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Fertilizer use in semi-arid areas of Kenya: analysis of smallholder farmers' adoption behavior under liberalized markets

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Abstract

This paper analyzes the factors influencing farm level fertilizer adoption decisions under an era of liberalized markets in Kenya using a Tobit regression model. The level of education of the household head, experience using fertilizer, growing a cash crop, availability of fertilizer in rural retail outlets, availability in small packages, and land pressure positively influenced fertilizer use, while the size of family labor and location in the drier semi-arid zone were negatively associated with fertilizer use. The paper concludes with policy and research implications for strategies aimed at achieving greater fertilizer use on smallholder farms.

Introduction

Improving soil fertility management on smallholder farms is increasingly recognized as a major issue in reversing the declining trends in per capita food production in Africa (Donovan and Casey 1998; Scoones and Toulmin 1999). Sustained fertilizer use has been an important factor in increasing crop productivity in many countries, but use of the input remains very low in sub-Saharan Africa. Average consumption of fertilizer in 1998 was 13.8 kg of nutrients per hectare of arable and permanently cropped land (UNDP 2001). Adoption of fertilizer is even lower in semi-arid areas, despite research findings that fertilizer can be a feasible and profitable soil fertility maintenance option that is consistent with farmers' risk preferences (McCown and Jones 1992; Sanders et al. 1996). Low adoption of fertilizer in semi-arid areas has been attributed to high levels of risk associated with low and highly variable rainfall patterns, inefficient input distribution systems that make the input unavailable when it is needed, unavailability of the input in rural retail shops, and difficulty farmers have in assessing the relative returns to fertilizer (Sanders et al. 1996; Rohrbach and Okwach 1999; Rao and Mathuva 2000).

Widespread and intensive use of fertilizer in semi-arid areas is particularly important in Kenya, where about two-thirds of the country is semi-arid and many farmers depend on small-scale dryland agriculture (Probert 1992). The policy goal of increasing fertilizer use among smallholder farmers has resulted in a series of policy changes since independence (Nyangito and Kimenye 1995). Prior to the mid-1980s, the government was extensively involved in the import, pricing, and marketing of fertilizer using policy instruments such as price subsidies, price control, licensing of importers and distributors, and import quotas. A state parastatal, the Kenya Farmers Association (KFA) – which later became the Kenya Grain Growers Cooperative Union (KGGCU) – had significant control over fertilizer procurement and domestic distribution. These policies diminished the role of the private sector in fertilizer pricing and marketing and led to a near monopoly status of the KFA with the parastatal controlling over 80 percent of the fertilizer market in Kenya by the early 1980s (Agriconsult, undated). During this period access to fertilizer in rural areas was difficult, particularly in semi-arid areas with poor infrastructure, and where many smallholder farmers did not use the input. This widely perceived failure in fertilizer policy put increasing pressure on the government to liberalize fertilizer markets, culminating in a series of policy changes between 1983 and 1993 (Argwings-Kodhek 1996). These policies included authorization of a surcharge on small fertilizer packages that allowed traders to break up the traditional 50 kg fertilizer bags into smaller packages and elimination of import quotas, price control, import licenses, and foreign exchange controls. The expectation was that these policies would lead to the development of efficient fertilizer markets that would stimulate widespread use of the input by smallholder farmers and generate sustained growth in crop productivity.

The available evidence on the impact of market liberalization on fertilizer use has been mixed. Evidence from farm surveys suggests that many smallholder farmers in semi-arid areas started using fertilizer following market reforms (Mose 1998; Omiti et al. 1999). This is commonly attributed to increased physical access to fertilizer in rural areas due to the rapid expansion of private fertilizer retailers and the breaking up of fertilizer into smaller packages (Argwings-Kodhek 1996; Mose 1998; Omiti et al. 1999; Omamo and Mose 2001). Private fertilizer retailers did not exist in rural areas in the pre-reform era when fertilizer prices and distribution were controlled. However, this situation has changed following liberalization of markets with current estimates of about 7000–8000 retailers operating in domestic markets during the peak fertilizer sales season (Argwings-Kodhek 1996; IFDC 2001).

Data on fertilizer use intensity in Machakos district is scanty. Nonetheless, farm surveys in the district suggest that use of the input was low even in the pre-reform period. A small farm survey in 1978 estimated fertilizer use intensities on maize of 1.1 kg ha^{-1} of nitrogen and 2.9 kg ha^{-1} of phosphorus and 0.8 ha^{-1} of nitrogen and 5.2 ha^{-1} of phosphorus in the semi-humid and transitional agro-ecological zones, respectively (Jaetzold and Schmidt 1983). Recent estimates of fertilizer use intensity suggest that application rates in semi-arid areas, measured by the total amount of nutrients applied per hectare, have declined since markets were liberalized. For instance, estimated total nutrients applied on maize averaged over all farmers in the sample declined from 19.5 kg per hectare in 1992 to 13 kg per hectare in 1997 (Hassan et al. 1998; Omiti et al. 1999). Notwithstanding the need to interpret these estimates with caution, the observed declining trend in fertilizer use intensity in semi-arid areas of Kenya corroborates other findings (Mose 1998).

It is not quite clear how these trends in fertilizer use have been influenced by price changes. Nominal fertilizer prices have risen following market reforms, due in part to the depreciation of the exchange rate. But maize grain prices increased during the same period. Consequently, the maize grain – fertilizer crop ratio fell following market liberalization before rising slightly above the pre-reform level (Table 1).

Thus, the available evidence suggests that changes in fertilizer marketing and distribution network fol-

Table 1. Maize/nitrogen price ratio for the Machakos district (1988–2000).

Year	Price of maize per kg (Kshs)	Price of DAP fertilizer per kg (Kshs)	Price of nitrogen per kg (Kshs)[a]	Maize/nitrogen price ratio[b]
1988	3.33	5.83	32.39	0.10
1989	3.60	6.95	38.59	0.09
1990	4.00	9.00	50.00	0.08
1991	4.33	12.74	70.78	0.06
1992	8.89	16.50	91.67	0.10
1993	12.22	22.80	126.67	0.10
1994	13.33	23.60	131.11	0.10
1995	8.00	23.00	127.78	0.06
1996	10.00	28.00	155.56	0.06
1997	14.44	26.00	144.44	0.10
1998	13.33	25.60	142.22	0.09
1999	15.56	26.00	144.44	0.11
2000	16.67	26.00	144.44	0.12

[a] Price of nitrogen = Price of DAP fertilizer ÷ 0.18 (DAP contains 18% nitrogen). [b] The maize/nitrogen ratio is obtained by dividing column 2 by column 4. Source: Ministry of Agriculture, Government of Kenya.

lowing market liberalization encouraged many farmers to start using the input; yet these changes, though necessary, are not sufficient to achieve greater intensity of fertilizer use on smallholder farms. This conundrum has led to the speculation that fertilizer market liberalization has not resulted in the expected growth in agricultural productivity and rural incomes. This paper uses a multivariate regression model to examine factors influencing fertilizer adoption at the farm level with a view to understanding why intensity of use is still low after market reforms.

The following sections describe the analytical model and data used in the study. This is followed by a discussion of the empirical model, results, and implications arising from the study.

Analytical model

Farmers are assumed to make fertilizer adoption decisions on the basis of utility maximization (Rahm and Huffman 1984; Adesina and Zinnah 1993). Given that the utility function is unobserved, it is postulated that the utility derived from application of a given level of fertilizer is a function of observable variables representing the incentive and capacity of farm households to invest in the input.

The specification of farmers' fertilizer adoption decision is based on a Tobit model defined as:

$$Y_i^* = \beta' X_i + \varepsilon_i$$
$$Y_i = Y_i^* \text{ if } Y_i^* > c$$
$$Y_i = 0 \quad \text{if } Y_i^* \leq c \qquad (1)$$

where Y_i^* is a latent variable indexing adoption, Y is an observable but censored variable measuring both the adoption and intensity of use of fertilizer, c is an unobservable threshold, β is a vector of unknown parameters, X is a vector of explanatory variables, and ε_i are residuals that are independently distributed with zero mean and constant variance. Since the observed data on fertilizer use contain a cluster of zeros, c is censored at the lower tail. If Y_i^* is greater than c then the observation is of Y_i^*, otherwise the observation is 0.

The coefficients from the Tobit model can be used together with values of the standard normal distribution and density functions to make predictions about the probability of adoption of fertilizer as well as the levels of fertilizer applied conditional on the farmer adopting the input. Given the model specified in Equation 1 the expected value of fertilizer use intensity conditional on initial adoption is defined as (Maddala 1983; Shakya and Flinn 1985):

$$E(Y|Y^* > 0) = \sigma Y \phi + \sigma \varnothing \qquad (2)$$

where ϕ and $\varnothing$ are the standard normal and density functions, respectively and σ is the standard error of the estimate of the dependent variable Y. The standard normal function is used to estimate the probability of adopting fertilizer, while Equation 2 simultaneously estimates the expected level of fertilizer application conditional on initial adoption of the input.

Data

Data for this study were collected in a cross-section household survey in the semi-humid, transitional, and semi-arid zones in Machakos district of eastern Kenya from May to November 1997. The sample comprised 399 households selected at random from administrative records of the local district office. Selected household characteristics from the sample survey are shown in Table 2.

The study area has a bi-modal rainfall distribution with average annual rainfall ranging from 400 mm per annum in the semi-arid zone to 1000 mm per annum in the semi-humid zone (KARI 1995). The production system is characterized as a mixed crop-livestock system with the relative importance of crops and livestock varying between agro-ecological zones. Data were collected by structured questionnaires and included information on farmer and household characteristics, crop production, livestock holding, ownership of farm implements and equipment, and soil fertility management practices.

The empirical model

The empirical model examines the fertilizer adoption process at the farm level. Table 3 shows descriptive statistics for the dependent and explanatory variables. The dependent variable, intensity of fertilizer use per farm, is measured by the total level of fertilizer nutrients applied on each farm during the first rain season of 1997 divided by the total cultivable area. The vector of explanatory variables measures the household's levels of resource endowments and cash, exposure to technical information on fertilizer use,

Table 2. Household characteristics by agro-ecological zones in Machakos, 1997.

Characteristic	Agro-ecological			
	Semi-humid tropics (n = 84)	Transitional (n = 206)	Semi-arid (n = 109)	Total (n = 399)
Socio-demographic				
Average age of household head	54	47	46	48
	(19)	(15)	(16)	(17)
Average family size	6	8	7	7
Percent of household heads				
Female	55	64	63	62
Male	45	36	37	38
At least primary education	73	80	72	76
Land holdings				
Average cultivated area (ha)	2.2	1.5	2.1	1.8
	(9.3)	(1.6)	(2.6)	(4.6)
Percent of households				
Growing coffee	71	18	5	26
Purchasing fertilizer from local shops[a]	69	93	100	83
Purchasing fertilizer in 5 kg package or less	35	43	40	40
Average distance to closest market (km)	3.1	4.1	5.6	4.3
	(4.1)	(4.8)	(6.7)	(5.3)
Percent of households using fertilizer	81	35	13	38
Percent of households that started using fertilizer after market liberalization	42	60	60	54
Total nutrients applied (kg/ha)[b]	44	15	5	19

Source: CARMASAK Project. Figures in parentheses are standard deviations. [a]Includes purchase from village shops and local market center; [b]average for all farmers in the sample.

changes in farm level fertilizer cost following market liberalization, and the physical environment in which fertilizer adoption decisions are made.

Household resource endowment is represented by farm size, family labor size, and gender of the household head. Farm size is used as a proxy for household wealth (Feder et al. 1985; Clay et al. 1998). This variable is expected to be positively related to intensity of fertilizer use, since wealthier farmers are more likely to have additional resources that can be used for on-farm investments. Family size is an indicator of available labor supply. In areas where labor markets are not well developed, family size becomes an important determinant of technology choice since alternative technologies have different labor use intensity. Family size is expected to be negatively related to fertilizer use, since fertilizer technology is less labor intensive compared to alternative soil fertility mainte-

Table 3. Descriptive statistics for variables in regression.

Variable	Type	Description	Mean	Standard deviation
FARMSIZE	Continuous	Total farm size in hectares	3.6	7.9
FAMSIZE	Continuous	Number of family members resident on the farm	7.3	3.4
GENDER	Binary	Gender of main decision maker (1 = male, 0 = female)	0.4	0.5
EDUCATION	Binary	Education of household head (1 = has formal education, 0 = no formal education)	0.7	0.4
EXPERIENCE	Continuous	Number of years farmer has been using fertilizer	4.1	8.0
EXTENSION	Binary	Frequency of extension contact (1 = frequent contact, 0 = infrequent contact)	0.1	0.2
CASHCROP	Binary	Whether or not farmer grows coffee (1 = grows coffee, 0 = does not grow coffee)	0.1	0.3
CREDIT	Binary	Whether or not farmer is credit constrained (1 = credit constrained, 0 = not credit constrained)	0.4	0.5
SOURCE	Binary	Normal source of fertilizer supply (1 = local shops; 0 = otherwise)	0.3	0.5
SIZE5KG.	Binary	Normally purchasing fertilizer in 5 kg size or less (1 = Yes, 0 = No)	0.1	0.3
DISTANCE	Continuous	Distance to closest market (km)	4.3	5.3
SEMI-HUMID	Binary	Location (1 = located in semi-humid zone, 0 = otherwise)	0.2	0.4
SEMI-ARID	Binary	Location (1 = located in semi-arid zone, 0 = otherwise)	0.3	0.5
POPPRESSURE	Continuous	Population pressure on land	10.8	15.7
INTENSITY	Continuous	Total nutrients applied per cultivable area	26.8	58.9

nance options, such as application of animal manure and composting, that many farmers use. It is hypothesized that gender is negatively related to fertilizer use. Even though women farmers play key roles in providing labor and decision making in semi-arid cropping systems, they are less likely to be using fertilizer because they frequently lack access to productive inputs, cash income, credit, education, extension and technical information (Doss 1999). Given the imperfections in credit market in the study area, own cash resources and farmers' liquidity situation are critical for making investments in fertilizer. The influence of these factors on fertilizer use is represented by two variables, access to cash resources and credit constraint status. Access to cash resources is measured by whether or not a household is growing coffee, an important cash crop in this area. Farmers were classified as credit constrained or non-credit constrained based on their responses from the survey. It is expected that obtaining income from cash crop cultivation is positively related to the intensity of fertilizer use while credit constraint is negatively related. Farmers' exposure to technical information on fertilizer use is represented by farmer's experience, frequency of extension contact, and level of education of the key decision maker, usually the head of the household. It is plausible that more experienced farmers are likely to have accumulated technical information on fertilizer use from various sources and thus are more likely to be proficient in using the input. These farmers might also be in a better position to assess the risks and relative returns from using fertilizer. Similarly, frequent contact with extension and education exposes farmers to information that may make them more receptive to acquire, interpret, and use technical advice. Thus, experience, frequency of extension contact, and education are expected to be positively related with intensity of fertilizer use. Liberalization of fertilizer markets has been associated with improvements in the marketing and distribution network for fertilizer in rural areas (Kherallah et al. 2000; Omamo and Mose 2001; Freeman and Kaguongo 2001). Three proxy variables, the usual source for fertilizer supply, the size of package normally bought, and distance to market, were used to represent the influence of market liberalization on farmers' adoption decisions. Farmers who normally purchase fertilizer in local market centers are expected to have lower search and transportation costs as a result of improved availability and physical access to fertilizer in rural areas, hence this variable is expected to be positively related to intensity of fertilizer use. The re-packaging of fertilizer in smaller packs resulted in lower transportation costs and made fertilizer affordable for many farmers who could not afford the traditional 50 kg bags. It is expected that this variable is positively related to intensity of fertilizer use. The distance of the farmer to the closest market is expected to be negatively related with fertilizer use decisions, since farmers who are located further away from supply sources are likely to incur higher transportation and search costs. The physical environment in which fertilizer adoption decisions are made affects potential yields and profits which, in turn, influence incentives to use the input (Kelly et al. 1999). Location specific binary variables representing the different agro-ecological zones in the study area are used to capture the ecological context in which fertilizer adoption decisions are made. These variables capture, among other things, the riskiness of cropping due to differences in water availability and soil quality. The agronomic response from fertilizer is expected to be higher in a more favorable environment, hence fertilizer use intensity is hypothesized to be higher in the wetter semi-humid zone compared to the drier semi-arid zone. At the plot level a variable measuring the ratio of family size to cultivated land is used as a proxy for population pressure on land. It is hypothesized that population pressure on land is positively correlated with fertilizer use, since households with high pressure on land may have greater incentives to intensify crop production.

Results

The estimated coefficients, t-ratios, and other relevant statistics from the regression analysis are presented in Table 4.

The log-likelihood ratio test, significant at the 1% level, indicates that the explanatory variables fitted the data reasonably well. The level of education of the household head, experience using fertilizer, growing a cash crop, availability of fertilizer in rural retail outlets, availability in small packages, and land pressure have a positive and significant influence on fertilizer adoption and the intensity of use. On the other hand, the size of family labor and location in the drier semi-arid zone are negatively associated with intensity of fertilizer use. Educated or experienced farmers are more likely to have or can acquire technical information that is necessary to use fertilizer

Table 4. Tobit model results.

Variable	Coefficient	Standard error	Asymptotic t-ratio
FARMSIZE	−0.577	0.605	−0.945
FAMSIZE	−3.127*	1.712	−1.827
GENDER	2.480	10.313	0.241
EDUCATION	28.537**	12.118	2.355
EXPERIENCE	4.818**	0.605	7.963
EXTENSION	19.441	16.403	1.185
CASHCROP	75.489**	12.294	6.141
CREDIT	−15.116	9.940	−1.521
SOURCE	38.533**	16.877	2.283
SIZE5KG.	43.318**	12.891	3.360
DISTANCE	−0.567	1.125	−0.504
SEMI-HUMID	18.170	12.061	1.506
SEMI-ARID	−31.012**	13.157	−2.357
POPPRESSURE	1.198**	0.296	3.739
Constant	−88.143**	17.633	−4.999
Sigma	74.007	4.434	16.692
Log likelihood function	−916.2695		

** = significant at the 5% level; * = significant at the 10% level.

effectively, so it is plausible that they tend to use the input intensively (Kebede et al. 1990). Farmers who have diversified into cash cropping activities are more likely to be using and applying a higher level of fertilizer. This is consistent with the finding that increased production of cash crop not only raises the returns to land and labor but may have significant benefits for soil fertility as well (Poulton et al. 2001). Farmers who have access to fertilizer in local retail shops and in small affordable packages are more likely to be using the input intensively. This suggests that improvements in fertilizer marketing and distribution networks following market liberalization provided incentives for many farmers to intensify fertilizer use. Thus, the state of fertilizer markets strongly influences adoption of the input, with consumption likely to be higher where retail markets are well developed (Mwangi 1997). The positive and significant coefficient on the land pressure variable confirms the hypothesis that farm households facing land pressure are more likely to adopt improved soil fertility management technologies, such as fertilizer, as a means to satisfy their subsistence needs (Adesina 1996).

Family size has a significant negative effect on the adoption and intensity of fertilizer, suggesting that households with smaller family size are more likely to adopt and apply greater quantities of fertilizer which utilizes less labor per hectare compared to alternative fertility management practices such as use of animal manure or compost (Freeman and Coe 2002). This finding might also reflect rural households' preference for labor-saving technologies, particularly when there are alternative income earning opportunities off-farm. The finding that credit constraint is not significant in explaining fertilizer adoption suggests that lack of credit by itself does not hinder the adoption of a scale neutral technology such as fertilizer (Feder et al. 1985). This effect is even more pronounced in this case given that the repacking of fertilizer into small sizes makes it more affordable for many cash-constrained smallholder farmers. Although distance to markets has the expected negative sign, it does not significantly influence adoption and intensity of fertilizer use. The lack of significance on this variable probably reflects the declining importance of distribution constraints on fertilizer use given that the growth in fertilizer retail outlets increased availability and access to the input in rural areas. A surprising finding is that even though the coefficient on the variable measuring frequency of extension contact was positive, it did not have a significant influence on farmers' decision to intensify fertilizer use. This supports available evidence on the mixed performance of formal extension systems in disseminating technical information and stimulating adoption of fertilizer in Africa (Barrett et al. 2002).

The empirical model can be used to provide further insights on strategies for achieving greater use of fertilizer on smallholder farms. Model results are substituted into Equation 2 to obtain predictions on the probability and intensity of fertilizer use conditional on initial adoption (Table 5). Estimated probabilities and expected levels of fertilizer application are computed for the semi-humid and semi-arid agro-ecological zones using five variables that have a

Table 5. Predicted probabilities of adoption and intensity of fertilizer use on cultivable land (kg/ha).

	With cash crop		Without cash crop	
Fertilizer available in 5 kg or less	Probability	Intensity (kg/ha)	Probability	Intensity (kg/ha)
Semi-humid zone				
Fertilizer available in local shop	0.91	57	0.63	24
Fertilizer not available in local shop	0.80	39	0.43	13
Semi-arid zone				
Fertilizer available in local shop	0.76	34	0.37	11
Fertilizer not available in local shop	0.57	20	0.20	4

positive and significant effect on application of fertilizer: education, family size, cash cropping activities, availability of fertilizer in local retail shops, and availability of fertilizer in 5 kg packages or less.

The probability of adopting fertilizer and intensity of use is highest among farmers who have diversified into cash cropping activities and can get access to fertilizer in packages of 5 kg or less in local retail shops. However, despite the 90 percent probability that such a farmer is likely to use fertilizer, the predicted level of application at 57 kg per hectare of total nutrients is about two-thirds of the application rate recommended by extension. Availability of fertilizer in local retail outlets stimulates adoption and intensity of use irrespective of the agro-ecological zone, particularly among farmers who have not diversified into cash cropping. However, diversification into cash cropping strongly influences adoption and intensity of fertilizer use, with the difference in use intensity between farmers who cultivate a cash crop and those who do not rising to up to 30 kg per hectare in the sub-humid zone. In general, probabilities of adoption and fertilizer use intensity are lower in the semi-arid zone compared to the sub-humid zone, highlighting the importance of ecological factors in farmers' fertilizer adoption decisions.

Conclusions and implications

This paper contributes to the debate on the impact of fertilizer market reforms in smallholder agriculture in Africa. A multivariate Tobit model was used to examine the determinants of farmers' fertilizer adoption decisions in an era of liberalized markets in Kenya. The results find no a priori reason why fertilizer cannot be an important component of smallholder farmers' fertility management strategies in semi-arid areas. Indeed, the results corroborate previous findings that liberalization of fertilizer markets in Kenya stimulated use of the input in these areas. This was mainly achieved through the expansion of private retail trade in rural areas that improved access to the input in affordable packages. Intensifying smallholder fertilizer use to achieve the expected productivity gains that will generate growth in agricultural output and incomes, however, remains a formidable challenge. The policy and research implications drawn from these results can provide useful insights for formulating strategies to intensify fertilizer use on smallholder farms in semi-arid areas.

The finding that improvements in fertilizer marketing and distribution in rural areas stimulated adoption raises the important policy question of how to get the input out into rural areas more cheaply. High transportation costs within Kenya are a key contributor to high domestic fertilizer retail prices (IFDC 2001). The lack of significance of the distance-to-market variable might reflect the fact that fertilizer market reforms led to the establishment of several fertilizer retail outlets in rural areas, which reduced supply constraints on use of the input. Policy interventions, however, need to further exploit the scope for reducing delivery cost that could be translated into lower farm level fertilizer cost. The lack of significance of credit constraints in adoption decisions and improved access to the input in rural areas suggests that a reduction in fertilizer costs would do more for increasing fertilizer use than an extended credit program.

The result showing that farmers' experience and level of education stimulates adoption and intensity of fertilizer use underscores the importance of learning and knowledge in fertilizer adoption decisions. On the other hand, the finding that frequency of extension contact does not significantly influence fertilizer adoption decisions raises serious questions about the role of formal extension systems in intensifying fertilizer use. It is plausible that many extension workers, typically armed with advice on optimal rates of fertilizer application per hectare, do not have very useful advice for many farmers who could not afford to make those investments. And the prospects for improving the effectiveness of disseminating technical advice from formal extension systems is expectedly limited given the funding crisis facing many extension systems in Africa. The policy implication from this is that sustained efforts need to be given to strengthening general rural education and evaluating the effectiveness of alternative methods of disseminating technical advice to farmers such as extension-farmer groups and farmer field schools. An under-explored alternative is providing technical training for fertilizer traders, so that they can effectively disseminate fertilizer use information to farmers. Private traders have become the primary source of fertilizer supply for smallholder farmers since markets were liberalized, yet many report that they lack technical skills to advice farmers (Freeman and Kaguongo 2001). Sustained effort to improve the technical capacity of private traders to disseminate fertilizer use information is therefore likely to have substantial payoffs.

This study suggests that facilitating smallholder farmers to diversify into cash crops is a promising strategy for increasing intensification of fertilizer use on smallholder farms. Cash crops offer higher returns per hectare, thus providing additional resources that could be used for farm investments including fertilizer. Under the conditions of missing or incomplete markets in many developing countries, issues involved in intensification of fertilizer use cannot be separated from those involving commodity marketing. This begs for the need to broaden the conceptual framework in soil fertility management research from its strong production focus to a focus on food subsystems that encompass production, post harvest, and market interventions. Marketing arrangements and policies that improve marketing efficiency and reduce risk would facilitate the process through which farmers are linked to commercial market opportunities and encourage the intensification of fertilizer use on smallholder farms.

Our findings support previous research in Kenya which shows that even though a growing proportion of farmers are using fertilizer following market liberalization, levels of application remain below recommended levels (Mose 1998; Omiti et al. 1999). This suggests the need for a major re-thinking of strategies to formulate fertilizer recommendations for smallholder farmers. Farmers are more likely to utilize fertilizer recommendations when it is consistent with their objectives and investment preferences. Conventional wisdom is that the application of small quantities of fertilizer may not show any agronomic response and that farmers should be encouraged to use the optimal rates of application recommended by extension. However, the finding that many farmers are willing to invest their scarce capital in fertilizer suggests that researchers need to shift their focus on how to maximize output per unit of fertilizer applied from the small quantities that farmers are willing to invest in, not to assume that more farmers might be able to purchase the recommended optimal rates. Rohrbach (1998) argues that in developing practical soil fertility management recommendations, researchers need to work with farmers to answer their own questions rather than assuming that they know what technologies are appropriate for farmers. Thus, practical advice that facilitates farmers' experimentation with a range of fertility management options, including targeting the limited quantities of fertilizer that many smallholder farmers are willing to invest in, is likely to be more useful than advice on optimal rates of fertilizer application.

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