GUIDING INVESTMENTS IN SUSTAINABLE AGRICULTURAL INTENSIFICATION IN AFRICA (GISAIA)

A profitability analysis of fertilizer use for maize production in Nigeria

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Synopsis:

Inorganic fertilizer use across sub Saharan Africa is generally considered to be low. Yet, the notion that fertilizer use is ***too*** low is predicated on the assumption that it is profitable to use rates higher than currently observed if indeed we consider rural farmers to be rationale expected profit maximizers. As a result of this assumption, the literature generally looks to other constraints to its adoption (financial market imperfections (credit/insurance/savings), knowledge, or lack of demand and thus the realization of economies of scale on the supply side (agro-dealer network), or lack of access to markets to sell the produce, but these all link again to profitability issues. Consequently this brief summarizes a study that focuses on the profitability of fertilizer use as a likely explanatory factor for observed fertilizer use rates in Nigeria. Using the Nigeria Living Standard Measurement Study-Integrated Survey on Agriculture, a rich national representative panel data set with plot level information, this study explores the profitability of fertilizer use for the production of maize (one of the top 3 most important cereals grown in Nigeria) across Nigeria.

Key findings:

The study reveals that fertilizer use in Nigeria is not as low as conventional wisdom suggests. Low marginal physical product and high transportation costs significantly reduce the profitability of fertilizer use in maize production.. In addition to investments in rural infrastructure, strategies to reduce the distances (currently estimated at 40-70 km from the LSMS-ISA data) farmers have to travel to purchase inputs could also play an important role. This could be through supporting private input dealers to establish presence closer to rural communities by setting up shops in rural areas or in retail arrangements with farmers in rural communities. Apart from reduced transportation costs, other constraints such as timely access to the product, availability of complementary inputs such as improved seeds, irrigation and credit, as well as good management practices are also necessary for sustained agricultural productivity improvements. Finally further attention is needed to understand why the yield response to applied nitrogen is so low in maize production. In addition to complementary inputs and management practices, issues of soil quality are critical. Understanding the nature and characteristic of Nigerian soils and the consequent nutritional requirements are important for determining fertilizer application rates and achieving optimal yield responses.

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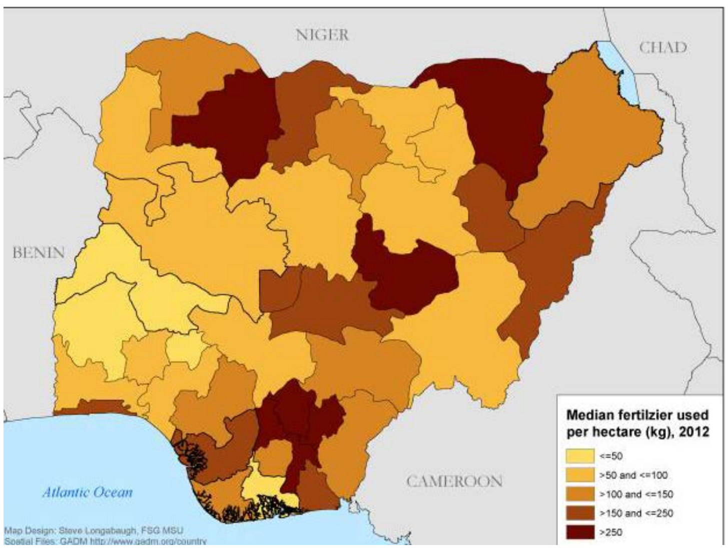
An overview of fertilizer use in Nigeria:

Since the 1940s, Nigerian governments have generally perceived that fertilizer use in the country was low. The cited explanatory factors include farmers' awareness of fertilizer's benefits, credit constraints and policy inconsistency in the country (Whetam, 1961; Ogunfowora and Norman, 1973; Nagy and Edun, 2002). The numerous strategies used to stimulate fertilizer use include input subsidies, extension services to develop soil fertility management technologies and programs to increase farmers' access to credit. These programs are generally considered not to have significantly raised fertilizer demand (Nagy and Edun, 2002). However, our study finds that fertilizer is commonly used in Nigeria, naturally varying across agro-ecological and market conditions, government policies, cropping systems and yield responsiveness. Its use in the Northern states is typically higher than in southern states (Figure 1). This is partly attributed to lower soil fertility, larger area cultivated and the growth of high value crops such as cereals and vegetables in the region. Northern states have also traditionally provided greater fertilizer subsidies since the colonial era.

Figure 1: Fertilizer use in Nigeria, 2012



Median quantity of inorganic fertilizer applied per hectare, 2012

Fertilizer use in Maize production in Nigeria

Maize is a versatile crop; grown across a wide range of agro ecological zones (IITA, 2001). It was one of the six priority crops under the flagship agricultural program of the Nigerian government since 2012. Thus maize farmers have received intentional support in terms of access to subsidized fertilizer and improved seeds (Federal Ministry of Agriculture, 2011). Every part of the maize plant has economic value: the grain, leaves, stalk, tassel, and cob can all be used to produce a large variety of food and non-food products. In Nigeria, the growing demand for maize is also partly attributed to its use for poultry feed (IITA, 2008). To understand the heterogeneity of fertilizer use and profitability across Nigeria's agro ecological and market conditions, the study adopts the categorization of maize farmers in Nigeria by farming systems as defined by Dixon et al (2001) but only focuses on maize producers in the Cereal – root crop mixed farming system (C-RCFS). This farming system is the largest farming system in our sample (comprising over 60% of all maize plots) and likely most representative of maize production in Nigeria

Table 1 reveals that fertilizer use across the survey years is relatively consistent over time in the main maize farming system. However, there does not appear to be a significant difference in yields between fertilizer users and the average sample. This likely reflects that there are other important factors explaining maize productivity and the effect of fertilizer use on maize yields besides fertilizer use. These could include the quality of the soil, input and output costs, the availability of fertilizer and other complementary inputs (such as water, seed, and organic manure) or other management practices.

Table 1: Fertilizer use rates and maize yield in the cereal root crop farming system

	2010	2012
Mean fertilizer use per hectare *	197.8	211.0
Proportion of plots using fertilizer	0.64	0.67
Mean maize output per hectare (kilograms)	1054	1256
Mean maize output per hectare for fertilizer users (kilograms)	1115	1332
Number of observations (plots)	584	637

Source: Authors' estimations from the LSMS-ISA data. *These mean values are conditional on use

Findings

The marginal physical products (MPP) for applied nitrogen in Nigeria appears to be quite low. The average MPP of nitrogen in the main maize farming system where almost 60% of maize production in our sample occurs is about 7.7 kg (in 2012). Though usually focused on a very specific location, other studies in Nigeria reflect these relatively low fertilizer yield responses Onuk et al. (2010) and Gani and Omonona (2009) find MPP values about 2 kg while Kehinde et al.(2012) found negative APP values. This is much lower than the potential yields of up to 50kg of maize per kg nitrogen when researcher management protocols are followed (Snapp et al., 2014). It is also quite different from what has been found in East and Southern Africa. Sheahan et al. (2013) estimate an overall MPP of nitrogen for maize production to be about 17 kg (though this varies across space and time). Matsumoto and Yamano (2011) found marginal products ranging between 11 and 20 kg across the western and higher potential regions of Kenya while Marenya and Barrett (2009) found the marginal product of nitrogen to be 17.6 kg for Vihiga district (Western Province) of Kenya. *The low MPPs of applied nitrogen in maize production indicate that increasing fertilizer use alone might not be sufficient to increase maize yields to desired levels in Nigeria.*

The proportion of maize plots for which nitrogen application is profitable (for a risk neutral farmer) at the observed fertilizer acquisition prices and maize price is quite low. In the C-RCFS, it is only profitable for about 46% of maize plots in 2012. It is expected that this percentage will be even lower for risk averse farmers because their use of fertilizer require a higher spread between the expected profit of using fertilizer versus not using it.

Transportation costs to acquire fertilizer are high in Nigeria. The average price paid per kilogram of NPK fertilizer in 2010 was about N330 and N320 in 2012. However, when we factor in the transportation cost to acquire the fertilizer, the average acquisition cost in 2010 was about N370 and N375 in 2012. This indicates that about 12%-18% of the actual cost incurred by farmers using fertilizer is due to transportation costs in each survey year. This is also a likely conservative estimate when you consider that farmers are likely to bear the relevant transportation costs to the market or input seller at planting time whether purchasing a kilogram of fertilizer or 10kgs of fertilizer. Thus other assumptions about the transportation cost calculation could yield higher transportation cost effects on the acquisition cost for rural farmers. See Sheahan et al (2013) and Liverpool-Tasie (2016) for some alternative assumptions. The high cost of transportation echoes the findings of other studies that have found transportation costs to account for 20-25% of the urban retail prices at regional hub cities in Nigeria (Liverpool-Tasie and Takeshima, 2013). This effect is likely exacerbated at rural markets and (even further in remote villages) to capture the costs of getting the fertilizer to more remote areas with poorer road networks. High transportation costs were similarly observed in rural Ethiopia where Minten et al. (2013) found that farmers living about 10km away from a distribution center faced transaction and transportation costs (per unit) that were as large as the costs needed to bring fertilizer over about a 1,000km distance from the international port to the input distribution center. In our sample, farmers are on average about 15km from the nearest road, 70km from the nearest market about 80Km from the state capital city.

Comparing actual nitrogen application rates on maize plots to expected profit maximizing rates indicates that **fertilizer use for maize is often higher than expected profit maximization for risk neutral farmers would indicate (see figure 2).**

Increasing the profitability of fertilizer use:

The profitability increasing effect of reduced transportation costs on nitrogen application for maize production in Nigeria is evident (see figure 3). Using a simulation of fertilizer profitability with and without transportation costs provides some useful insights. Making fertilizer available in the village increases the proportion of plots on which fertilizer use is profitable by close to 35% in 2012 for risk neutral farmers. This indicates that while the low profitability of nitrogen application in the C-RCFS is partly driven by the low MPP of nitrogen, reducing the cost of fertilizer acquisition can significantly affect the profitability of nitrogen application for maize production in this farming system.

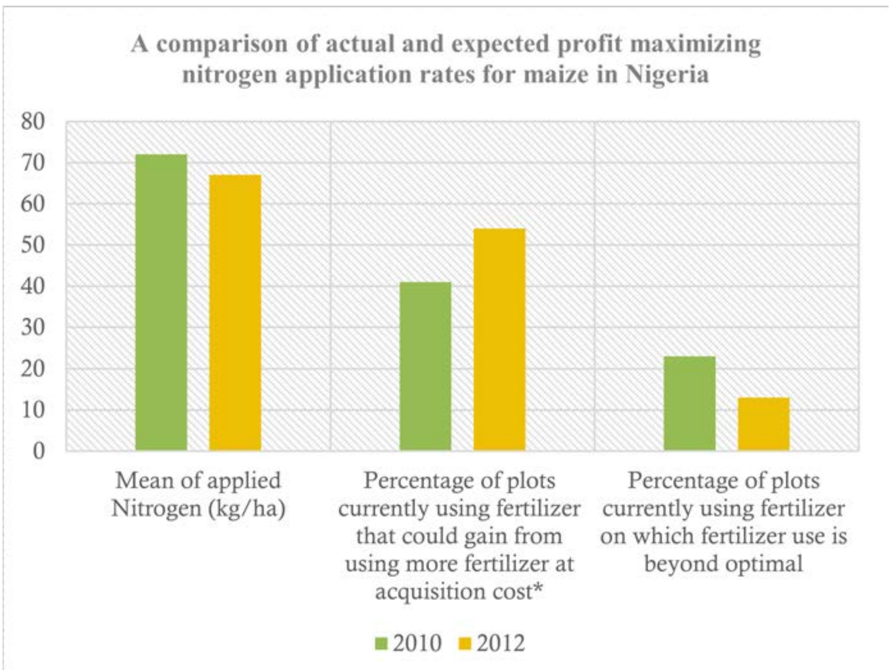


Figure 2: Fertilizer application rates are too high for some farmers

Price reduction through subsidies?

The profitability of fertilizer use could be increased via a reduction in the price of fertilizer (See equation 1). One way this could happen is the use of fertilizer subsidies. Throughout most of Nigeria's recent history, fertilizer subsidies have been a dominant component of agricultural input programs; accounting for substantial shares of government capital spending on agriculture (Mogues et al., 2012). In 2012 (when our second round of data was collected) the Nigerian government began a new fertilizer program. Prior to 2011 (and when our first round of data was collected), the subsidy program in existence was called the Federal Market Stabilization Program (FMSP). Under the FMSP, each Nigerian state government would submit a request to the federal government for a certain quantity of subsidized fertilizer it wanted to procure. Depending on the federal agricultural budget, the federal government then determined the total amount of subsidized fertilizer to be allocated to each state (Takeshima and Nkonya, 2014). Empirical evidence supports less than 20% of applied fertilizer in Nigeria is likely to be subsidized (Takeshima and Liverpool-Tasie, 2015). Thus, it is likely that not all maize farmers have access to subsidized fertilizer and calls for a careful consideration of the relative costs and benefits of such an expensive strategy.

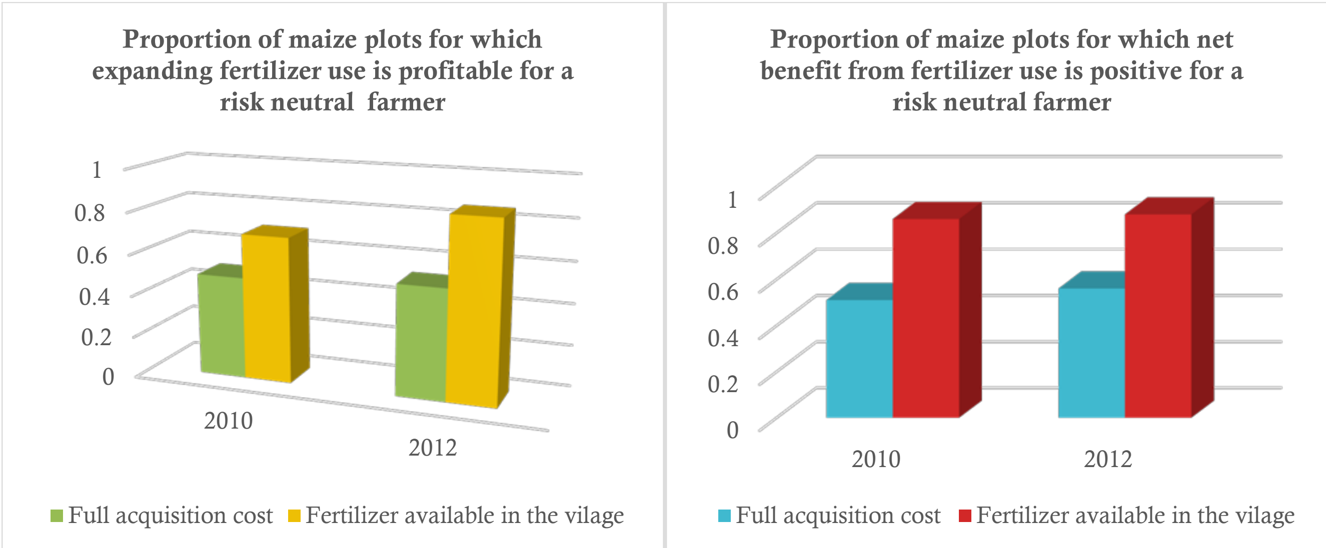


Figure 3: There is scope to raise profitability by reducing transport costs for both risk averse and risk neutral farmers

Some technical details of the profitability assessment

Examination of the profitability of fertilizer use requires an understanding of 1) fertilizer agronomics, i.e. the yield response and 2) fertilizer economics (the output/input price ratio as well as quantities and costs of inputs such as seed, chemicals, labor and transportation. First we focused on the agronomics, measuring the relationship between maize output and the relevant factors of production (including inorganic fertilizer). We estimated a modified quadratic production function using a fixed effects model which attenuates potential biases by using variation in fertilizer use within a household over time to identify the causal effect of fertilizer on yields. This addresses the fact that he decisions both to use fertilizer and the quantity of fertilizer applied on a maize plot are endogenous—they themselves are components of household decision-making. It is likely that fertilizer application is correlated with farmer and plot specific characteristics (such as unobserved variation in soil characteristics or farmer ability) that are also likely to influence yields. This correlation between the unobserved individual effect in the error term of production function and the rate of application of fertilizer would cause a bias in ordinary least squares (OLS) estimators.

Production function estimates are then used to calculate the *marginal and average physical products* of nitrogen in maize production (MPPs and APPs respectively). The MPP of applied nitrogen (which describes how much extra maize output can be produced by using one additional unit of applied nitrogen, all else held constant) is obtained by taking the first derivative of the production function with respect to applied nitrogen. The APP is the gain in maize yield per unit of applied nitrogen relative to not using any nitrogen. These MPPs and APPs are calculated at the plot level and then used to calculate partial profitability measures. These are defined as the marginal value cost ratio (MVCR) and the average value cost ratio (AVCR) for plot *i* and household *j* at time *t* as follows:

Marginal value cost ratio: $\left(MVCR_{nijt}\right) = \frac{(P_{mtv} * MPP_{nijt})}{p_{nijt}}$ (1)

Average value cost ratio: $\left(AVCR_{nijt}\right) = \frac{(P_{mtv} * APP_{nijt})}{p_{nijt}}$ (2)

where p_n is the price of nitrogen and p_m is the price of maize.

The study considers the use of fertilizer to be profitable for *risk-neutral* farmers if the MVCR is greater than or equal to 1. For *risk-averse* farmers, a higher MVCR threshold than 1 is considered necessary for fertilizer use to be considered profitable.

Policy Implications:

While use rates among current users are not low, **there are likely opportunities for expansion in fertilizer use** in the cereal-root crop farming system. Consequently, efforts to understand and improve the likely yield response of applied nitrogen are necessary to expand fertilizer use in the main maize farming zone, especially if they are risk averse.

Increasing the profitability of fertilizer through reduced transport costs has a high potential. While this could be achieved through improvements in infrastructure which are more universally spread among rural farmers relative to programs like fertilizer subsidies, this cost reduction could also be achieved through programs that encourage the setup of retail depots within communities or in smaller towns closer to farmers. It should be noted that though this study only focusses on transportation costs, there are other transactions costs associated with securing modern inputs such as multiple trips to the market and or arrangements necessary to identify where the input is available worthy of consideration. Moreover, improving the response to nitrogen through complementary practices (such as irrigation facilities, good quality seed and other more efficient methods of fertilizer use or crop management practices) could also play a significant role. Issues of soil organic content and other properties likely to increase the efficiency of applied nitrogen use should also be explored (Marenya and Barrett, 2009).

Cognizant that some maize farmers in Nigeria are already applying nitrogen beyond levels considered economically optimal, this indicates the need for further studies on fertilizer profitability in Sub-Saharan Africa**. This indicates that just promoting an increased use of fertilizer is unlikely to be sufficient to transform Nigerian agriculture.** More effort is needed to understand the rational for the current nitrogen application rates across smallholder farmers and to increase the profitability of fertilizer use by addressing transportation costs and other factors (such as timeliness of availability and management practice) currently mitigating the yield and profitability effects of fertilizer use.

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