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Full Length Research Paper

Factors that control the adoption of inorganic fertilizer by maize farmers. A case of Kakamega District, Western Kenya

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This study identifies the factors that influence adoption of inorganic fertilizers by maize farmers in Kakamega District. A probit model was used to analyze data collected from 169 maize farmers. The results showed that growing of a cash crop, off-farm income, access to an agricultural extension agent and use of improved maize seed positively and significantly influenced adoption of inorganic fertilizer. Households with more tropical livestock units were less likely to use inorganic fertilizer and instead used animal manure. The inorganic fertilizers used supplied two nutrients mainly phosphorous (P) and nitrates (N). Potassium (K) rich fertilizers were not used despite the fact that maize requires 3 nutrients N, P and K. Almost 80% of the farmers used very low amounts (< 10 kg ha^{-1}) of Diammonium Phosphats (18:46:0) and UREA (46:0:0) or CAN (26:0:0) in a given season. Given the low inorganic fertilizer application rates, the farmers are unable to maintain or improve high maize yield. Therefore, efficiency and targeted application of inputs among the low-input farms should be improved in order to raise maize productivity. Testing the soils for nutrient status will improve precision and efficiency of inorganic fertilizers and boost maize productivity.

Key words: Probit analysis, income, markets, extension agents, productivity.

INTRODUCTION

Declining soil quality on farmlands in SSA undermines prospects for ending chronic poverty and food insecurity in the region (Morris et al., 2007). Low use of fertilizer and degraded soils are the major factors limiting agriculture productivity in SSA (Vlek, 1990), where soil nutrient outflows far exceed inflows in most farming systems resulting in negative nutrient balances (Sanchez et al., 1997; Vanlauwe and Giller, 2006; Vanlauwe et al., 2010). Studies of soil nutrient balance across countries in SSA show evidence of widespread nutrient mining leading to nutrient deficiencies across agro-ecological zones (Smaling et al., 1993).

Recent estimates show that SSA faces what the World Bank study referred to as “an escalating soil fertility crisis” (Morris et al., 2007). The region lost 4.4 million tons of nitrogen, 0.5 million tons of phosphorous, and 3 million tons of potassium during the period of 1980–2004, costing the continent more than $ 4 billion worth of soil nutrients per year (IFDC, 2006). The importance of soil nutrient depletion to the overall economic development in SSA was confirmed by the June 2006 international fertilizer summit in Abuja, Nigeria, attended by representatives of forty African heads of state and governments. The summit resolved that fertilizers were strategic inputs in SSA because soil nutrient recapitalization is crucial for raising agricultural productivity in a region lagging in food production and fertilizer use (IFDC, 2006). SSA has the lowest fertilizer use of any region in the world, only 8 kg ha^{-1} annually, against a world average of 93 kg ha^{-1} annually and 200 kg ha^{-1} per year in East Asia (IFDC 2006).

Smaling et al. (1993), for example, showed that average annual net mining from the soils in western

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Kenya was 42 kg ha^{-1} of nitrogen (N), 3 kg ha^{-1} of phosphorous (P) and 29 kg ha^{-1} of potassium (K). As a result, improving on farm soil fertility management is recognized as a major factor in reversing the declining trends in per capita food production and land degradation (Donovan and Casey, 1998).

Reversing these trends through investments in soil fertility is crucial to agricultural productivity and poverty (Place et al., 2003).

In Kenya, most farms fail to make sufficient soil fertility replenishment investments, resulting in declining soil fertility, low returns to agricultural investment, decreased food security and high food prices (Odera et al., 2000). For this reason, the full potential of improved crop varieties cannot be realized even with maximum adoption of the same. Crop production in the region is strongly limited by soil N, K and available P. The gap between the actual and the attainable yield of maize may be as wide as 5 t grain ha^{-1} $year^{-1}$ (Rutunga et al., 2003).

In western Kenya, maize is the most important crop as well as the staple food. Studies in Western Kenya region consistently reported that maize yields are lower than the expected yields based on research recommendations. For example, the annual maize yield in the region was 27% less than the potential yield (1.80 against 6.67 tons ha^{-1}) (Salasya et al., 2007). According to earlier findings, the first constraint in maize production is low soil fertility (Vanlauwe et al., 2010).

Unfortunately, the use of fallow land to allow restoration of soil fertility is no longer a viable option in Kakamega District, due to land scarcity caused by the declining average land holding per household occasioned by rapid population growth. The current population exerts pressure on land to meet household basic needs such as food, employment and income. There is no possibility of area expansion in Kakamega since the forest frontiers are closed. Therefore, farmers struggle to maintain production levels by increasing cropping intensity, intercropping and multiple cropping which further cause soil mining.

Attaining improved food security and livelihoods of farmers in Kakamega through increased agricultural productivity will remain an illusion if soil mining and land degradation remain unchecked. However, this situation can be reversed if farmers extensively adopt the use of recommended soil improvement strategies such as inorganic fertilizer to increase productivity. Unfortunately, adoption of inorganic fertilizer is still low in the region despite research findings that this could be a feasible and profitable soil fertility maintenance option that is consistent with farmers' risk preference (Freeman and Omiti, 2003). So far, no deliberate effort has been made to understand the factors influencing fertilizer among maize farmers in Kakamega. The objective of this study is to determine factors that influence use of fertilizer in maize production. "Inorganic fertilizer use" was defined as the application of any amount of basal or top-dress fertilizer to the field in 2006 by the respective farmers.

MATERIALS AND METHODS

A survey was carried out on 169 farm-households from Kakamega District in the month of December, 2006. The district is comprised of Lower Highland (LH), Upper Highland (UH), Lower Midland (LM) and Upper Midland (UM) Agro-ecological zones (AEZs). The southern part of the district is classified as Lower Highland (LH) mainly growing tea and the northern part is mainly Lower Midlands (LM) and classified as sugarcane growing areas (Jaetzold and Schimdt, 1982). Sampling of households was done using the Kenya's fourth National Sample Survey and Evaluation Programme (NASSEP IV) document; that is used as a master sampling frame designed to guide household surveys in Kenya. The clusters are found in different rural sub-locations and represent the typical livelihood zones of the district. This study used a two-stage sampling design. First 13 clusters were randomly selected. After identifying the clusters to be visited, 13 households were randomly pre-selected from each cluster. Interactive structured questionnaire surveys and general field observations were used to solicit answers and responses to issues on household socio-economic information, gender dimension, maize production, and land use dynamics, for example, land acquisition, tenure, farm sizes, and share of fallow land.

Response to the use of inorganic fertilizer as an agricultural intensification strategy was recorded as a binary variables represented by 1 if yes or 0 for no. Since the dependent variable is dichotomous, the use of linear probability models is not appropriate because the predicted value can fall outside the relevant probability range of 0 and 1. To overcome this problem, logit or probit models have been recommended (Gujarati, 1988). Logit and probit models translate the values of the independent variables (X_i), which may

range from $-\infty$ to $+\infty$, into a probability for Y_i

which ranges

from "0" to "1" and compel the disturbance terms to be homoscedastic. The forms of probability functions depend on the distribution of the difference between the error terms associated with a particular choice.

The probit and logit models assume the existence of an underlying latent variable y^* for which a dichotomous realization is observed (Gujarati, 1988), thus:

$$y^* = \beta_0 + \sum_{j=1}^{k} \beta_j x_{ij} + \varepsilon_i \quad (1)$$

where y^* is not observed and commonly called a latent variable and includes desire or ability to use a technology. What is observed is a dummy variable y_i defined by:

$$y_i = \begin{cases} 1 \approx y^* > 0 \\ 0 \approx otherwise \end{cases} \quad (2)$$

Probit was used in this study since the results are similar with logit. Probit model was used to determine factors affecting use of fertilizer as a capital-intensive strategy as follows:

$$Y_i = \alpha + \beta_i \quad X_i + \varepsilon_i \quad (3)$$

Where Y_i is the observed response of the i^{th} farmers' using inorganic fertilizer, while X_i are the factors that affect the

Table 1. Socio-economic characteristics of households according to zones in Kakamega District in the year 2006.

Variables		Ikolomani and Shinyalu N=85	Lurambi and Navakholo N=84
Household characteristics			
Age of household head (yrs)	Mean	47.3 (1.45)	45.0 (1.31)
Household size (number)	Mean	6.5 (0.21)	5.7 (0.24)
Gender (%)	Male	45.0	88.2
Occupation (%)	Farmer	52.6	69.7
	Informal sector	30.2	15.8
	Formal sector	17.2	14.5
Farm level characteristics			
Total farm size (ha)	Mean	0.9 (0.01)	1.1 (0.02)
Per capita farm size (ha)	Mean	0.2 (0.00)	0.2 (0.01)
Land share maize crop (ha)	Mean	0.5 (0.01)	0.3 (0.03)
Distance to access road (km)	Mean	0.5 (0.02)	0.8 (0.18)
Distance to market (km)	Mean	2.6 (0.21)	4.4 (0.18)
Tropical Livestock Unit (TLU)	Mean	2.7 (0.16)	2.4 (0.29)
Cash crop on farm (%)	Yes	14.2	52.0
Number of extension visit yearly (%)	None	78.0	76.0

Numbers in parenthesis present the Standard Errors of the means.

probability that a farmer uses inorganic fertilizer and include: farm size, market access and socio-economic characteristics of the households, α is the intercept and β are the parameters estimated, ε_i comprises the unobserved errors.

The choice of independent variables for this study was based on the adoption literature (Adesina and Zinnah, 1993). The farm households' decision to adopt use of inorganic fertilizer may be related to the characteristics and composition of the household, the size of the farm, and capital out lay of the household. The household composition and characteristics were captured by the number of household members, age, and gender of the household head.

Age (*hhage*) and education (*hi_educ*) represent the human capital. The influence of age on adoption is described as a composite of the effect of farming experience and planning horizon (Fernandez-carnejo et al., 2001). Older farmers are known not to be enthusiastic about a new technology, especially if the benefits are not expected in the near future, but at the same time, farmers with advanced age are associated with more experience and thus likely to adopt.

Gender (*hhgender*) represents the household heads' differences in terms of access to assets, education and other critical services such as credit, technology and input supply. In many developing countries, male-headed households have higher access to resources and information more than the female-headed households, and therefore greater capacity to adopt technologies (Kaliba et al., 2000). Household size (*tthhno*) is often linked to supply of farm labour and exerts a positive effect on adoption of relatively labour-intensive technologies.

Farm characteristics are represented by farm size and land tenure systems which affects adoption in different magnitudes and direction. The effect of land size is mixed in that large farmers are assumed to be less risk averse and therefore able to adopt new technologies, or they could be under less pressure for alternative ways to improve their income via new technologies, while small farmers adopt labour intensive technologies as they use relatively more family labour which has low opportunity cost (Genius et al., 2006).

In most developing countries, farmers are often cash strapped and unable to meet their financial obligations. Whenever deemed appropriate, households convert assets into cash, implying that the assets accumulated may be used to judge a household's wealth status. Ownership or access to assets that can be put to productive use is the cornerstone of the capacity of poor households to chart a route out of poverty (Moser and Barrett, 2003). The Total Livestock Units (TLU) number and off farm income are important measures of household assets, which signify the wealth status of the household, and are expected to have a priori positive sign for influencing the use of inorganic fertilizer (Janke, 1982). Distance to the market is expected to have a negative impact on the use of inorganic fertilizers. The further away farmers are from markets the lesser they consider profitability as an objective of farming but rather self-sufficiency and hence less willingness to purchase inorganic fertilizer. Distance to access road is also expected to be negatively related with the use of inorganic fertilizers since they increase the transaction costs.

Contact with extension agent could have a positive effect on use of inorganic fertilizers in maize production based on innovation-diffusion theory. Such contacts expose the farmers to availability of information and can be expected to stimulate adoption (Polson and Spencer, 1991). However, some adoption studies have shown that contact by farmer with agriculture extension agent has had mixed impact in developing countries by either not having any effect at all or positive effect (Moser and Barrett, 2003).

RESULTS

Farmers in the study area were considered to be smallholder farmers since their farms are less than 12 ha. Table 1 shows the socio-economic characteristics of the sampled population. The tea zone is comprised of

Table 2. Percentage of households using different amounts (kg ha^{-1}) of fertilizer in maize production in selected administrative divisions of Kakamega District, in 2006.

Amount of fertilizer application (kg ha^{-1})	Percentage (%) of households per division			
	Navakholo (n=42)	Lurambi (n=42)	Shinyalu (n=44)	Ikolomani (n=41)
0	25	29	9	10
1-5	45	21	40	50
5.1-10	10	40	21	15
>10	20	10	30	25

Shinyalu, and Ikolomani divisions of Kakamega District, while the sugarcane zone is comprised of Lurambi and Navakholo divisions. Over 50% of the farmers practiced farming as their main occupation. This varied between the zones with 52 and 69% in the tea and sugarcane zone relying on farming as main occupation, respectively. Other main occupation included the informal sector with approximately 30 and 16% of the household heads from the tea and sugarcane zones respectively. Only 25% of the household heads had regular off-farm employment with occupation as teachers or civil servants being the main career. All farmers grew maize annually, either as a mono-crop or intercropped with beans. The average area under maize per household was 0.4 ha.

The relative importance of the industrial crops for commercial purpose differed between the Northern and the Southern parts of the districts. Thus, 52% of the farmers in Lurambi and Navakholo grew sugarcane as a commercial crop. Only 14% of the farmers had tea as a commercial crop in Shinyalu and Ikolomani. It was noted during the survey that most tea plantation were over twenty years old. Therefore, farmers were not planting any new tea plantation in the study area.

Inorganic fertilizer was used in maize production by approximately 70% of the households, even though it was sub-optimally applied. The main type of mineral fertilizer used in all sub-locations was Diammonium Phosphate (DAP) (18:46:0) which was mainly applied at planting, followed by Calcium-Ammonium Nitrate (CAN) and Urea (46:0:0) mainly for top dressing. There was a variation in the amount of the inorganic fertilizer used ha^{-1} per season across the selected administrative divisions as shown in Table 2. The administrative divisions were Navakholo, Lurambi, Shinyalu and Ikolomani. In Navakholo and Lurambi divisions, 25 and 29% of the farmers respectively do not use inorganic fertilizer, while Shinyalu and Ikolomani divisions, 9 and 10% of farmers were not using inorganic fertilizer respectively. At least 20% of the farmers used between 1-10 kg ha^{-1} of inorganic fertilizer in maize production in the year 2006 in all the divisions. Over 70% of the farmers perceived that anyone who used inorganic fertilizer (ranging from 1- >10 kg ha^{-1}) was an adopter of the same. They admitted that if it were not for the high cost of the inorganic fertilizer, they were willing to apply more fertilizer ha^{-1} per planting season.

There was a significant and positive influence of the current use of improved maize seed and the use of inorganic fertilizer in the study area. The estimated coefficients and P-values from the probit model regression analysis are presented in Table 3.

The presence of a cash crop (tea and sugarcane) on the farm had a positive and significant influence on the use of inorganic fertilizer in maize production. The cash crop industries supplied farmers with inorganic fertilizer for their respective cash crop. However, many farmers diverted some of this inorganic fertilizer for maize production on their own farms thus improving the nutrient balances.

A positive relationship observed between off-farm income and use of the inorganic fertilizer supports the hypothesis that off-farm income was used for purchasing the inorganic fertilizer among other farm inputs like the hybrid maize seed.

The number of contacts a farmer had with an extension agent in a year also had a positive and significant influence on the use of inorganic fertilizer, reflecting the role played by access to information on adoption decision. From this analysis, it is clear that government extension was the most preferred information source by the selected population, which ranked first with a score index of 0.27. Field days and other farmers ranked second with a score index of 0.16 each, while mass media (radio and television) ranked third with a score of 0.11.

Although, the distance to input and output markets had a negative sign (shows market access is important) it does not significantly influence the use of inorganic fertilizer in maize production. The study established that sugarcane and tea industries supply inorganic fertilizer at farm gate to commercial crop out growers who later sell some of it to the neighbors. This explains why the distance to the market had the expected negative sign, but did not significantly influence the adoption of fertilizer. It may also be an indication of an improvement in distribution of inorganic fertilizer. The growth in the inorganic fertilizer input outlets, and distribution by the cash crop companies had increased availability and access of the input in rural Kakamega.

DISCUSSION

The farmers that used improved maize seed had a high

Table 3. Probit results of factors affecting the adoption of inorganic fertilizers by farmers of Kakamega District, 2006.

Variable	Coefficient	P-value
Constant	-0.277	-0.81
Used improved seed since 1994	-0.12	-0.662
Age of household head (years)	0.033	-0.354
Total number of people resident in household	-0.045	-0.405
Distance from farm house to nearest market	-0.026	-0.719
Farm size	-0.028	-0.618
Current use of improved maize seed	0.692	(0.056)**
Tropical livestock unit	-0.002	-0.506
Household has a cash crop (sugarcane or tea)	0.224	(0.004)***
Number of contact with extension agent in a year	0.267	(0.101)*
Farmers' experience squared	-0.001	-0.307
Gender of household head (1=male, 0 female)	0.388	-0.171
Off farm income	0	(0.049)**
Statistics		
N	169	
Log likelihood function	-62	
Pseudo R	24	
Dependent variable	Fertilizer adoption by farmer (1=yes, 0=no)	

***Significant at 1% level of error probability, **Significant at 5% level of error probability and *Significant at 10% level of error probability.

probability of using inorganic fertilizer compared to those who did not use improved maize seeds. This is attributed to the responsiveness of the improved maize seed to inputs, thus becomes an important catalyst for the adoption of the inorganic fertilizer (Morris and Byerlee, 1998).

The presence of a cash crop (tea and sugarcane) on the farm had a positive and significant influence on the use of inorganic fertilizer in maize production. It was earlier observed that increased production of commercial crops not only raises returns to land and labor but also have significant benefits for soil fertility as well as for other food crops production in the area where the cash crops are grown (Poulton et al., 2001). This result was consistent with the above findings by Poulton et al. (2001).

It is acknowledged that farmers are likely to be influenced to make adoption decisions by information sources which they consider most important since such sources are associated with reliability and credibility (Rogers, 2003). The result shows the important role played by extension agents as sources of information that influence adoption of inorganic fertilizers.

The government extensions were the most preferred source of agricultural information. Field days and other farmers ranked second, while mass media (radio and television) ranked third. This indicates that farmers' still trust the government extension service when it comes to delivery of agricultural information. It is not only important to avail farmers with the information about a new innovation, but also the method of delivering this information is critical in determining adoption. The high preference for field days by the sampled population corroborates the findings of Murage et al. (2011) on farmers' preferences for Push pull technology dissemination pathways in stemborer and striga weeds control. The results could be attributed to the properties of the field days where physical demonstrations is done, thus farmers are able to see and even have hands-on experience on the technology being disseminated (Murage et al., 2011). Over 70% of the surveyed farmers admitted that if it were not for the high cost of the inorganic fertilizer, they were willing to apply more fertilizer ha^{-1} since they were aware of its importance. The farmers desire to buy and use inorganic fertilizer for alleviation of soil fertility depletion could be attributed to promotion of mineral fertilizers by the Government of Kenya as the most important input for improving soil fertility. This was echoed by the June 2006 International Fertilizer Summit which resolved that soil nutrients from both organic and inorganic sources are strategic inputs for raising agricultural productivity in Africa, but emphasized increased use of mineral fertilizers because of low levels of soil nutrients in Africa (IFDC, 2006). However, the farmers have accepted and are willing to adopt inorganic fertilizers in their farming system; but it is not affordable and accessible given the fact that they are subsistence producers.

Conclusion

The results show that farmers in the study region do

apply the inorganic fertilizers even though the application levels per unit area were low. Perhaps testing of the soil nutrient before fertilizer application will improve precision and efficiency of the same. This information is relevant to research organization and policy makers in devising strategies for improved uptake of fertilizer.

Off farm income, number of contacts with the extension agents and the current use of improved maize seed positively influence the use of inorganic fertilizers in maize production.

The role of information in farming cannot be overemphasized. Agricultural information reaches the targeted population via different pathways each of which has different adoption enhancement capabilities. The results showed that the sampled population mainly accessed information from government extension agents, print media, and other farmers. However, the most preferred source of information was government extension service. The implications for this finding is that since farmers seemed to still trust the information from the government, efforts should be made to avail this information preferably through print media such as farmers magazines and newspapers which could probably be distributed periodically to farmers as reference materials.

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