CHAPTER 12

Maize Farming and Fertilizers: Not a Profitable Mix in Nigeria

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Overview

Common wisdom: *Despite being profitable, fertilizer use among African farmers is too low.*

Findings:

- *Fertilizer use is common in Nigeria, although varying widely across farming systems.*
- *Where most of the maize is produced, fertilizer application is not profitable for many farmers.*
- *The two major factors behind low profitability are*
  - *Low yield response to nitrogen*
  - *High acquisition costs.*
- *Fertilizer use and application rates are higher than the optimal levels for some farmers—that is, the levels indicated by estimated profitability.*

Policy messages:

- *Increased attention needs to be paid to interventions that raise the yield response to fertilizer application.*
- *In addition to complementary input use and improved management practices, increasing yields also requires improving soil health and ensuring fertilizer quality.*
- *Maize profitability will be well served by investment in infrastructure and strategies to reduce the distance farmers have to go to secure fertilizer.*

The Issue: How Profitable Is Fertilizer Use?

The notion that inorganic fertilizer use in Africa is too low is based on the assumption that it is profitable to use higher rates than is currently the case. Because of this, the literature generally looks to other constraints to fertilizer adoption—financial market imperfections, inadequate knowledge, or lack of access to markets. But these constraints all link again to profitability issues. This study therefore analyzes the profitability of fertilizer use as a likely explanatory factor for observed fertilizer use rates, focusing on maize production in Nigeria.

Overall, there is little rigorous empirical evidence on fertilizer profitability in Africa. Although various studies have explored the yield response of fertilizer in crop production, few studies have explored the profitability of fertilizer use. Most studies of profitability are outdated or based largely on unrepresentative case study evidence. The study takes advantage of recent nationally representative data in Nigeria to put this discussion on a more secure empirical footing. It addresses two gaps in the literature. First, it addresses a key issue as yet untested in the literature, which appears to believe that fertilizer use is low in Sub-Saharan Africa, although it is profitable. Second, the study identifies more consistently the yield response to fertilizer application, by accounting for unobserved time-invariant household characteristics that are likely to affect fertilizer application and the resulting yields.

The Nigerian Context

Fertilizer Is Commonly Used in Nigeria, Especially in the Northern States

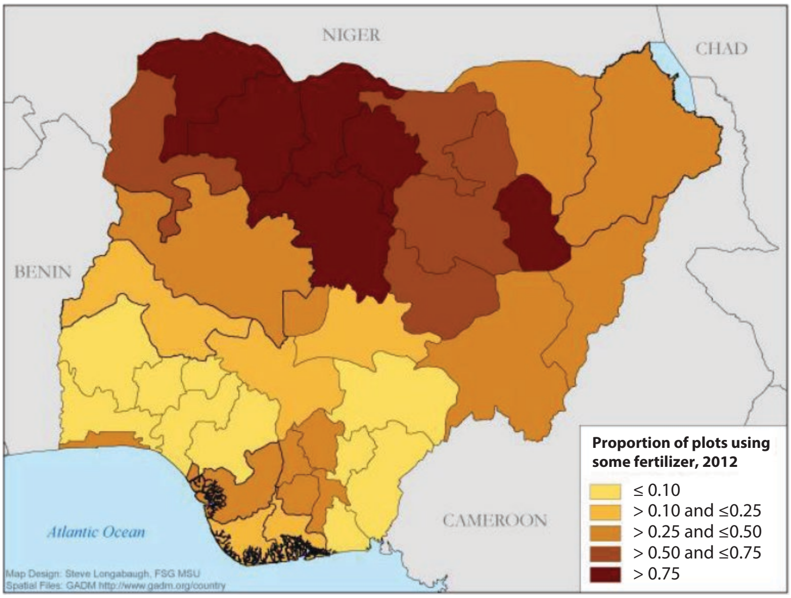
There is limited empirical evidence on the nature and rationale for the patterns of observed inorganic fertilizer use rates across Nigeria's diverse farming systems. Fertilizer use will naturally vary depending on agroecological and market conditions, government policies, cropping systems, and yield responsiveness. Its use in the northern states is typically higher than in the southern states (map 12.1). This is partly attributed to lower soil fertility, larger area cultivated, and the growth of high-value crops, such as vegetables and particular cereals, in the region. Northern states have also traditionally provided greater fertilizer subsidies since the colonial era.

Why Maize?

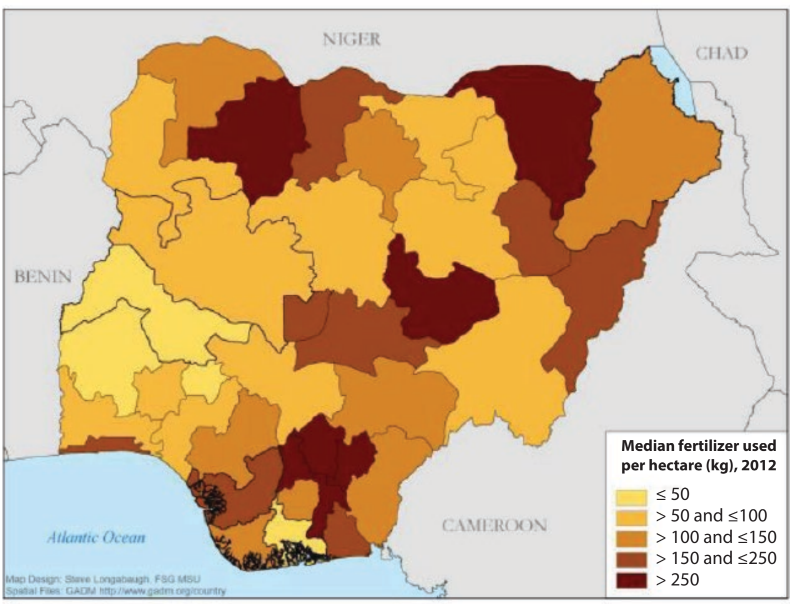
Maize is one of the three most important cereals grown in Nigeria, alongside sorghum and millet. Maize is a versatile crop, grown across a wide range of agroecological zones. Every part of the maize plant has economic value. As a priority under the flagship agricultural programs of the Nigerian government since 2012, maize farmers have received support through access to subsidized fertilizer and improved seeds. The study focuses on the main cereal-producing area, selecting plots where maize is grown. These account for over 60 percent of the plots in the study sample. Although the results are not nationally representative, they can be

Map 12.1 Inorganic Fertilizer Use on Plots in Nigeria, 2012

a. Proportion of plots on which inorganic fertilizer is applied



b. Median quantity of inorganic fertilizer applied per hectare



Sources: Data generated from the 2012 LSMS-ISA; map generated by Steve Longabaugh (2014). Used with permission; further permission required for reuse.

considered representative of the main farming system for maize production in the country. Maize is produced mainly by smallholders in Nigeria. The average maize plot is between 1 and 1.5 hectares, managed by a middle-aged male with limited use of irrigation and mechanization. Although only about 20 percent of the maize plots use purchased seed, almost 50 percent of the farmers use some chemicals (herbicides and pesticides) in maize production. For those who apply fertilizer, the average fertilizer use is between 150 and 170 kilograms (kg) per hectare.

The Analysis: Estimating Maize Yields and Profitability in Nigeria

The Data

The Nigeria Living Standards Measurement Study–Integrated Survey on Agriculture (LSMS-ISA) provides a rare opportunity to estimate the yields and profitability of fertilizer use in the country. LSMS-ISA is a nationally representative panel data set with detailed agricultural information at the plot level. This makes it possible to address specifically the profitability of fertilizer use in a production function framework. The LSMS-ISA data set includes georeferenced plot locations and Global Positioning System–based plot areas. It also includes plot-level information on input use, cultivation, and production. The information was collected over two visits per household per year in 2010/11 and again in 2012/13. The first visit each year collected information on planting activities; the second visit collected information on postharvest outcomes. The study selects all plots on which maize was grown in the main agricultural season in each survey year. It therefore draws on information on the size of plots, amount of fertilizer and other inputs used, and yields for about 1,200 maize plots over the two survey periods.

From Production to Profitability

The profitability of fertilizer use requires an understanding of the following:

- *Fertilizer agronomics*, that is, the yield response to applying fertilizer under different circumstances (such as soil quality or water availability).
- *Fertilizer economics*, which involves the output/input price ratio as well as the quantities and costs of inputs, such as seed, chemicals, labor, and transportation. Understanding fertilizer economics requires detailed information on agricultural practices and input costs.

The study deals first with the agronomics, measuring the relationship between maize output and the relevant factors of production (including inorganic fertilizer). The production function estimates (box 12.1) are 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

Box 12.1 Challenges of Estimating the Maize Production Function

To estimate the profitability of the use of inorganic fertilizer in maize production, the study first estimates the impact of fertilizer use on maize yields, other things constant. The emphasis is on the application of nitrogen. The basic model is specified as:

$$Yield_{ijt} = f(X_{kijt}, Z_{hijt}, u_{ijt})$$

where $Yield_{ijt}$ refers to the yield per hectare (in kilograms) of maize on plot *i* for household *j* at time *t*, which is a function of several vectors of endogenous and exogenous factors. The term X_{kijt}, refers to a vector of plot- and time-specific determinants of maize yields, including the use of various *k* inputs (including applied nitrogen); Z_{hijt} is a vector of *h* controls that affect crop production, such as soil quality, access to information and markets, as well as the level and distribution of rainfall. The term Z_{hijt} also includes household characteristics, including the age and gender of the plot manager and household wealth. Finally, $u_{ijt} = \varepsilon_{ijt} + c_i$ is a composite error term comprising time-invariant (c_i) and time-varying unobserved characteristics (ε_{ijt}) of the production system.

A key problem in estimating the effect of fertilizer on yields is that the decisions to use nitrogen and the quantity of nitrogen applied on a maize plot are endogenous—they 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 endogeneity restricts any causal interpretation of the coefficient on fertilizer use in a yield response model. The correlation between the unobserved individual effect in the error term (C_i) and the rate of application of fertilizer would cause a bias in ordinary-least-squares (OLS) estimators. Therefore, estimation of the effects of fertilizer on yields is largely based on a fixed-effects model. This method attenuates potential biases by using variation in fertilizer use within a household over time to identify the causal effect of fertilizer on yields.

Although the fixed-effects model addresses bias caused by *time-invariant* factors (such as farmer ability), it does not deal with any bias caused by *time-varying* unobservable factors that may be correlated with yields and the household's fertilizer use. A unique feature of this study is the availability of plot-level characteristics, which are included in the production function estimates. This addresses some of the usually absent but important time-varying unobserved characteristics of concern when using a fixed-effects model, by accounting for factors such as the plot wetness potential index and the slope and elevation of the plot.

The estimates of this production function highlight the importance of addressing the effects of unobserved household-specific characteristics when estimating nitrogen yield response functions. The difference between the pooled OLS and fixed-effects results indicates the presence of some invariant, unobserved factors that are likely correlated with nitrogen application as well maize yields. The consistency of these results was confirmed with other models, including the correlated random-effects model.

Using the production function estimates, the study calculates the marginal physical product of the use of nitrogen in maize production as the derivative of the yield with respect to the

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Box 12.1 Challenges of Estimating the Maize Production Function *(continued)*

nitrogen variable for each plot. The average physical product is defined as the change in output due to the use of applied nitrogen compared with not applying any nitrogen. The marginal product of applied nitrogen (which describes how much extra maize output can be produced by using one additional unit of nitrogen, all else held constant) is obtained by taking the first derivative of the production function with respect to applied nitrogen.

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. MPPs and APPs are calculated at the plot level and then used to calculate partial profitability measures. These measures are defined as the marginal value cost ratio (MVCR) and average value cost ratio (AVCR) for plot *i* and household *j* at time *t* as follows:

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

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

where p_{nijt} is the acquisition price of nitrogen (market price plus transportation cost) and p_{mtv} is the price of maize in the farmers' community. The output price is the median community selling price of maize per kilogram. The nitrogen price is a simple average of the market price of the nitrogen components of urea and nitrogen, phosphorus, and potassium converted to a 1 kilogram equivalent.

When $\text{AVCR}_{\text{nijt}}$ is greater than or equal to 1, the net benefit from using fertilizer is positive for a risk-neutral household and it is profitable to use fertilizer. When $\text{MVCR}_{\text{nijt}}$ is greater than 1, it implies that a risk-neutral household could increase its income by increasing its nitrogen application rate, as the current rate is not profit maximizing. The study assumes risk neutrality, but recognizes that measured profitability under this assumption would overestimate profitability for risk-averse farmers.

The Results: Fertilizer Is Not Profitable for Many Maize Farmers

Among risk-neutral farmers in the main maize-growing zone, the net benefit of the use of fertilizer is positive in about a half the plots covered in 2012 (that is, plots for which AVRC > 1). About 50 percent of the maize plots could increase their income by expanding nitrogen application (MVCR > 1). But this points to limited profitability in the remaining half of the plots.

Why Is Maize Not Profitable for Many Farmers?

Yield Response to Applied Fertilizer Is Quite Low

The MPP of maize for applied nitrogen in the main farming system in Nigeria was just 7.7 kg (in 2012). This is much lower than the potential yields of up to 50 kg of maize per kg of nitrogen when research management protocols are followed (Snapp et al. 2014). It is also lower than recent estimates from East Africa of about 17 kg of maize per kg of nitrogen (Sheahan, Black, and Jayne 2013). The study explores possible interventions that would increase this response—such as irrigation, use of improved seeds, and enhanced crop management practices.

Transport Costs Clearly Harm Maize Profitability

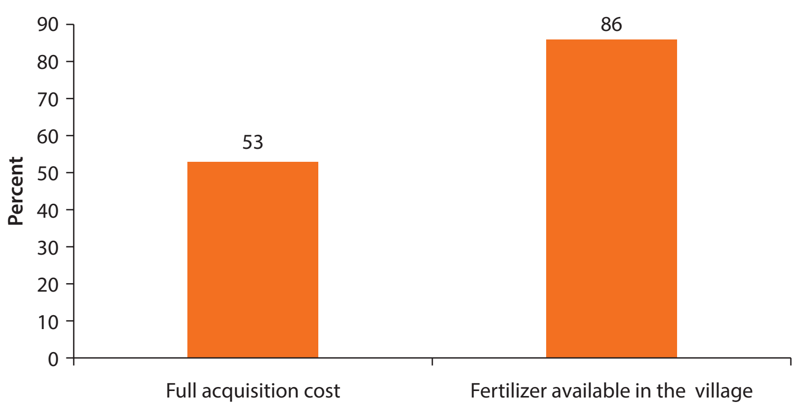
Given transport costs, the study finds that expanding fertilizer use would be profitable on 53 percent of the plots in 2012, assuming risk neutrality. But if fertilizers were available in the village (avoiding transportation costs borne by the farmer), fertilizer use would be profitable on most of the plots (86 percent of them—figure 12.1). These are large effects. They indicate that although the low profitability of nitrogen application is partly driven by its low MPP, reducing the cost of fertilizer acquisition can significantly enhance its profitability.

Fertilizer Subsidies Could Also Raise Profitability

Fertilizer subsidies have been a dominant component of agricultural input programs throughout most of Nigeria's recent history. Under the current scheme in Nigeria, participating farmers receive two bags of subsidized fertilizer (typically subsidized at 50 percent of market price). If the majority of maize farmers

Figure 12.1 There Is Scope to Raise Fertilizer Profitability by Reducing Transportation Costs

Percent of maize plots where expanding fertilizer use was profitable for risk-neutral farmers in 2012



Source: Data generated from the 2012 LSMS-ISA in Nigeria.

received subsidized fertilizer, this could significantly reduce the cost of fertilizer use. But recent empirical evidence suggests that typically larger and more affluent farmers benefit from such programs. Furthermore, given that less than 20 percent of applied fertilizer in Nigeria is likely to be subsidized (Takeshima and Liverpool-Tasie 2015), the relative costs and benefits of such a strategy should be carefully considered.

Nitrogen Use Is Not Too Low, Given Its Expected Profitability

The study compares the profitability of plot-level nitrogen application with the observed application. Are observed use patterns in line with those indicated from expected profitability, as estimated from the survey data? For the cereal–root crop farming system, the study demonstrates that fertilizer use is only profitable in expectation for about half the plots. Yet, the surveys report about 65 percent of the maize plots use some fertilizer. This finding indicates that fertilizer use is not purely driven by observed market prices and yields. For example, given food security concerns (especially when faced with poor quality soils and poor infrastructure), the shadow price of maize might be much higher than the observed market prices. But are fertilizer application levels too low, given predicted profitability? Taking individual plots, application rates are higher than desirable for between about 15 and 25 percent of current fertilizer users (with an average gap of between 10 and 15 kg across all plots). Thus, many farmers are using too much fertilizer—at least from the perspective of farm profits.

In sum, the study does not support the conventional wisdom. Fertilizer application is not too low compared with what can be considered profitable; rather, the reverse is true. Some Nigerian farmers are applying fertilizer more than what is indicated to be profitable by the study.

The Implications

This study confirms that fertilizer use can be profitable for maize producers in Nigeria. However, at current input acquisition costs and output prices, and given the current yield response to applied nitrogen, such profitability remains a reality for only a subset of maize farmers. The study also shows that current application rates exceed optimal (based on profitability) levels of fertilizer use for some farmers.

Policy Agenda

Since the 1970s, Nigerian governments have tried to stimulate fertilizer demand, grow the commercial fertilizer sector, and lower fertilizer prices. The strategies that have been used to stimulate fertilizer use include subsidies and programs to increase farmers' access to credit. These programs were reported to have not significantly raised fertilizer demand. This study indicates that attention needs to be paid to the profitability of fertilizer use as a key factor driving fertilizer demand. Significant reforms are under way in the Nigerian agricultural sector, particularly on fertilizer. Such reforms (including improvements in infrastructure and increased access to fertilizer and seed for smallholder farmers) might change the results of the study. But these findings could provide a basis for the evaluation of such programs in the future.

The study has three important messages for policy. First, among farmers engaged in the cereal–root crop farming system, nitrogen fertilizers are not profitable for many maize producers under current conditions.

Second, policies to reduce fertilizer acquisition costs, such as transportation policies, could be effective in enhancing fertilizer profitability and use. Such policies would not only raise expected profitability, they would also reduce the risks associated with maize production. The findings of the study call for programs that encourage setting up retail depots within communities or in smaller towns closer to farmers. Although the market price may increase, it is likely that transporting fertilizer in bulk closer to many farmers (say, in a state in Nigeria) would cost less than the cost that many farmers would have to bear to travel individually 40–70 kilometers to a fertilizer distributor.

Third, improving the yield response to nitrogen in Nigeria is key for the profitability of fertilizer use. In addition to the likely gains from complementary input use and improved management practices, more attention likely needs to be paid to understanding and addressing soil health and issues of fertilizer quality. Understanding the soil's organic matter and chemical properties is very important, and likely necessary for any increased use of fertilizer in Nigeria to translate into a meaningful increase in farmer productivity. This will also likely increase the effectiveness of subsidy programs geared to increase farmers' access to inorganic fertilizer. Better understanding of issues related to fertilizer quality could also potentially help explain cases of beyond-optimal use or limited adoption.

Research Agenda

Further research on strategies to increase the efficiency of fertilizer application for maize and other cereals in Nigeria (and Sub-Saharan Africa, more generally) is needed. Such research is crucial for farmers to use fertilizer profitably and increase smallholder demand for the product. Identification and evaluation of schemes to strengthen farmers' links to input dealers are also worthy of further attention. In addition to observed market prices, other factors explain fertilizer use. Therefore, more effort is needed to understand the rationale for the current nitrogen application rates across smallholder farmers.

Additional Reading

This chapter draws on:

Liverpool-Tasie, Lenis Saweda O., Bolarin T. Omonona, Awa Sanou, and Wale O. Ogunleye. 2017. "Is Increasing Inorganic Fertilizer Use for Maize Production in SSA a Profitable Proposition? Evidence from Nigeria." *Food Policy* 67: 41–51. https://doi.org/10.1016/j.foodpol.2016.09.011.

Other key references:

Liverpool-Tasie, L. S., and H. Takeshima. 2013. "Moving Forward with Fertilizer in Nigeria: Fertilizer Promotion Strategies within a Complex Fertilizer Subsector." *Agricultural Economics* 44 (6).

Sheahan, M., R. Black, and T. S. Jayne. 2013. "Are Kenyan Farmers Under-Utilizing Fertilizer? Implications for Input Intensification Strategies and Research." *Food Policy* 41: 39–52.

Snapp, S., T. S. Jayne, W. Mhango, T. Benson, and J. Ricker-Gilbert. 2014. "Maize Yield Response to Nitrogen in Malawi's Smallholder Production Systems." Working Paper 9, Malawi Strategy Support Program, International Food Policy Research Institute, Washington, DC. http://fsg.afre.msu.edu/gisaia/masspwp9_Snapp_et_al_2014.pdf.

Takeshima, H., and L. S. O. Liverpool-Tasie. 2015. "Fertilizer Subsidies, Political Influence and Local Food Prices in Sub-Saharan Africa: Evidence from Nigeria." *Food Policy* 54: 11–24.