SOIL MANAGEMENT AND TECHNICAL EFFICIENCY OF SMALL-SCALE MAIZE FARMERS IN NORTHWESTERN KENYA

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ABSTRACT

This paper examined the technical efficiencies of two groups of smallholder maize farmers in Lugari and Trans Nzioa districts, one within the contact areas of soil management project and the other comprising the counterfactuals. The analysis was based on Translog stochastic production functions estimated from maize production data for 2006 season. The empirical results indicate that farmers within the project area were more technically efficient than those outside the project area, given their respective technologies. The frontier output was 26 percent higher for farmers who applied the integrated soil fertility management practices. Educational attainment, soil fertility management choice, extension contacts and market access were significant determinants of technical efficiency. It is therefore likely that maize production in Kenya will require continuing policy and technological support addressing these factors in order to raise the level of efficiency and productivity to sufficiently higher levels. To this end, we recommend increased dissemination of integrated soil fertility management technologies to wider farming community and collective action approach to increase efficiency, access to credit and enhance returns at farm levels.

Key words: *technical efficiency, maize, smallholders, soil fertility, stochastic frontier*

INTRODUCTION

Declining soil fertility in high agricultural potential areas of Kenya has raised concerns regarding sustainability of small-scale maize production. Given that small-scale farmers produce most of maize output in Kenya, it is imperative that they raise total factor productivity in order to satisfy increasing food consumption needs. The declining productivity in maize production, reflecting low technical efficiency attributable to use of inefficient technology hinders progress in this direction (Seyoum *et al*., 1998). Technical efficiency reflects the ability of a farmer to obtain maximum possible output from a given set of inputs and technology (Tchale, 2005). Ideally, technical efficiency is output-increasing measure that relates to operation on the boundary of the technology, that is the production possibility frontier.

In Northwestern Kenya, a soil management project was initiated in 1994 to develop and disseminate appropriate technologies to curb declining agricultural productivity blamed on reduction in soil fertility (Mureithi *et al*., 2002). Several promising integrated soil fertility management (ISFM) technologies were developed and availed to farmers in Trans Nzoia and other KARI Kitale mandate districts. The technologies included combination of inorganic fertilizers and organic nutrient sources such as farmyard manure, compost manure and legumes such as soya beans, groundnuts, pigeon peas, *Mucuna pruriens* and *Crotolaria* and suitable crop varieties for maize, vegetables, sorghums and millets (Mureithi *et al*., 2002).

The expectation was that better application of the interventions would eventually lead to improved crop and livestock productivity and enhance incentives and skills for farmers to effect beneficial changes in their farming practices, thereby contributing to sustainable soil fertility management and improve welfare of their households. However, maize productivity is still low as manifested in the increase of net maize buying households in the region, ranging from 34 percent in Trans Nzoia district to about 70 percent in Vihiga district (Nyoro *et al.,* 2002; Mose *et* *al.,* 2004). Since maize is one of the most important crops produced by smallholders, overcoming possible constraints to technical efficiency in its production would contribute to sustainable use of on-farm resources. For this goal to be accomplished, detailed empirical information was required on the existing technical efficiency levels. The prevailing technical efficiency was not known and its determinants were not clear.

The current effort to investigate the efficient allocation of productive resources is essential since it presents potential source of practical information for achieving higher maize productivity using available inputs at farm level. This study contributes to clear understanding of factors that cause variations in efficiency measures. The knowledge about these relationships would provide valuable information that will inform policy and practice leading to improved maize yields, sustainable food security and soil fertility management at household level.

This study hypothesized that despite measurable progress in the generation and dissemination of ISFM technologies over the last decade, there was still much room to improve their impact on maize productivity, net returns and soil fertility management in Northwestern Kenya. Efforts aimed at enhancing technical efficiency in smallholder maize-based farming system could be desirable to realize such impacts. Therefore, this study endeavored to investigate whether the ISFM technologies have had impacts on technical efficiency in small-scale maize production in the region. The study aimed to evaluate differences in technical efficiency in small-scale maize production attributable to soil fertility management choices.

METHODOLOGY

Data and variables

The data used in this study were collected from contact farmers in Trans Nzoia district forming the experimental group and counterfactuals in Lugari district constituting the control group.

Stratification based on major agro-ecological zones was employed to minimize variability attributable to environmental factors. Between March and June 2007, a stratified sample of 354 farmers was interviewed through administration of semi-structured questionnaires during single visits to obtain input and output data on maize for 2006 agricultural year. Farmers also provided information on the components of integrated soil fertility management that they used in maize production. In addition, household data was collected on farmer's age, farming experience, family members and their level of education. Farmers also provided information on the cost of market access, whether they obtained credit and their contacts with agricultural extension workers, distance and condition of main roads.

Stochastic frontier model

The economic theory of production provides the analytical framework for most empirical research on efficiency (Debertin, 1986). The fundamental idea underlying the measurement of technical efficiency is that of attaining maximum possible output from a set of physical inputs. Consequently, a farmer is technically inefficient if too little output is produced from a given bundle of inputs (Ogundari *et al.,* 2006).

Stochastic frontier Translog production functions were estimated from production data to generate technical efficiency values. Stochastic functions attribute part of inefficiencies to external factors and are suitable when analyzing the role of measurable socio-economic factors in observed differences in efficiency scores (Coelli, 2006). This was important in this study because efficiency gains had to be estimated taking into consideration all possible relationships. Stochastic Translog production functions for farmers within the SMP project and those outside the project were estimated separately to generate their respective technical efficiency thus:

$$\ln(y_i) = \beta_0 + \sum_{i=1}^{5} \beta_i \ln(x_i) + \frac{1}{2}\sum_{i=1}^{5} \sum_{j=1}^{4} \beta_{ij} \ln(x_i)\ln(x_j) + (v_i - u_i) \qquad [1]$$

Where y_i is maize output (Kg/ha), and x_i are physical inputs β_0 is a parameter common to all farms while β_i and β_{ij} are unknown input coefficients to be estimated. v_i is the ordinary two-sided error term assumed to be normally, identically and independently distributed with mean zero and constant variance (σ^2) taking care of the effect of all other omitted inputs on maize output and u_i is the one-sided error term assumed to be half-normal and asymmetrical that captures technical inefficiency in maize production.

A set of explanatory variables were simultaneously estimated in a linear regression function in order to determine factors influencing technical efficiency in maize production. The factors included soil fertility management choices, market access, credit services, extension contacts, formal education, farming experience, off-farm income earning, and household size.

RESULTS AND DISCUSSIONS

Technical efficiency results

The results in Table 1 indicate that farmers in the study area on the average achieved 64 percent technical efficiency. Therefore, it is possible to improve yields by an additional 36 percent from the same physical inputs by improving technical efficiency, for example through adoption of more efficient practices such as better soil fertility management, early land preparation, timely planting, proper spacing, use of suitable maize varieties and effective weed control.

The significant gamma (γ) value of 0.60 means that 60 percent of the observed shortfall in maize yields could be explained jointly by the socio-economic variables. The underlying hypothesis in this study is that when efficiency is achieved in the use of inputs at current levels, farmers are more likely to expand their scale of production since as observed by Debertin (1986), most of them may operate at inefficient levels due to lack of finances to buy more inputs.

Table 1: Common stochastic production frontier estimated using maximum likelihood method to test for existence of technical inefficiency in maize production

Variable	Coefficient	Std.Error
INTERCEPT	0.30	0.27
Fertilizer	0.24**	0.06
Seed	3.59***	1.81
Labour	-4.26***	1.68
Fertilizer squared	0.09*	0.06
Seed squared	-0.26	0.53
Labour squared	0.17	0.13
Fertilizer X Seed	-1.96***	0.99
Fertilizer X Labour	2.31	9.19
Seed X Labour	-0.02	0.43
Gamma, $\sigma_{\mu}^2/(\sigma_{\mu}^2+\sigma_v^2)$	0.60**	0.18
Mean technical efficiency	64%	

*, **, *** significant levels at 10%, 5% and 1%, respectively

The coefficients for chemical fertilizer and seed are statistically significant indicating that inorganic fertilizer and seed are the main limiting inputs in maize production because as shown by positive coefficients, their use beyond the current levels will increase yields. This means that on average farmers are operating in the inefficient stage I of production. In this stage the marginal physical product of any input holding others constant, is greater than its average physical product. Therefore, it is rational (consistent with maximization of net returns) to use additional inputs until the marginal and average physical products are equated, that is diminishing returns sets in. Moreover, the significant positive coefficient (0.09) for fertilizer squared implies that current levels are sub-optimal and that increasing rates will lead to more maize yields. However, the interactive coefficient for fertilizer and seed (-1.96) is negative and significant at 1 percent level indicating that yields will decrease with simultaneous increase in both inputs. It is intuitive that yield cannot be increased indefinitely by increasing fertilizer and seed rates because ultimately other inputs become more limiting. If the combination of fertilizer and seed, which is increased progressively, is taken as a composite input, it will eventually display diminishing marginal returns.

The coefficient for labor is negative but highly significant suggesting that at the margin, labor had a decreasing effect on maize yields because more than optimal amount of labor is applied in maize production. Since most of labor (67%) was sourced from own-family, it was likely under-valued and over-used. The result is consistent with other findings by Seyoum *et al*. (1998) who associated negative marginal product for labor with production systems that rely on cheap family labor and usually employ it beyond the economically optimal level.

Evaluation of differences in technical efficiency among small-scale maize farmers

Results in Table 2 show that farmers who were exposed to ISFM interventions are 84 percent technically efficient compared to 58 percent technical efficiency observed among those in the comparative area. Moreover, technical efficiency differentials were minimal within the project area. On average, farmers within the contact area achieved 26 percent more yields than those outside the intervention area.

Table 2: Differences in technical efficiency between farmers within and outside the project area

Region	Efficiency (%)			
	Mean	Std. Dev	Min	Max
Within project area	84***	11	38	98
Outside project area	58***	19	15	91

*** mean values are significantly different at 1% level

This finding is consistent with Tchale (2005) in demonstrating that application of ISFM practices would reduce the shortfall observed in maize production by narrowing this gap. This means that there is room to increase yields through more use of ISFM options and eventually returns would be higher especially for smallholder farmers who cannot afford recommended rates of chemical fertilizers.

Determinants of technical efficiency in smallholder maize production

The estimated coefficient for farming experience is positive indicating that technical efficiency decreases with number of years in farming (Table 3). Although efficiency is expected to increase the longer the experience of the farmer, the knowledge and skills gained may become less relevant with new technologies and constraints. Moreover, older farmers have reduced physical strength to execute or supervise major agronomic practices. In addition, younger farmers are more market-oriented, eager to experiment with new production techniques unlike the older ones who are likely to continue with the traditional practices and in most cases, they focus mainly on satisfying subsistence food requirements.

Table 3: Determinants of technical efficiency among small-scale maize farmers

Variable	Parameter	Coefficient	Std.Error
Dependent variable =	Technical inefficiency		
Constant	δ_0	-0.54	1.55
Farming experience	δ_1	0.03^{**}	0.01
Education level	δ_2	-0.03^{*}	0.02
Household size	δ_3	0.04	0.03
Soil fertility management	δ_4	-0.01^{***}	0.001
Extension contacts	δ_5	-0.05^{*}	0.04
Credit access	δ_6	0.22	0.22
Off-farm income earning	δ_7	0.61	0.61
Market access	δ_8	0.004^{**}	0.001

*, **, *** significant levels at 10%, 5% and 1%, respectively

The coefficient for education variable is negative indicating that technical efficiency increases with an additional year spent in formal schooling. The result points to the importance of human capital in making and implementing informed and timely farming decisions. This means that most educated farmers have the capacity to source for, interpret and apply technical information better than the less educated ones. Moreover, better adoption of complex production technologies may call for technical knowledge and skills. Therefore, it is possible that these decisions and skills most likely benefit from some level of formal education.

The coefficient for agricultural extension is negative showing that farmers with more extension contacts were more technically efficient. This means that extension information is valuable in enabling farmers to apply modern production techniques more effectively to counteract the declining soil fertility and other limiting factors in maize farming in the study area. This finding is consistent with a study by Seyoum *et al.* (1998) among maize producers in eastern Ethiopia who found that farmers who were consistently exposed to extension advice operated closer to their technically efficient frontier.

The coefficient for dummy variable for soil fertility management choice is negative meaning that integrated soil fertility management practices in maize production led to higher technical efficiency than the use of chemical fertilizers alone. This observation point to the beneficial role played by organic matter in improving the productive capacity of the soil. This finding is in agreement with technical efficiency studies elsewhere that have advocated for combination of inorganic and organic nutrient sources in maize farming. For instance, Tchale (2005) and Seyoum *et al.* (1998) made similar conclusion in their studies among small-scale farmers in Malawi and Ethiopia, respectively. In the study area, it was found that only forty percent of the sampled farmers used some components of low cost integrated soil fertility management options. Figure 1 shows that incorporation of maize crop residues, use of farmyard and compost manures were the most preferred of the ISFM practices by farmers in Northwestern Kenya. The popular legume crops were crotolaria and groundnuts mainly because the former doubles up as a delicious vegetable and the latter offers bonus output which is either consumed at home or sold in local markets.

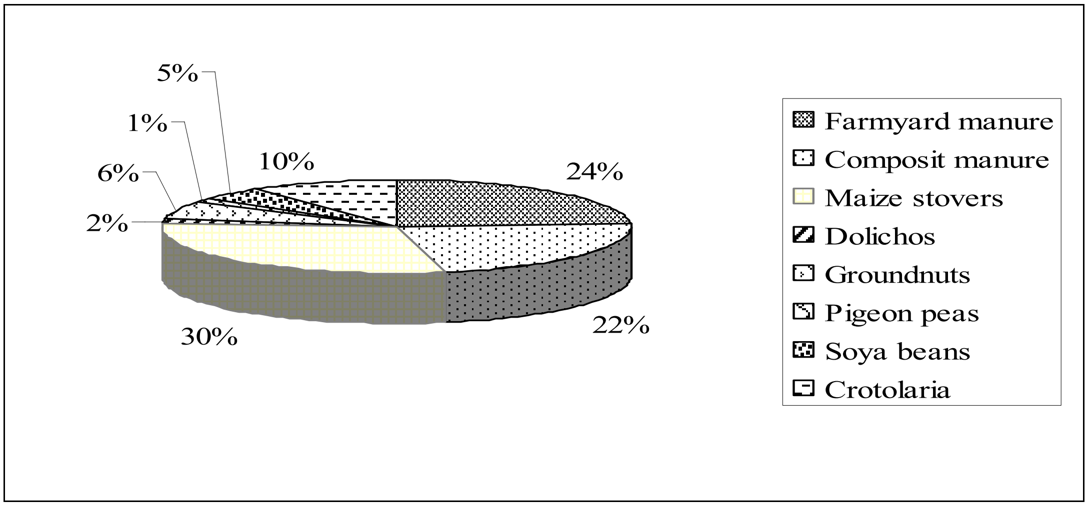

Figure 1: Type of ISFM options used by smallholder farmers in Northwestern Kenya

As expected, the positive coefficient for market access shows that high transportation costs (and in turn low market access and participation) lead to lower technical efficiency in maize production. This probably caused low use of purchasable inputs such as chemical fertilizers and hybrid seeds, in maize production. In the study area, it was found that on average farmers incurred about KES150 per 50 kg bag of fertilizer as market access cost due to poor roads and unreliable transport system.

CONCLUSIONS AND RECOMMENDATIONS

The results in this study indicate that farmers within the project area achieved relatively higher technical efficiency than those outside the project. This implies that the technological interventions promoted by the soil management project had significantly improved maize productivity. It is estimated that 26 percent more output was realized in areas where integrated soil fertility management options such as maize stovers incorporation, farmyard/compost manure application and legume cover crops were promoted.

However, it is likely that maize production in Kenya will require continuing policy and technological support for some time until the level of efficiency and productivity increases to sufficiently higher levels. The study recommends strengthening of farmer-to-farmer extension for disseminating integrated soil fertility management technologies to wider farming community as well as empowering farmer groups for collective action to increase efficiency, access to credit and enhance returns from maize farming. In addition, although this study appropriately used cross-sectional data to estimate efficiency in maize production and provide useful information on spatial efficiency variations, we suggest further research based on time-series data to capture changes in efficiency over time. Changes in on-farm resources such as soil fertility and other attributes important for crop production take place gradually over time indicating the need for dynamic bio-economic analysis that would offer insights into temporal variations. Finally, the research scope of this study only focused on maize as a crop produced mainly by smallholders in Northwestern Kenya. Similar studies for cash crops in general and horticultural crops in particular are recommended. Further efficiency studies could have merit for fish, dairy and beef production so that Kenya can have a competitive edge in these agricultural products over other countries in the region on the export market.

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