, and thereby build on the gains in smallholder experience with fertilizer use from 2008 to the present. This begs the question of what is the appropriate role for the GoT in influencing the three key components of the profitability of fertilizer use on maize: (i) How can smallholder maize-N response rates be increased? (ii) How can expected maize sale prices levels and predictability be improved? (iii) How can the unit cost of fertilizer be lowered for inland regions?

#### **Strategies to improve smallholder maize-fertilizer response rates: A) knowledge generation**

The overwhelming focus of funding under NAIVS was to improve farmer physical access to fertilizer and reduce its cost by 50%. However, our results show that for fertilizer use to be profitable, farmers need more than just access to fertilizer, they need to adopt a package of improved inputs and crop/plot management practices. This implies that the GoT need to adopt a more holistic approach in designing strategies to facilitate sustainable improvements in smallholder maize yields, that goes beyond a primary focus of improving physical access to fertilizer and subsidizing the price of fertilizer or access to a loan for it. In addition, it is clear from the existing MAFC district-level fertilizer recommendations (from 1993) that blanket fertilizer recommendations are not appropriate. Thus, there is an urgent need to increase focus and funding on the generation and dissemination of updated knowledge of soil conditions throughout the country as well as knowledge of best practices (input use and plot management) needed to increase smallholder maize yields.

First, Tanzania's existing soil map is over 30 years old (De Pauw, 1984), thus there is an urgent need for widespread soil sampling and in order to update knowledge of current soil characteristics. Fortunately, there are currently two efforts underway toward a goal of providing an updated soil map for all currently cropped areas by 2017. These include the GoT Tanzania Soil Information System (TanSIS) and the Taking Maize Agronomy to Scale in Africa (TAMASA) project, which are coordinating their efforts so as to avoid duplication (Meliyo, 2015).

Second, there is a need for widespread agricultural research trials to update existing fertilizer recommendations for maize, rice, etc. The existing district-level recommendations for most districts are from 1993, and trials organized by Mlingano in 2010 and 2011 in 11 districts showed that updated recommendations are in fact needed, due to negative changes since 1993 in soil health. The National Soil Service project has also recently done trials in an additional 12 districts, though it plans to continue until covering all districts. In addition, the findings of low soil fertility (MAFC, 2013) and our results suggest that significant efforts should be made to evaluate not only optimal fertilizer use in a given district, but also agronomic and economic returns to various forms of Integrated Soil Fertility Management (ISFM), such as maize/legume intercropping, crop rotations, improved fallows, etc, that are needed to help improve and maintain a level soil fertility required for inorganic fertilizer to be profitable.

#### **Strategies to improve smallholder maize-fertilizer response rates: B) effectively disseminate new fertilizer recommendations & best practices**

Our results show that there is a large positive effect of a household receipt of an extension visit on maize-N response rates and thus the profitability of fertilizer use on maize. Yet, the majority of smallholder maize producers never receive a visit. Although the extension system has been rapidly increasing the number of total extension agents in recent years, the farmer-to-agent ratio is still very high. The good news is that there are existing methods of knowledge dissemination that can complement extension agents (i.e. farmer field schools), as well as new innovations in extension that can complement and/or improve upon existing methods by taking advantage of new information technologies. For example, video training sessions via tablet may be more cost-effective than setting up and maintaining demonstration plots, while extension agents may be able to reduce travel time and costs if they or their district office can use text messaging to disseminate information. That said, while public/private extension services may work very well in Tanzania for smallholders growing cash crops, the only extension that subsistence smallholder maize growers are likely to receive is from the GoT, and thus a combination of increased funding and institutional innovation is needed to improve coverage of public extension that reaches these kinds of smallholders.

However, simply increasing funding for public extension will not be sufficient unless agents and other methods disseminate up-to-date fertilizer recommendations and other best practices needed for sustainable increases in smallholder maize yields. For example, recent research in four key regions found that agro-dealers and extension agents know the NAIVS blanket fertilizer recommendations for maize, but not the 1993 district-specific ones (Mather *et al*, 2016a). In addition, in villages targeted by NAIVS across 11 regions, a majority of voucher recipients did not know the recommended application rates for urea or DAP on maize in 2011, and virtually none of the non-recipients knew them (*ibid*, 2016a). Of those who responded, most gave the NAIVS blanket recommendations. In addition, MAFC's own district-level recommendations from 1993 indicate that blanket recommendations are not appropriate in the first place. The findings above suggest a need for more effective linkages between zonal agricultural research stations and district-level extension offices, in order to ensure that technical information disseminated to farmers is both appropriate and up-to-date.

#### **Strategies to improve expected maize sales price levels that smallholders receive and their predictability**

There is an inherent link between trade and marketing policy and sustained technology adoption, because higher and more stable/predictable maize and rice prices will lead to increased demand for commercial fertilizer by smallholders and increased incentive for investment by the private sector in storage for both fertilizer and maize (over time). By contrast, unexpected changes in trade and marketing policy for grains not only result in financial losses for farmers and wholesalers in the season in which an export ban is implemented or an import tariff is removed (both cause a decline in domestic grain prices), but they can also dramatically increase the uncertainty regarding future post-harvest grain prices for actors throughout the maize supply chain. Subsequently, increased maize price uncertainty can significantly reduce investment throughout both the fertilizer and maize supply chains. For example, when farmers are not confident that post-harvest maize prices will be high enough for fertilizer use to be profitable, this can serve as a disincentive for them to use fertilizer on maize due to the financial risk involved.

Although the GoT pledged in 2013 to stop using maize export bans, potential exporters now must obtain an export permit from a district official in order to export maize, and approval of such permits is sometimes

refused (i.e. a region in the southern highlands has recently declared a maize export ban). Thus, continuing grain price uncertainty caused by unpredictable export bans and/or removal of import tariffs may well be undermining the gains made during NAIVS in smallholder demand for commercial fertilizer for use in maize and rice production. There is thus an urgent need for GoT to adopt predictable, transparent, rules-based trade & marketing policies to reduce the risk/uncertainty of farmer, trader, and wholesalers' expectations of future maize prices.

Second, if GoT's Big Results Now (BRN) initiative to establish warehouse receipt systems for maize and rice is successful, Collective Warehouse Based Marketing Systems (COWABAMAs) could help to sustain smallholder demand for yield-enhancing inputs such as fertilizer by enabling participating farmers to obtain much better prices for their surplus maize, while also providing them with a source of credit for inputs the following season.

#### **Strategies to reduce the unit costs of fertilizer for smallholders**

Urea and DAP are the most commonly used fertilizers on maize, and both are imported. However, approximately 40% (33%) of the cost of urea (DAP) in rural Tanzania are domestic costs including port charges, transportation to an inland region, and wholesaler/retailer costs and margins (IFDC, 2012). These costs can be considerably reduced with a combination of investments and regulatory reforms:

- 1) Increased investment in improved port infrastructure (IFPRI, 2012).
- 2) Regulatory reform to enable the Tanzania Fertilizer Regulatory Authority (TFRA) to truly be a 'one-stop-shop' for importers to meet internationally-recognized regulatory standards – currently there are overlapping mandates among a large number of regulatory agencies, which result in costly delays in unloading ships and duplication of effort (and taxes).
- 3) Reform of central & TAZARA railways management – maize/fertilizer are bulk commodities that could be shipped much cheaper to inland regions, but importers use trucks because of the unreliability of rail
- 4) Increased investment in rural trunk and feeder roads to lower transportation costs for both farm inputs and outputs. Road investments should focus on reducing transport costs on rural

roads, because they account for the largest share of transport costs, despite the shorter distances covered (World Bank, 2009b).

Investment in (1) port and (4) road infrastructure would both reduce village-level costs of fertilizer while improving the prices at which farmers can sell their surplus maize. Likewise, improved ports/infrastructure will reduce input costs for both farm and non-farm businesses while increasing the output prices they receive. This helps to explain why evidence from southeast Asia shows that rural roads consistently have the highest rate of return of all potential rural investments in reducing poverty. (EIU, 2008; Fan, Gulati, and Thorat, 2008).

In addition, a recent study (Ariga and Jayne 2009) argues that Kenya's impressive growth in smallholder fertilizer use during the 2000s was due to synergies between liberalization of input and maize markets and investment in public goods (such as in rural roads) in support of smallholder agriculture (both beginning in the 1990s), which appear to have stimulated investment by the private sector in both maize and fertilizer marketing. These investments led to dramatic reductions in average distances from the farm to private fertilizer retailers and lower real fertilizer prices over time (*ibid*, 2009), which these authors credit with driving increases in smallholder fertilizer use since 1997. For example, as of 2007, between 85 to 95% of smallholder maize producers in medium to high potential zones in Kenya applied inorganic fertilizer to maize (Mather and Jayne, 2015). The case of Kenya therefore demonstrates that a stable policy environment – with respect to fertilizer, land, and maize markets – can induce an impressive private sector response over time that has helped to make fertilizer accessible to most small farmers (Minde et al 2008).

## ACKNOWLEDGEMENTS

Financial support for this study was provided by the Bill & Melinda Gates Foundation (BMGF) through the Tanzania component of the GISAIA project (Guiding Investments in Sustainable Agricultural Intensification in Africa). We thank Dr. David Nyange (MSU) for facilitating meetings with MALF officials (current and past) and non-governmental actors, which helped inform this study.

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