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The effect of sustainable farming practices and soil factors on the technical efficiency of maize farmers in Kenya

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Abstract

This study analyzed the effect of sustainable farming practices and soil factors on the technical efficiency of maize farmers in Kenya. Data were obtained from household survey carried out on 320 maize farmers in two districts in Kenya. Data were analyzed using descriptive statistics and the stochastic production frontier model. The result showed that about 58.00 percent of the farmers were male, while about 42.00 percent were female. The result on sustainable farming practices showed that majority (62.50%) of the maize farmers employed sustainable farming practices on their farmlands. The significant estimates of the production function were farm size (1.04) at one percent, vegetative cover (0.03) at 10 percent and labor (0.24) at one percent. The significant determinants of technical inefficiency were household size (0.18) at five percent, sex (-6.00) at one percent, education (-3.83) at one percent, mostly sandy soil (20.77) at one percent, sand-clay soil (12.09) at one percent, clay soil (11.03) at one percent, loamy soil (-7.31) at 10 percent, good fertile soil (10.60) at one percent, very good fertile soil (7.34) at one percent and sustainable farming practices (-6.74) at one percent. The study concluded that sustainable farming practices and soil factors had significant effect on the technical efficiency of maize farmers in the study area.

Introduction

The practice of obtaining food from the wild and forests, which had little or no impact on the soil and the environment, was the main stay of the people before the practice of Agriculture (McNeill & Winiwarter, 2004), but with a shift to Agriculture, humans started to till the soil so as to cultivate crops to provide food to live. The activity of tilling the soil continued with little consideration about its negative impact on the soil, in terms of soil nutrients depletion (deGraffenried & Shepherd, 2009; McNeill & Winiwarter, 2004). The problem of soil nutrients depletion worsened with a rising population, and an urgent need to meet food demand. This growing population, which is at a faster rate in Africa, has reduced the available lands used for fallow system of farming (Tilman, Cassman, Matson, Naylor, & Polasky, 2002), which has resulted in other means of replenishing soil nutrients to increase food production. Amongst such means are the use of non-organic fertilizers and other unsustainable farming practices which are employed in the production of varied crops including maize, which is a staple food crop in Kenya.

Maize is a fast-growing crop worldwide (Ishaya, Tunku, & Kuchinda, 2008) and a major crop in Kenya on which more than three quarter of the population depends. Its production is affected by farming practices employed by the farmers. Mafongoya, Kuntashula, and Sileshi (2006) attributed reduced maize output to unsustainable practices employed by the farmers. Meanwhile, Badgley et al. (2007) and Hobbs (2007)

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reported increased farm output with sustainable farming practices such as crop rotation, cover cropping, intercropping, tree planting, minimum tillage system and mulching amongst others, by myriad of studies. Aladesanwa and Adigun (2008) reported cover cropping to be effective in controlling weed on maize cultivated land, which could result in higher maize output. Also, Mwangi, Mboya, and Kihumba (2001) reported an increase in maize output in Kenya with the use of terraces, hedgerows and grass strips.

Although, many studies have analysed the effect of some of the sustainable farming practices on yield, the myriad of studies do not account for farming practices and other soil factors in estimating the efficiency of farmers. These farming practices could also influence farmers' efficiency as Chakraborty et al. (2008) stated, in that the practice of mulching increased the efficiency of farmers. When these farming practices are not accounted for in estimating the efficiency of farmers it may lead to incomplete and bias recommendations to farmers, extension agents and policy makers. This study, therefore, examined the socio-economic characteristics of maize farmers in the study area, estimated the technical efficiency of maize farmers, and determined the effect of sustainable farming practices, soil factors, and socio-economic characteristics of the farmers on their technical inefficiency.

Literature Reviews

Technical Efficiency

Technical efficiency of a farmer is measured by its ability to produce maximum output from possible amount of inputs and technology (Al-Feel & Al-Basheer, 2012). Any deviation from the optimum production is referred to as technical inefficiency attributable to factors controllable by the producers (Aigner, Lovell, & Schmidt, 1977). Technical efficiency estimation was first proposed by Farrell (1957), who estimated it without the use of parameters, which therefore stimulated further study by Aigner and Chu (1968), who estimated technical efficiency parametrically. Parametric is divided into deterministic and stochastic. The most recently employed parametric method is the stochastic production frontier, from which parametric studies are developed (Scarpa & Alberini, 2005). The deterministic frontiers have the constraint of attributing any deviation from the frontier to inefficiency in input use, making it a one-sided component, while the stochastic model or composed error model accounts for errors due to inefficiency and stochastic noise (Aigner et al., 1977).

Rahman and Hasan (2008) estimated the efficiency of farmers in allocating their resources, taking account of their practices and other climatic conditions that affected output. Results showed that farming practices and other climatic conditions had positive and significant effect on the efficiency of the farmers. This result was similar to that of Sherlund, Barrett, and Adesina (2002), Pascual (2005) and Long and Yabe (2011). Sherlund et al. (2002) used translog form of the stochastic production frontier to estimate efficiency of farmers taking into account their output, input, farming practices and other climatic conditions. Results showed that farming practices and climatic conditions had positive and significant effect on the efficiency of the farmers. Pascual (2005) analysed important ways farmers in Mexico could be more productive, while at the same time conserving the environment. Cobb-Douglas form of stochastic production frontier was employed. Results showed that employment of practices that reduces infertility of the soil also affected the maximum amount of output farmers could produce without necessarily increasing their use of input. Long and Yabe (2011) employed stochastic production frontier model and reported that farming and climatic conditions had effect on the output farmers produce and their efficiency.

Lohr and Park (2007) employed the stochastic frontier production model in estimating the efficiency of the farmers. The result showed that sustainable farming practices had significant effect on the efficiency of the farmers as the inefficiency level of the farmers increased when the practices were accounted for. Furthermore, it was reported that this result varied across locations and across farmers based on how long they had engaged in the practices.

Methodology

Area of Study

The two districts covered in this study were Suba and Laikipia districts in Kenya. Suba district is located in Western Kenya, with latitude and longitude 0^0 20′ to 0^0 52′ S, 34^0 E to 34^0 E. The population of Suba district was 155,666 (1999 census). Majority of the people are engaged in small scale farming. Laikipia district covers 9723 km^2 and lies on the equator, bounded by the lower slopes of Mount Kenya to the East, by the Aberdarea range to the South West, and by the rift valley escarpment to the West. The population of Laikipia district was 399,227 (2009 census). Majority of the farmers are subsistence farmers.

Kenya is in the Eastern part of Africa. It is about 580,000 km^2 in size. Kenya is bounded by Ethiopia in the North, by Tanzania in the South, by Indian Ocean in the South East, by Somalia in the North East and by Uganda in the West. It is made up of different provinces and districts.

Data Collection

The data used for this study were obtained from International Food Policy Research Institute (IFPRI) website and it is on household survey carried out on 320 maize farmers; however, responses from only 248 maize farmers were useful for this study as some important variables were missing from the responses of some farmers.

The survey was undertaken in two districts in Kenya, namely Suba in Nyanza Province and Laikipia district in Rift Valley Province. The survey was undertaken in 4 sub-locations per district making a total of 8 sub-locations for the study. These were randomly selected from a cluster of 10 sub-locations in each district. Each of these clusters was expected to have almost the same agro-ecological conditions with a wide range of tenure systems. In each selected cluster, a list of the household heads was compiled. Simple random sampling technique was thereafter used to select a total of 40 respondents from each selected sub-location making a total of 320 maize farmers.

The data is titled "Land tenure, agricultural productivity and the environment: Suba and Laikipia Districts, Kenya" and covers information on farm production, environmental degradation, farming practices, farm land, soil type, soil fertility and socioeconomic characteristics of the households.

Data Analysis

Descriptive and inferential statistics were employed in this study. Descriptive statistics employed were frequencies and percentages, while, the inferential statistic was stochastic production frontier model. Statistical analysis was done using the frontier software (version 4.1; New England, Armidale, Australia) and IBM SPSS software (version 21; IBM Corp., New York, USA).

Stochastic Production Frontier Model

The technical efficiency of maize farmers, and the effect of sustainable farming practices, soil fertility and soil type as soil factors, excluding socio-economic characteristics that affect the technical efficiency of maize farmers were analysed using the stochastic production frontier model. This was first formalized by Aigner et al. (1977).
Cobb-Douglas form of the model was employed in this study as shown in Equation 1 as:

$$\ln Y_i = \beta_{0+} \sum_{j=1}^{3} \beta_j \ln X_{ji} + \nu_{i-} \upsilon_i \quad (1)$$

The explicit form of the Cobb-Douglas form of the model is shown in Equation 2 as:

$$\ln Y_i = \ln\beta_0 + \beta_1 \ln X_{1i} + \beta_2 \ln X_{2i} + \beta_3 \ln X_{3i} + \nu_i - \upsilon_i \quad (2)$$

Y = Maize output (kg); X_1 = farm size (ha); X_2 = vegetative cover; X_3 = labour (man days)

$\beta_0 - \beta_3$ = unknown parameters to be estimated.

ν_i = symmetric error term accounting for statistical noise. It assumes a normal distribution.

υ_i = non-negative term accounting for technical inefficiency. It assumes a half-normal distribution. i stands for the individual farmer.

The Technical Efficiency (TE) is shown in Equation 3 as:

$$TE = \frac{Y_i}{Y_i^*} = \frac{f(X_i\beta)\exp(\nu_{i-}\upsilon_i)}{f(X_i\beta)\exp(\nu_i)} = \frac{f(X_i\beta)\exp(-\upsilon_{ii}).\exp(\nu_i)}{f(X_i\beta)\exp(\nu_i)} = \exp(-\upsilon_i) \quad (3)$$

Y_i = Actual or observed output of the i^{th} farmer; Y_i^*= Frontier output of the i^{th} farmer

The inefficiency parameters of the farmers were estimated using the inefficiency model, extended to account for environmental/soil variables (*W*) as shown in Equation 4:

$$Z_i = \sum_{i=1}^{4} T_i\delta + \sum_{i=1}^{8} \varphi_i W_i + e_i \geq 0 \quad (4)$$

Extending the stochastic frontier analysis to account for other variables was explained in Coelli, Prasada Rao, O'Donnell, and Battese (2005); Rahman and Hasan (2008); and Long and Yabe (2011).

Explicit form of the inefficiency model is shown in Equation 5.

$$Z_i = \delta_0 + \delta_1 T_1 + \delta_2 T_2 + \delta_3 T_3 + \delta_4 T_4 + \varphi_1 W_1 + \varphi_2 W_2 + \varphi_3 W_3 + \varphi_4 W_4 + \varphi_5 W_5 + \varphi_6 W_6 + \varphi_7 W_7 + \varphi_8 W_8 + e_i \quad (5)$$

Z_i = level of technical inefficiency; T_1 = household size; T_2 = sex; T_3 = education; T_4 = farming experience; W_1 = mostly sandy soil; W_2 = sandy–clay soil; W_3 = clay soil; W_4 = loamy soil; W_5 = fairly fertile soil; W_6 = good fertile soil; W_7 = very good fertile soil; W_8 = sustainable farming practices (1 = at least one is applied and zero for none). $\delta_0 - \delta_4$; φ_1–φ_8 = parameters to be estimated; and e ~N(0, σ_e^2, e = error term.

Results and Discussion

Descriptive Statistics of Maize Farmers in the Study Area

The result in Table 1 shows that about 58.00 percent of the farmers were male, while about 42.00 percent were female. The findings indicate that maize production was a male dominated enterprise in the study area. The result on the educational level of the farmers showed that about 59.00 percent had primary education, 24.60 percent had no form of education and less than one percent had university education. This implies that majority of the farmers had low level of education. Majority (62.50%) of the farmers employed sustainable farming practices on their farmlands. This indicates that sustainable agriculture was well practiced in the study area. In the aspect of soil fertility, the result shows that about 51.00 percent of the farmers perceived their soils to be good. This implies that more than 50.00 percent of the farmers perceived their soils to be good. The findings of the study also showed that about 48.00 percent of the farmers cultivated on loamy soil, 32.30 percent on clayey soil, and only about one percent on sandy soil.

Maximum Likelihood Estimates (MLE) of Stochastic Frontier Production Function for Maize Production (SFPF) in the Study Area

The result of the Maximum Likelihood Estimates (MLE) for maize production in the study area is presented in Table 2. It provides estimates of the Stochastic Frontier Production Function (SFPF). The results of the log-likelihood function for maize production was -391.41. These gave the log-likelihood ratio (LR) test of 217.31 significant at one percent. This indicates the presence of inefficiency effects in the model implying that OLS is not an adequate representation of the data but the use of MLE. The sigma squared was significant at one percent. This implies a 'good fit' and the correctness of the specified distributional assumptions of the composite error term. The significant gamma estimate of 0.98 indicates that 98.00 percent variations in the output of maize farmers were significantly due to the inefficiency factor.

Table 1 Descriptive statistics of maize farmers in study area

Variable	Frequency	%
Sex		
Male	144	58.10
Female	104	41.90
Educational level		
None	61	24.60
Primary	145	58.50
Secondary	27	10.90
Technical/College	14	5.60
University	1	0.40
Sustainable farming practices		
None	13	37.50
Tree planting	55	22.20
Terracing	23	9.30
Fallowing	13	5.20
Ridging	6	2.40
Grass strips	47	19.00
Strip cropping	11	4.40
Soil fertility		
Poor	8	3.20
Fair	105	42.30
Good	126	50.80
Very good	8	3.20
Soil type		
Mostly sand	3	1.20
Sandy clay	30	12.10
Clay	80	32.30
Loam	118	47.60
Rocky	17	6.90
Maize variety		
Local variety	165	66.50
PH1 Paner	6	2.40
H513, H511	2	0.80
H614	40	16.10
H625, H626, H627	34	13.70
H512	1	0.40
Tenure system		
Individual	238	96.00
Communal	8	3.20
State land	2	0.80

Table 2 Maximum likelihood estimates of stochastic frontier production function for maize production in the study area

Variable	Parameter	MLE	*t*-values	*SE*
Constant	b_0	2.57***	9.22	0.28
Farm size (X_1)	b_1	1.04***	17.51	0.06
Vegetative cover (X_2)	b_2	0.03*	1.66	0.02
Labor (X_3)	b_3	0.24***	3.95	0.06
Sigma squared	σ^2	12.95***	2.63	4.93
Gamma	γ	0.98***	210.54	0.01
Log-likelihood function		-391.41		
LR test	LR	217.31		

*** $p < .01$, * $p < .1$.

The result of the combined estimates of the production function based on the MLE of the SFPF shows that all the variables had significant effects on maize output. This means that a one percent increase in farm size will lead to 1.04 percent increase in output. This is in line with the findings of Adesiyan (2015); he reported positive and significant effect of farm size on maize yield. Also, one percent increase in the use of vegetative cover will lead to 0.03 percent increase in output and one percent increase in labor will lead to 0.24 percent increase in output. These results suggest that increasing farm size, vegetative cover and labor would increase maize output in the study area. A similar result of the effect of labor on maize yield was reported in the work of Omonona, Egbetokun, and Akanbi (2010). Labor is therefore an important variable in increasing maize yield in the study area, which is as expected, as extra labor is required in employing sustainable farming practices.

Technical Efficiency Scores of Maize Farmers in the Study Area

The technical efficiency scores of the farmers as presented in Table 3 show that it ranges from .00 to .89 with a mean of .45. The result shows that about 58.00 percent of the farmers were within the range of .00 to .54 and only about 4.00 percent were within the range of .85 to 1.00. This indicates that on average, maize farmers in Kenya had low level of technical efficiency. This is in line with the findings of Olwande (2012) on smallholder maize production in Kenya, which showed low mean technical efficiency score of the farmers.

Determinants of Technical Inefficiency of Maize Famers in the Study Area

The result of the estimated inefficiency parameters of the maize farmers as presented in Table 4 shows that sex had a significant effect on the technical inefficiency of the farmers at one percent level of significance, and the female farmers had a higher level of technical inefficiency than the male farmers. Education was significant at one percent, and the farmers with formal education were least technically inefficient by about four times more than farmers with no formal education. This is in line with the findings of Olwande (2012) that reported higher efficiency with increased level of education. Maize farmers that planted on mostly sandy soil, sandy–clay soil, and clayey soil were 20.77, 12.09, and 11.03 times respectively more technically inefficient than famers that planted on rocky soils. Farmers that planted on loamy soil were about seven times less technically inefficient than farmers that planted on rocky soil. This was as expected, as research has shown that the best soil for planting maize is rich loamy soil.

Table 3 Technical efficiency scores of maize farmers in the study area

Technical Efficiency Ranges	Frequency	%
.10 <	23	9.27
.10 –.24	47	18.95
.25 –.39	46	18.55
.40 –.54	27	10.89
.55 –.69	38	15.32
.70 –.84	58	23.39
.85 and above	09	3.63
Minimum	.00	
Maximum	.89	
Mean	.45	

Table 4 Determinants of technical inefficiency of maize farmers in the study area

Variable	Parameter	MLE	*t*-values	*SE*
Constant	δ_0	-19.35***	10.00	1.94
Household Size (T_1)	δ_1	0.18**	2.14	0.09
Sex (T_2)	δ_2	-6.00***	8.92	0.67
Education (T_3)	δ_3	-3.83***	4.42	0.87
Farming experience (T_4)	δ_4	-0.0	0.37	0.02
Mostly sandy soil (W_1)	φ_1	20.77***	7.71	2.69
Sand-clay soil (W_2)	φ_2	12.09***	11.60	1.04
Clay soil (W_3)	φ_3	11.03***	13.47	0.82
Loamy soil (W_4)	φ_4	-7.31*	1.86	3.92
Fairly fertile soil (W_5)	φ_5	-0.66	0.82	0.81
Good fertile soil (W_6)	φ_6	10.60***	10.30	1.03
Very good fertile soil (W_7)	φ_7	7.34***	6.49	1.13
Sustainable farming practices (W_8)	φ_8	-6.74***	7.51	0.89

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Also, the farmers that perceived their soil to be fairly fertile were less technically inefficient than those that perceived their soil to be poor, while farmers that perceived their soils to be good and very good in terms of fertility were more technically inefficient. This was not as expected, buttressing the need for an actual soil test rather than relying on the perception of the farmers. Furthermore, farmers that employed sustainable farming practices were about seven times less technically inefficient than farmers that did not employ sustainable farming practices. This is in line with the findings of Poudel, Johnson, Yamamoto, Gautam and Mishra (2015) as they reported higher efficiency with the practice of sustainable farming.

Conclusion and Recommendation

Sustainable farming practices and soil factors had significant effect on the technical efficiency of maize farmers in the study area. The study showed that farmers that planted on loamy soil were more technically efficient. Also, the farmers that perceived their soil to be fair were less technically inefficient, while farmers that perceived their soils to be good and very good were more technically inefficient. This study therefore recommends further research where an appropriate soil test be carried out rather than relying on the perception of the farmers. Also, since sustainable farming practices increased the efficiency of the farmers in the study area, they are therefore encouraged to practice sustainable agriculture and also to cultivate on loamy soils.

Conflict of Interest

There is no conflict of interest.

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