Journal of Sustainable Development; Vol. 8, No. 9; 2015
ISSN 1913-9063 E-ISSN 1913-9071
Published by Canadian Center of Science and Education

Factors Affecting the Fertilizer-use Decision of Maize Farmers in Ghana

Alexandra Hill[1] & Barrett E. Kirwan[2]

[1] Department of Agricultural and Resource Economics, University of California, Davis, USA

[2] Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, USA

Correspondence: Barrett Kirwan, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, Urbana, IL 61801, USA. Tel: 1-217-244-1388. E-mail: bkirwan@illinois.edu

Received: August 25, 2015 Accepted: September 6, 2015 Online Published: November 29, 2015

doi:10.5539/jsd.v8n9p273 URL: http://dx.doi.org/10.5539/jsd.v8n9p273

Abstract

This work examines the factors that influence whether or not a farmer applies inorganic fertilizer in the Ghanaian context. Current maize yields in Ghana average only one-third of their estimated potential, but this yield gap can be reduced by improving farming practices and growing conditions in Ghana; specifically, yields in Ghana can likely be increased by intensifying the use of inorganic fertilizer, other inputs, and irrigation systems. Recently, Ghana introduced a fertilizer subsidy program to help increase fertilizer-use rates. This paper examines alternate instruments for increasing fertilizer use by determining farm-holder characteristics correlated with inorganic fertilizer use. The results show that the farmer's distance from the closest weekly market, whether the farmer has a pre-harvest contract, and whether the farmer has property rights on the field have a significant effect on fertilizer use.

Keywords: inorganic fertilizer, Ghana, maize production, agriculture

1. Introduction

Soil quality in Sub-Saharan Africa (SSA) has long been deteriorating, and the soil in Ghana is no exception. Significant soil nitrogen-potassium-phosphorus (NPK) deficiencies have been found throughout Ghana and appear to be at least partially due to poor cultivation practices. Overall, Ghana is estimated to have annual nutrient losses around 60 kg/Ha NPK, among the highest rates in SSA (Stoorvogel, Smalling, & Janssen, 1993; Henao & Baanante, 1999). In fact, current maize yields in Ghana average only one-quarter of their estimated potential, but this yield gap can be reduced by improving farming practices and growing conditions in Ghana; specifically, yields in Ghana can likely be increased by intensifying the use of fertilizer, other inputs, and irrigation systems.

To increase fertilizer use in SSA, governments have several options: decrease the cost of fertilizer; increase the availability of fertilizer; educate farmers on proper application and the benefits of fertilizer (Druilhe & Barreiro-hurlé, 2012). Several African countries have recently begun fertilizer subsidy programs in an attempt to reduce the cost of fertilizer to farmers, including Burkina Faso, Ghana, Malawi, Nigeria, Rwanda, Senegal, Tanzania, and Zambia. Among these countries Ghana serves as an interesting example of a growing economy in which increases in agricultural yields could contribute significantly to economic development. The GDP of Ghana has more than quadrupled since 2004, from $8.9 billion to $40.7 billion, and while the share of the agricultural sector with respect to GDP has been decreasing, the sector remains a large part of the economy; as of 2010, the agricultural sector accounted for about 30% of GDP and employed 42% of the labor force (Food and Agriculture Organization of the United Nations [FAO], 2014). The aggregate value of agricultural production has been significantly increasing, from $5.4 billion in 2004 to $13.2 billion in 2011, despite this decreased share of GDP (FAO, 2014).

1.1 Agriculture in Ghana

Agriculture in Ghana is primarily smallholder, consisting mainly of farms less than two hectares in size. On average Ghanaian farmers do not use very many inputs and very few have established irrigation systems. As a result, agricultural yields vary greatly with the quantity and distribution of rainfall, as well as with the soil quality (Ghana Ministry of Food and Agriculture [MoFA], 2010). Fertilizer application could decrease yield

variability by replenishing soil nutrients. However, current fertilizer use in Ghana averages 6 kg/Ha, representing one of the lowest rates in SSA (Banful, 2009; FAO, 2014).

This article focuses on farmers' decision to use inorganic fertilizer on their maize crop. Maize is the most important smallholder cereal crop in Ghana; it accounts for about 20 percent of their calories, roughly half of it enters into the market, and it accounts for the largest planted area of all food crops in Ghana (Morris, Tripp, & Dankyi, 1999; Braimoh & Vlek, 2006). Current yields average 1.7 mT/Ha, roughly a quarter of their potential according to Ghana's MoFA (MoFA, 2010).

1.2 Potential Determinants of Fertilizer Use

Kyle (2004) give some potential reasons for the low fertilizer use rates in Africa as: (1) high fertilizer costs, (2) lack of irrigation systems, (3) the prevalence of traditional crop varieties that are less responsive to fertilizer, and (4) low incentives to invest in land-saving technologies. Other factors that may impact fertilizer use include availability of information on correct usage, information on the effects of fertilizer use on yields and profits, and the effectiveness of fertilizer on a particular field.

Among these potential reasons for low fertilizer use in Africa, high fertilizer costs and the lack of irrigation systems are the most apparent in Ghana. In 2008, Ghana's fertilizer subsidy reduced the price of fertilizer by one half, yet even at those prices some farmers claimed that the subsidized fertilizer was not affordable (Yawson, Armah, Afrifa & Dadzie, 2010). Farmers who did not use fertilizer or used it at less than recommended rates stated they did so because of the high prices of the product (Banful, 2009). The lack of irrigation systems in Ghana is another potential deterrent of fertilizer use, since only 0.4 percent of the area under cultivation is under irrigation (FAO, 2014).

These potential determinants of fertilizer use only begin to explain the low application rates in Ghana; the literature suggests many other factors that may affect fertilizer application. Neighbors or "information neighbors" have been found to contribute to the farmer's knowledge of fertilizer profitability and management (Foster & Rosenzweig, 1995; Munshi, 2004; Duflo, Kremer, & Robinson, 2008; Conley & Udry, 2010). Lack of access to credit markets has been found to reduce farmers' ability to afford fertilizer at planting season (Ouma, Groote, & Owuor, 2006). A farmer's perception of their risk may alter their fertilizer-use decision (Reardon, 1999). Finally, poor road infrastructure, distance from the market, and lack of suitable transportation can cause the farmer difficulty in physically accessing fertilizer (Fufa & Hassan 2006).

2. Method

2.1 Data

The data are from the Ghana Agricultural Production Survey (GAPS), a project spearheaded by the Ministry of Food and Agriculture of Ghana (MoFA), with support from the Ghana Strategy Support Program (GSSP) of the International Food Policy Research Institute (IFPRI). The GAPS includes questions on plot level production, inputs, revenues, and farmer demographics. This study employs data from the first wave of GAPS, spanning the 2011-2012 major growing season. The GAPS I is a household-level survey collecting data from a total of 8,000 agricultural holders in the country: 10 randomly selected holders in each of 40 enumeration areas in each of 20 districts (two randomly selected districts in each region). Each holder was visited twice during the major season—once during the land preparation and planting period and once after harvest and marketing. Figure 1 shows the regions and districts where the GAPS were employed. The final cleaned GAPS dataset contains observations on 6,102 crops grown by 4,291 holders and includes responses to 297 questions.

2.2 Percent of Farmers Applying Inorganic Fertilizer

Table 1 shows the percentage of farmers in the sample that report applying fertilizer in some amount. The majority of farmers in the sample did not apply any fertilizer. Farmers in the North, however, are considerably more likely to apply fertilizer than those in the South. Less than one-fifth of southern farmers report applying fertilizer in any amount, while slightly more than one-half of farmers in the North report applying at least some fertilizer.

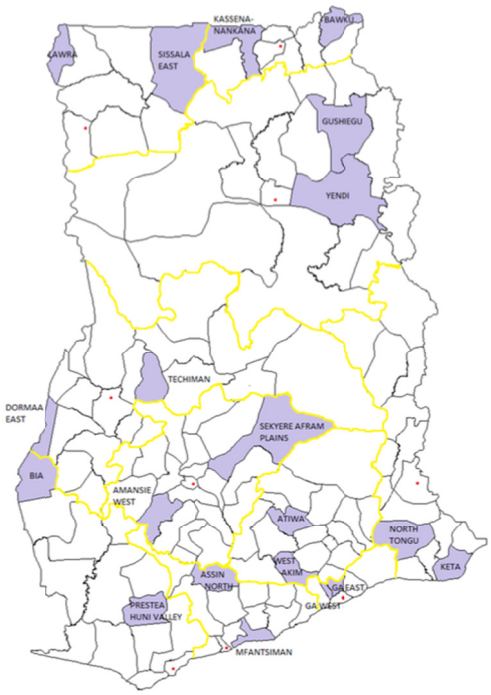

Figure 1. The GAPS districts

Table 1. Percent of farmers applying inorganic fertilizer

	Percent	Total #
Farmers in Northern Ghana	56.79	243
Farmers in Southern Ghana	13.34	757
Farmers in all of Ghana	23.9	1000

2.3 Observable Differences Between Farmers Who Use Fertilizer and Those Who Do Not

Panels A and C of table 2 illustrate substantial differences in the characteristics discussed above between farmers who use fertilizer and those who do not. Fertilizer users spend less on non-fertilizer inputs such as seeds, machinery to plough/till, pesticides, herbicides, and labor-tending. These expenditure patterns might indicate that farmers intensify use of other production inputs in lieu of fertilizer. Although users and non-fertilizer users are roughly the same age, fields used by fertilizer users have been cultivated for a substantially longer time. About 89 percent of both groups list farming as their primary occupation. Fertilizer users operate slightly larger farms, but farmers who use fertilizer are about 65-percent more likely to have property rights to their land. Interestingly, fertilizer users generally have less education than non-users.

Panels B and D of table 2 report summary statistics for characteristics that are likely to affect maize yield through their effect on fertilizer use. One of the most important determinants of fertilizer use is the price, and fertilizer users face a lower fertilizer price. The holder's heads of goats as well as the household characteristics serve as indicators of the farmer's level of income and development. Fertilizer users, however, have slightly fewer goats.

Table 2. Summary statistics of variables for access to fertilizer

	Fertilizer (N=239)		No Fertilizer N=(761)	
	Mean	Median	Mean	Median
A.				
Seeds	8.75	0	9.06	0
Plough/Till	21.05	0	32.25	0
Pesticides	0.56	0	1.81	0
Herbicides	4.49	0	15.69	2
Labor-Tending	3.41	0	9.21	0
Age	46.32		47.5	
Number of Chickens	13.38		6.26	
Years Cultivating	26.78		9.96	
Total Area (Ha)	1.68	1.21	1.19	0.49
B.				
District Price NPK	32.89	30.45	41.91	35
Distance Extension Agent (km)	67.46		47	
Extension Visits	0		0	
Time to Weekly Market (min)	42.83		54.64	
Head of Goats	1.23		1.42	
	Percent		Percent	
C.				
Holder has Property Rights	41. 00		24.97	
Farmer	89.54		89.22	
Household Head Male	89.12		72.54	
No Education	63.6		50.33	
Kindergarten	0		0	
Primary	7.53		9.99	
Middle	9.21		12.61	
Secondary	15.48		24.57	
Beyond	4.18		2.5	
D.				
Access Credit	0.84		4.6	
Pre-Harvest Contract	0.84		1.31	

2.3.1 The Fertilizer Subsidy Program

In the 2008 and 2009 fertilizer subsidy program, extension agents distributed vouchers for reduced-price fertilizer that could be purchased from participating fertilizer dealers. Both the extension agents and the participating fertilizer dealers were located in the district capitals (Banful, 2009). Farm operations farther from the district capital were less likely to receive a voucher and less likely to redeem it if they did receive one. It is plausible that this discrepancy will last over time as farmers farther from district capitals are less familiar with the fertilizer subsidy program. The summary statistics indicate, however, that on average farmers who use fertilizer are farther from the extension-agent office in the district capital than non-fertilizer users. But fertilizer users are closer to weekly markets where information about the fertilizer program might be exchanged.

2.3.2 Potentially Important Determinants of Fertilizer Use

Whether the holder accesses credit may influence their ability to purchase fertilizer at the time it is needed. And whether the holder had a pre-harvest contract could indicate that there were agreed upon inputs, that the contractor helped pay for inputs, or simply that the farmer had less uncertainty in their post-harvest profits. It is thus unexpected to see that farmers who use fertilizer have less access to credit and are less likely to have a pre-harvest contract.

2.3 Modeling the Farmer's Fertilizer-use Decision

A farmer's decision to apply fertilizer is a binary outcome likely dependent on the factors that determine fertilizer profitability, the factors that contribute to the farmer's knowledge of effective fertilizer application practices and knowledge of its true profitability, and the factors that impact the farmer's ability to access fertilizer. While these are reasonable expectations of what factors impact the fertilizer-use decision of farmers in Ghana, the actual factors are unknown. To begin to determine what factors are significant and how they impact the farmer's decision, a linear probability model is implemented using Ordinary Least Squares (OLS) with fertilizer use as the outcome variable, taking on 1 if the farmer applied any fertilizer and 0 if they did not. A linear probability model is estimated instead of a nonlinear model because it is easy to interpret, because the odds ratio is not very close to 0 or 1, and because the farmer's decision to apply fertilizer most likely does not follow a standard normal distribution. The following equation is used to determine the effects of various factors on the farmer's decision to apply fertilizer (F):

$$P(F = 1|X) = X'\beta. \quad (1)$$

Where X is the vector of chosen regressors, and the parameters β are estimated using least squares. The vector of X's that were chosen consists of variables that could influence any of the factors in the farmer's decision function. Because those factors are functions of a large number of variables, examining the impact of those variables on the farmer's decision could provide insight as to how farmers in Ghana make this decision. To strengthen these results, a probit model was estimated with fertilizer use as the outcome variable, using the same set of regressors as in the linear probability model, and including indicator variables to control for district.

3. Results

To determine which variables are significantly correlated with fertilizer application, all of the variables reported in table 2 are used in the linear probability model for fertilizer application, equation 1.

3.1 Results for the Entire Country

Table 3 shows that among our variables of interest the farmer's decision to apply fertilizer is significantly correlated with the distance from the nearest weekly market and whether the farmer had a pre-harvest contract. The first column shows the regression results for the linear probability model including all control variables, using district fixed effects, and using robust standard errors clustered at the district level. The second column shows the results for the probit model including all control variables, using indicator variables for each district, and using robust standard errors clustered at the district level. In both models, the only variables that are significant at least the 10-percent level are the farmer's distance from the weekly market and whether the farmer has property rights over the field. Both regressions reveal that an increase in the time it takes the farmer to get to the weekly market decreases the probability that the farmer applies fertilizer and that having a pre-harvest contract increases the probability that the farmer applies fertilizer. The linear probability model is simply interpreted as an increase of 10 minutes to the distance from the weekly market decreases the probability of the farmer applying fertilizer by 0.011 percent, and the farmer having a pre-harvest contract increases the probability by 0.141. The results of the probit model are not as straightforward, and the coefficients are interpreted as changes to the z-score, however the probit model is mainly included as a check for the linear probability model, and since the results appear similar the discussion only address the linear probability model.

3.2 Results for the North and South Separately

Given the disparity in fertilizer use rates between the North and South, the significant factors in the fertilizer-use decision are examined separately for farmers in these areas. These results are shown in table 4. These results show that for farmers in the North, the only significant variables of interest are the distance from the weekly market and whether the holder has property rights, while for farmers in the South, whether the holder's primary occupation is farming and whether the farmer had a pre-harvest contract matter. Specifically, for farmers in the North, an additional 10 minutes to the weekly market decreases the probability that the farmer will apply fertilizer by 0.0141 and the holder having property rights on the field increases the probability they will apply fertilizer by 0.217.

Table 3. Farmer's decision linear probability model results

Dependent Variable: Fertilizer Dummy	Linear Probability Model	Probit Model
Distance from Extension Office	0.00035	0.00319
	-0.000965	-0.00525
Minutes from Weekly Market	-0.00110**	-0.00791**
	-0.000492	-0.00373
Holder Farmer	-0.0148	-0.081
	-0.0291	-0.184
Accessed Credit	-0.0451	-0.365
	-0.0633	-0.435
Pre-Harvest Contract	0.141*	0.971***
	-0.0719	-0.146
Holder Has Property Rights	0.0194	0.137
	-0.0621	-0.289
Observations	1000	1000
R-Squared	0.1	0.479

Notes: ***Significant at the 1 percent level **Significant at the 5 level percent level *Significant at the 10 percent

For farmers in the South, the holder's primary occupation being farming reduces the probability of applying fertilizer by 0.0524. This variable may also be indicative of wealth, since holders who are not primarily farmers, particularly in the South where there are more off-farm work opportunities, may be able to earn more money in other jobs and use that to help pay for inputs.

3.2.1 The Effect of Credit Access

The coefficient for whether the farmer accessed credit is negative in all models and is negative and significant in the linear probability model for farmers in the South. This suggests that farmers who obtain loans (these loans are specifically for their crops) are not allocating this money toward fertilizer for maize; these farmers may be spending the loans on inputs for other crops, more likely cash crops, or they may be spending it on inputs or practices besides fertilizer.

3.2.2 The Effect of Pre-harvest Contracts

We find that farmers who have a pre-harvest contract are more likely to apply fertilizer. Having a pre-harvest contract increases the probability by 0.204. Some preharvest contracts specify agreed upon inputs, which can include fertilizer, but even without those specifications, pre-harvest contracts provide farmers with more knowledge of their future revenues, so they may be more willing and able to invest in inputs.

Table 4. Farmer's decision linear probability model results for North and South

Dependent Variable: Fertilizer Dummy	North	South
Distance from Extension Office	0.00437	-0.00121
	-0.00635	-0.00108
Distance from Weekly Market	-0.00141***	-0.000317
	-0.000295	-0.000513
Holder Farmer	0.108	-0.0524*
	-0.0911	-0.0243
Accessed Credit	-0.046	-0.0172
	-0.297	-0.0132

Pre-Harvest Contract	0.172	0.204**
	-0.22	-0.0697
Holder Has Property Rights	0.217*	-0.00373
	-0.106	-0.0732
Observations	243	757
R-Squared	0.302	0.108

Notes: ***Significant at the 1 percent level **Significant at the 5 percent level *Significant at the 10 percent level

4. Conclusion

To determine other policies that may increase fertilizer use, this work has analyzed the factors that are significantly correlated with maize farmers' fertilizer application decision. Determining these factors could identify new policies to increase yields by impacting farmer or farm characteristics that encourage fertilizer use. The results show that fertilizer use is significantly correlated with the distance from the nearest weekly market and whether the farmer had a pre-harvest contract. These variables indicate that policies focused on increasing physical access to fertilizer and output-price security should be viable policy options for increasing fertilizer use and thus yields in Ghana. Further, for farmers in the North, providing long-term incentives to farmers without property rights to encourage soil maintenance should increase the probability of the farmer applying fertilizer.

Acknowledgments

The authors would like to thank Alex Winter-Nelson and Hope Michelson for helpful discussions and comments, and Shashidhara Kolavalli at the International Food Policy Research Institute and James Ayittey at the Ghana Ministry of Food and Agriculture for providing access to the data.

References

Banful, A. B. (2009). *Operational Details of the 2008 Fertilizer Subsidy in Ghana— Preliminary Report*. International Food Policy Research Institute. Washington, D.C.

Braimoh, A. K., & Vlek, P. L. G. (2006, June). Soil quality and other factors influencing maize yield in northern Ghana. *Soil Use and Management*, *22*(2), 165–171. http://dx.doi.org/10.1111/j.1475-2743.2006.00032.x

Conley, T. G., & Udry, C. R. (2010). Learning About a New Technology: Pineapple in Ghana. *American Economic Review*, *100*(1), 35–69. http://dx.doi.org/10.1257/aer.100.1.35

Druilhe, Z., & Barreiro-hurlé, J. (2012). *Fertilizer subsidies in sub-Saharan Africa*. Food and Agricultural Organization of the United Nations. Rome.

Duflo, E., Kremer, M., & Robinson, J. (2008). How high are rates of return to fertilizer? Evidence from field experiments in Kenya. *The American Economic Review*, 482-488. http://dx.doi.org/10.1257/aer.98.2.482

Food and Agriculture Organization of the United Nations. (2014). FAOSTAT.

Foster, A. D., & Rosenzweig, M. R. (1995). Learning By Doing and Learning From Others: Human Capital and Technical Change in Agriculture. *Journal of Political Economy*, *103*, 1176–1209. http://dx.doi.org/10.1086/601447

Fufa, B., & Hassan, R. (2006). Determinants of Fertilizer Use on Maize in Eastern Ethiopia: A Weighted Endogenous Sampling Analysis of the Extent and Intensity of Adoption. *Agrekon*, *45*(1), 38–49. http://dx.doi.org/10.1080/03031853.2006.9523732

Henao, J., & Baanante, C. (1999). *Nutrient Depletion in the Agricultural Soils of Africa*. IFPRI. Washington, D.C.

Kyle, S. C. (2004). Reforming agricultural markets in Africa (review). *Africa Today*, *50*(4), 120–122. http://dx.doi.org/10.1353/at.2004.0051

MoFA. (2010). *Facts and figures (2010)*. Ghana Ministry of Food and Agriculture. Ghana.

Morris, M. L., Tripp, R., & Dankyi, A. A. (1999). *Adoption and Impacts A Case Study of the of Improved Ghana Grains Maize Production Development Project Technology: Adoption and Impacts of Improved Maize Production Technology : A Case Study of the Ghana Grains*. CIMMYT. Mexico, D.F.

Munshi, K. (2004). Social learning in a heterogeneous population: technology diffusion in the Indian green revolution. *Journal of Development Economics*, *73*(1), 185–213. http://dx.doi.org/10.1016/j.jdeveco.2003.03.003

Ouma, J. O., de Groote, H., & Owuor, G. (2006). Determinants of Improved Maize Seed and Fertilizer Use in Kenya: Policy Implications. In *International Association of Agricultural Economists conference, Gold Coast, Australia* (p. 16).

Reardon, T. (1999). Global change in agrifood grades and standards: agribusiness strategic responses in developing countries. *The International Food and Agribusiness Management Review*, *2*(3-4), 421–435. http://dx.doi.org/10.1016/S1096-7508(01)00035-0

Stoorvogel, J. J., Smalling, E., & Janssen, B. (1993). Calculating Soil Nutrient Balances in Africa at Different Scales. *Fertilizer Research*, *35*, 227–235. http://dx.doi.org/10.1007/BF00750641

Yawson, D. O., Armah, F. A., Afrifa, E. K. A., & Dadzie, S. K. N. (2010). Ghana's Fertilizer Subsidy Policy: Early Field Lessons From Farmers in the Central Region. *Journal of Sustainable Development in Africa*, *12*(3), 191–203.