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Productivity and Efficiency Analysis of Smallholder Maize Producers in Southern Ethiopia

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ABSTRACT This study was undertaken in southern Ethiopia to assess productivity and technical efficiency of smallholder farmers and identify factors that determine productivity and technical efficiency. It was based on the data collected from 385 randomly selected farmers. A normalized translog production function was employed to assess maize productivity and factors conditioning productivity. In addition, data envelopment analysis was used to determine the levels of technical efficiency. Furthermore, a Tobit regression model was applied to identify factors influencing technical efficiency. The result depicted that productivity of maize was significantly influenced by the use of labor, fertilizer, and oxen power. The mean technical efficiency was found to be 40 percent indicating that there was substantial level of technical inefficiency of smallholder farmers in maize production. Important factors that significantly affected the technical efficiency were agro-ecology, oxen holding, farm size and use of high yielding maize varieties.

INTRODUCTION

Ethiopia, one of the world's centers of genetic diversity in crop germplasm (McCann 2001), produces more of maize than any other crop (CSA 2010). The area under maize cultivation in 2009/2010 was 1.69 hectares from which 37.8 million quintals of maize were produced which was higher than that of any other cereal crop. From the country's total grain production, maize accounts for more than 27 percent. Maize is major food crop in Wolaita and Gofa areas of southern region of Ethiopia. Past extension programs had given the highest priority to maize over long periods of time because of its known ability to respond positively to improved inputs and the possibility of achieving dramatic growth in productivity (Samuel 2006). However, the levels of productivity of the crop have remained to be low (Arega 2003). Production inefficiency of smallholder farmers representing major supply of agricultural production in Ethiopia has been one of the key factors limiting agricultural productivity especially that of cereal crops including maize.

In order to improve maize production and productivity, an efficient use of production inputs should be adopted by smallholder farmers. An understanding of the relationships between productivity, efficiency, policy indicators and farm-specific practices would provide policy makers with information to design programs that can contribute to increasing food production potential among smallholder farmers (Msuya et al. 2008). In Wolaita and Gofa areas of southern Ethiopia, information on the levels of productivity of maize and farm household technical efficiency in its production is lacking.

Objectives of the Study

The objectives of the study were:

a) to determine the productivity of smallholder maize production
b) to assess the technical efficiency of maize producer farmers and identify its determinant factors

RESEARCH METHODOLOGY

Study Areas

The study was carried out in Wolaita and Gamo Gofa zones of Southern Nations, Nationalities and Peoples Region (SNNPR) of Ethiopia. The Wolaita zone is one of the central zones of SNNPR. It encompasses agro-ecologies of highland, mid- altitude and lowland areas. Gamo Gofa zone is situated bordering Wolaita and has humid mountainous highland agro-ecology dissecting its mid and lowland agro-ecologies. These areas were specifically selected for the study on the basis of their high extent of maize production and representativeness for maize producing areas in southern Ethiopia.

Sampling Procedure and the Data

In order to select sample households, multi-stage sampling technique was followed. In the first stage, study districts were purposively selected from the study zones based on the extent of maize production. The number of districts selected was two each from Wolaita and Gamo Gofa zones. In the second stage, ten villages were selected from the selected districts based on the discussion with district agricultural extension service officers. Finally 385 sample farmers were randomly selected to administer the survey. The total sample was distributed to each sampling unit based on the probability proportional to size sampling technique. The dataset contained detailed information on households' socioeconomic and demographic characteristics, farm characteristics, input utilization, output produced and institutional as well as policy related variables.

Productivity Analysis

The analysis of productivity was carried out following the economic concept depicted by Coelli et al. (2005). A farmer uses amounts of N inputs (such as labor, seed, fertilizer, oxen power) to produce maize output. The technological possibilities of such a farmer can be summarized using the production function Q = f(**X, Z**) where Q represents output, **X** = (X_1, X_2, ..., X_N) is an Nx1 vector of inputs and **Z** = (Z_1, Z_2, ..., Z_M) is an Mx1vector of productivity shifter variables including household characteristics, management practices and institutional support services. The production function shows the maximum amount of the output Q that can be produced using alternative combinations of labor, seed, fertilizer and oxen power given the characteristics of famer, farm, management practices and institutional services. This production relationship can be expressed in several functional forms such as linear, polynomial, Cobb-Douglas and translog functional forms.

The normalized translog production function was used to assess determinants of the productivity of maize because it is assumed that yield response depends on nitrogen use efficiency and a second order polynomial function can approximate such a relationship (Saur and Tchale 2006). The normalized translog models have been widely used for describing the crop response to fertilization and tend to statistically perform better than other functional forms (Bock and Sikora 1990; Angus et al. 1993; Belanger et al. 2000).

The choice of normalized translog production function for this study was based on the fact that it is the best-investigated second order flexible functional form and certainly one with most applications (Saur et al. 2004). Another reason is that this functional form is convenient to estimate and proven to be a statistically significant specification for economic analysis as well as a flexible approximation of the effect of input interaction on yield. The normalized translog maize production model can be specified as:

$$\ln\left(\frac{Q}{Q'}\right) = \alpha_0 + \sum_{i=1}^{n} \alpha_i \ln\left(\frac{X_i}{X_i'}\right) + \frac{1}{2}\sum_{i=1}^{n-1}\sum_{j=i+1}^{n} \beta_{ij} \ln\left(\frac{X_i}{X_i'}\right)\ln\left(\frac{X_j}{X_j'}\right) + \sum_{k=1}^{m} \rho_k Z_k + \varepsilon_i \quad (1)$$

where Q is the yield (kg/ha), X_i are the variable inputs (fertilizer, labor, seed and oxen power), Z_k is a vector of productivity shifters such as husbandry practices (for example, weeding and date of planting), α_i are the linear input parameters, β_{ij} are the quadratic and interaction parameters, are the parameters for productivity shifters and is the error term assumed to be distributed with zero mean and constant variance σ^2. Following Saur and Tchale (2006), all variables were normalized to the sample mean by dividing by the mean value (Q', X_i', X_j'). A dummy variable for soil fertility management (that is, integrated management or use of inorganic fertilizer only) was included in the model in order to assess the effect of soil fertility management choice on yield response.

Technical Efficiency Analysis

Technical efficiency analysis is the ratio from actual productivity and frontier productivity. It, therefore, requires technical data for analysis. In this study, input-oriented analysis was applied to minimize inputs use of decision making units (DMUs) and still achieve the given current level of maize yields. If a DMU's actual productivity is equal to frontier productivity or lies on the frontier, it is perfectly technically efficient. On the contrary, if a DMU's actual productivity is less than frontier productivity or lies below the frontier, it is technical inefficient.

Estimation of technical efficiency follows non-parametric and parametric techniques. The non-parametric technique constructs frontiers and measures efficiency relative to the constructed frontier using linear programming techniques such as Data Envelopment Analysis (DEA). The parametric technique estimates frontiers and provides efficiency using econometric methods such as Stochastic Frontier Approach and distance functions. The conventional approach to the estimation of production functions consists of first specifying a parametric form for the function and then fitting it to observed data by minimizing some measure of their distance from the estimated function (Banker and Maindiratta 1988). Statistical tests are performed by postulating again a parametric form for the distribution of the deviations of observed data from the fitted production function. The fundamental weakness of this approach lies in its inability to theoretically substantiate or statistically test the maintained hypotheses about the parametric form for the production function and the postulated distribution for the disturbance term. Furthermore, it is not immediately apparent what restrictions these hypotheses impose on the production correspondence (Javed et al. 2008). Charner et al. (1978) described DEA as a mathematical programming model applied to observational data that provides a new way of obtaining empirical estimates of relations-such as the production functions and/or efficient production possibility surfaces-that are cornerstones of modern economies. Formally, DEA is a methodology directed to frontiers rather than central tendencies. Instead of trying to fit a regression plane through the center of the data as in statistical regression, for example, one floats a piece wise linear surface to rest on top of the observations. Because of this perspective, DEA proves particularly adept at uncovering relationships that remain hidden from other methodologies. Thus, DEA has main advantages in terms of not requiring the assumption of a functional form to specify the relationship between inputs and outputs, and the assumption about the distribution of the underlying data (Coelli 1995; Krasachat 2003).

DEA efficiency measures are relative, as they refer to the sample they are calculated from. These relative rankings can be fragile if the number of firms in the sample is small relative to the number of outputs and inputs being considered (Andreu 2008). In this study the number of farms was larger than the rule-of-thumb benchmark, M×N, where M is the number of outputs and N is the number of inputs. Overall, DEA's flexibility in accommodating multiple outputs and inputs in different units with no need to express a specific technical relationship among them has been seen as an advantage.

According to Coelli et al. (1998), it is necessary to select orientation from input oriented DEA model or output oriented DEA model according to which quantities the decision maker has more control over. Smallholder farmers in the study areas have more control over inputs than outputs. Accordingly, input oriented DEA model will be used in the study. Besides, it is pointed out that constant return to scale DEA model is only appropriated when all firms are operating at optimal scale. However, it is not possible to hold this assumption in agriculture in the study areas since smallholder farmers face constraints. As a result the variable returns to scale DEA model was applied for this study.

The outcomes of DEA of this study were efficiency scores which represent performance indicators as 1 = best performance and 0 = worst performance. The best of efficient DMUs lie on the frontier while the inefficient ones lie below the frontier. The efficient DMUs can be considered as benchmark of the inefficient DMUs. The inefficient DMUs can improve their performances to reach the efficient frontier by decreasing their current input levels (Cooper et al. 2006). The efficiency scores can be calculated by using a linear programming model as presented in Charner et al. (1978). The linear programming model for this study is, therefore, constructed as follows:

$$\underset{\Delta,\lambda}{Min}\,\Delta_j$$

Subject to: $\sum_{j=1}^{n} y_j \lambda_j - y_j \geq 0, \lambda_j \geq 0$ for $\forall_j$

$$x_{ij}\Delta - \sum_{i=1}^{m} x_{ij}\lambda \geq 0,$$

$$\sum_{j=1}^{n} \lambda_j = 1,$$

$$0 \leq \Delta \leq 1 \qquad (2)$$

where Δ_j is a scalar which indicates technical efficiency scores of the j^{th} household; y_j is a 1xn vector of output produced by n households; x_{ij} is a m x n input matrix and λ_j is a n x 1 vector of weight value.

The underlying assumptions of this model are that farm household j (1, 2, …, n) produces output y_j using a combinations of inputs x_{ij} (i = labor, seed, fertilizer, oxen power); and an input oriented production frontier of variable returns to scale (VRS). The objective function Δ_j is a scalar that represents the minimum level to which the use of inputs can be reduced without altering the output level. It is the global technical efficiency score (GTE) for the DMU ''j''. If this index is equal to one, the production unit is considered technically efficient. If it is less than one there is some degree of technical inefficiency. A Δ_j index equal to one ensures that the use of all inputs cannot be reduced at the same time, although a variation in the use of one of them may improve efficiency (Iraizoz et al. 2003).

The individual DEA efficiency score varies between 0.00 and 1.00. This means the efficiency scores are double-truncated at 0 and 1. Though other types of regression model such as multiple linear and one sided Tobit regression models can be applied only if the efficiency scores do not assume both or either of the upper and lower limits. Therefore, in this study, the two-limit Tobit regression model was applied to identify the sources of efficiency since the dependent variable in this case assumed 0 as lower limit and 1 as upper limit (Maddala 1999). The two-limit Tobit model is defined as:

(3)

where y_i^* is latent variable representing the efficiency scores of farm j, β is a vector of unknown parameters, X_{jm} is a vector of explanatory variables m (m = 1, 2, ..., k) for farm j and μ_j is an error term that is independently and normally distributed with mean zero and variance σ^2. Denoting y_i as the observed variables,

$$y_1 = \begin{cases} 1 & if \quad y_i^* \geq 1 \\ y_j^* & if \quad 0 < y_i^* < 1 \\ 0 & if \quad y_i^* \leq 0 \end{cases} \tag{4}$$

The distribution of dependent variable in equation (4) is not normal distribution because its value varies between 0 and 1. The ordinary least square (OLS) estimation will give biased estimates (Maddala 1999). Therefore, the alternative approach is using the maximum likelihood estimation which can yield the consistent estimates for unknown parameters vector. Following Maddala (1999), the likelihood function of this model is given by:

$$L(\beta,\sigma|y_j,X_j,L_{1j},L_{2j}) = \prod_{y_j=L_{1j}} \varphi\left(\frac{L_{1j}-\beta' X_j}{\sigma}\right) \prod_{y_j=y_j^*} \frac{1}{\sigma}\phi\left(\frac{y_j-\beta' X_j}{\sigma}\right) \prod_{y_j=L_{2j}} 1-\varphi\left(\frac{L_{2j}-\beta' X_j}{\sigma}\right) \tag{5}$$

where L_{1j} = 0 (lower limit) and L_{2j} = 1 (upper limit) where $\varphi(.)$ and are normal and standard density functions. In practice, since the log function is monotonically increasing function, it is simpler to work with log of likelihood function rather than likelihood function and the maximum values of these two functions are the same (Greene 2003).

The regression coefficients of the two-limit Tobit regression model cannot be interpreted like traditional regression coefficients that give the magnitude of the marginal effects of change in the explanatory variables on the expected value of the dependent variable. In a Tobit model, each marginal effect includes both the influence of explanatory variables on the probability of dependent variable to fall in the uncensored part of the distribution and on the expected value of the dependent variable conditional on it being larger than the lower bound. Thus, the total marginal effect takes into account that a change in explanatory variable will have a simultaneous effect on probability of being technically efficient and value of technical efficiency score. McDonald and Moffitt (1980) proposed a useful decomposition of marginal effects that was extended by Gould et al. (1989). From the likelihood function of this model stated in equation (5), Gould et al. (1989) showed the equations of three marginal effects as follows:

1) The unconditional expected value of the dependent variable

$$\frac{\partial E(y)}{\partial x_j} = [\varphi(Z_U)-\varphi(Z_L)].\frac{\partial E(y^*)}{\partial x_j} + \frac{\partial[\varphi(Z_U)-\varphi(Z_L)]}{\partial x_j} + \frac{\partial(1-\varphi(Z_U)}{\partial x_j} \tag{6}$$

2) The expected value of the dependent variable conditional upon being between the limits

$$\frac{\partial E(y^*)}{\partial x_j} = \beta_m.\left[1+\frac{\{Z_L\phi(Z_L)-Z_U\phi(Z_U)\}}{\{\{\varphi(Z_U)-\varphi(Z_L)\}\}}\right] - \left[\frac{\{\phi(Z_L)-\phi(Z_U\}^2}{\{\varphi(Z_U)-\varphi(Z_L)\}^2}\right] \tag{7}$$

3) The probability of being between the limits

$$\frac{\partial[\varphi(Z_U)-\varphi(Z_L)]}{\partial x_j} = \frac{\beta_m}{\sigma}.[\phi(Z_L)-\phi(Z_U)] \tag{8}$$

where = the cumulative normal distribution, = the normal density function, and $Z_U = (1-\beta X)/\sigma$ are standardized variables that came from the likelihood function given the limits of y^*, and σ = standard deviation of the model. The marginal effects represented by the equations above were calculated by the STATA command mfx which was complemented by specific options that allowed the estimation of marginal effects of change in explanatory variables.

The theoretical model discussed above assumes that the dependent variable which is defined as the technical efficiency of smallholder maize producers depends on the following explanatory variables: agro-ecological location of household, rainfall distribution, sex of household head, age of household head, education of the household head in years of schooling, family size of household, oxen holding of household, farm size, use of hybrid seed, frequency of extension visit, distance to development center, access to credit and consumption expenditure of household.

RESULTS AND DISCUSSION

The influence of each of the inputs used in maize production and their interaction effects are presented in Table 1. The use of human labor had a significant and positive effect on maize productivity at 10 percent level of significance. This suggests that increasing labor utilization in maize production in operations such as land preparation, planting, fertilizer application and weeding would significantly increase maize productivity because of the current underutilization of human labor. Similarly, the application of chemical fertilizer had highly significant and positive influence on maize productivity at less than one percent level of significance. This depicts that farmers who apply higher rates of chemical fertilizer receive higher maize yields. Therefore, increasing the current level of fertilizer use would significantly increase maize productivity. Using oxen power for farm operation enhances labor productivity and is a key input in maize production particularly if farmers have to use improved seeds and chemical fertilizers. This is evidenced from the result that both its own and interaction effects were significant at less than 1 and 5 percent levels of significance, respectively. Thus, increasing the availability and use of oxen for farm operation in maize production would lead to a significant increase in maize productivity.

Productivity shifter variables such as planting method, use of hybrid maize seed and application of integrated soil fertility management practices positively and significantly influenced maize productivity. Planting method which is measured as a dummy variable (that is, 0 for broadcasting and 1 for row planting) has positively contributed to maize productivity at 5 percent level of significance. This implies that increasing the extent of use of row planting would significantly increase maize productivity. Simi-

Table 1: Regression results of translog production function

Variable	*Coefficient*	*Standard error*	*Z*	*P>|Z|*
Labor	0.061*	0.032	1.910	0.056
Fertilizer	0.132***	0.028	4.640	0.000
Seed	0.071	0.050	1.400	0.161
Oxen power	0.077***	0.030	2.590	0.010
Labor X Fertilizer	-0.009	0.052	-0.170	0.866
Labor X Seed	0.074	0.066	1.130	0.257
Labor X Oxen power	0.058**	0.030	1.950	0.051
Fertilizer X Seed	0.058	0.040	1.470	0.142
Fertilizer X Oxen power	-0.035	0.040	-0.880	0.376
Seed X Oxen power	-0.028	0.063	-0.450	0.654
Planting method	0.342**	0.161	2.120	0.034
Hybrid variety	0.208***	0.061	3.410	0.001
Farm size	0.094***	0.027	3.510	0.000
Tropical livestock unit	0.052	0.036	1.460	0.144
Integrated soil fertility management	0.109**	0.047	2.290	0.022
Frequency of extension contact	0.014	0.023	0.610	0.542
Distance to development center	-0.084	0.069	-1.220	0.223
Credit	-0.061	0.054	-1.140	0.255
Off-farm income	-0.009*	0.005	-1.840	0.065
Constant	0.302	0.204	1.480	0.139
Log Likelihood	-44.982576			
Wald	127.75			
Prob. >	0.000			

***, ** and * indicate the level of significance at 1, 5 and 10 percent, respectively.

larly, use of hybrid maize seed and integrated soil fertility management practices positively influenced maize productivity at less than 1 and 5 percent level of significance, respectively. The hypothesis that maize yield is positively influenced by the application of integrated soil fertility management practice is confirmed by these results. Therefore, opportunities that promote the integrated soil fertility management practices and hence increase the level of its use would lead to increased maize productivity.

Expanding the level of use of hybrid maize seed would result in increased productivity of maize in these areas. The result supports the efforts of the government extension programs that promote the use of hybrid maize varieties as driver of gains in productivity. As indicated earlier, land is a key factor in maize production. If households have larger farm size it creates the possibility of expanding maize production and exploiting economies of scale by increasing the competitive advantage of farmers in input usage over households with smaller farm size. In line with *a priori* hypothesis, household farm size had a significant and positive effect on maize productivity of smallholder maize production at less than 1 percent level of significance. On the other hand, off/non-farm income has influenced maize productivity significantly and negatively at 10 percent level of significance. This is also in line with the hypothesis that increased off/non-farm opportunities take away farm resources and farmers effort that could otherwise be used for maize production and hence reduce maize productivity.

The results of DEA model indicate that the average technical efficiency was found to be about 0.40. This indicates that if the average farmer in the sample was to achieve the technical efficiency level of its most efficient counterpart, then the average farmer could realize 60 percent cost savings. This indicates that there was a substantial amount of technical inefficiency in maize production. However, about 7.26 percent of the DMUs operated at greater than 90 percent technical efficiency level in maize production (Table 2).

The results of Tobit regression model show that farm size, use of hybrid maize variety, agro-ecology, oxen holding and consumption expenditure of households were highly significant at affecting the technical efficiency of smallholder maize producers (Table 3). Earlier studies elsewhere showed a significant and positive effect of farm size, agro-ecological zones and access to improved technologies such as improved seed on technical efficiency (Amos 2007; Idiong 2007). The result indicated that farmers with larger farms better make use of economies of scale and have an opportunity to be efficient in production. This was consistent with other empirical literature that revealed positive relationship between technical efficiency and farm size (Alvarez and Arias 2004; Cheng and Lo 2004). The fact that technical efficiency was positively and significantly related to agro-ecology variable suggests that there is a room to increase maize productivity and efficiency in mid-altitude and even more in lowland parts of the study areas. The relationship between oxen holding and technical efficiency in maize production was positive and significant and was consistent with the *a priori* hypothesis. Thus, oxen availability is crucial to increase technical efficiency in maize production in the study areas. The positive and significant relationship between consumption expenditure and technical efficiency could be related to the efficiency-wage hypothesis in labor economics that improved consumption expenditure (or income) leads to better nutrition of laborers and hence the enhanced technical efficiency in production (Huang et al. 1998).

Table 2: Frequency distribution of technical efficiency of maize producers

Technical efficiency range	*Frequency*	*Percent*
0.00-0.10	27	7.26
0.11-0.20	86	23.12
0.21-0.30	76	20.43
0.31-0.40	51	13.71
0.41-0.50	30	8.06
0.51-0.60	35	9.41
0.61-0.70	20	5.38
0.71-0.80	13	3.49
0.81-0.90	7	1.88
0.91-1.00	27	7.26
Total	372	100.00

The marginal effects of changes in explanatory variables from Tobit regression analysis were computed following the procedure proposed by McDonald and Moffitt (1980) and Maddala (1999). The derived values for the significant explanatory variables indicate that the effects of a unit change in those variables on the unconditional expected value of technical

Table 3: Tobit regression results of determinants of technical efficiency

Variable	*Coefficient*	*Standard error*	*t-ratio*
Agro-ecology	0.048**	0.023	2.070
Rain distribution	0.024	0.031	0.780
Sex	0.041	0.069	0.590
Age	-0.001	0.001	-0.850
Education	0.000	0.003	-0.090
Family size	-0.007	0.006	-1.220
Oxen	0.021**	0.010	2.170
Farm size	0.074***	0.014	5.500
Hybrid variety	0.107***	0.026	4.060
Frequency of extension contact	0.003	0.002	1.590
Distance to development center	-0.033	0.048	-0.690
Credit	-0.020	0.028	-0.710
Consumption expenditure	0.001**	0.000	1.960
Constant	0.057	0.104	0.550

***, ** and * indicate the level of significance at 1, 5 and 10 percent, respectively.

efficiency, expected value of technical efficiency conditional upon being between 0 and 1, and probability of being between 0 and 1 (Table 4). The result showed that a unit change in agro-ecological variable ordered from highland to lowland in an increasing order increases the probability of a farmer being technically efficient by about 2.7 percent and the mean level of efficiency by about 3.7 percent with an overall increase in the probability and level of technical efficiency by 4.5 percent. That is a unit change in the agro-ecology brings about 4.5 percent increase in the expected value of unconditional technical efficiency.

Table 4: The marginal effects of change in explanatory variables

Variable	$\delta(E)\,y$	$\delta(E)y$	$\delta\,\psi\,(Z_u)\,-\psi\,Z$
Agro-ecology	0.04504	0.03686	0.02692
Rain distribution	0.02230	0.01836	0.01254
Sex	0.03763	0.03032	0.02621
Age	-0.00084	-0.00069	-0.00050
Education	-0.00029	-0.00024	-0.00018
Family size	-0.00660	-0.00540	-0.00394
Oxen	0.01952	0.01597	0.01166
Farm size	0.06955	0.05692	0.04156
Hybrid variety	0.09837	0.07919	0.06989
Frequency of extension contact	0.00277	0.00227	0.00166
Distance to development center	-0.03065	-0.02508	-0.01832
Credit	-0.01845	-0.01504	-0.01145
Consumption expenditure	0.00001	0.00001	0.00001

CONCLUSION

The study assessed the productivity and technical efficiency of maize smallholder producers in Wolaita and Gamo Gofa zones of southern Ethiopia. A total of 385 farmers were random selected to collect the data. The econometric analysis conducted to assess the productivity of maize and its determinants indicated that the productivity of maize was significantly determined by a number of factors in addition to the use of variable inputs such as labor, fertilizer and oxen. The use of labor had a significant and positive effect in improving maize productivity. Fertilizer was also found to be a key input in significantly improving maize productivity that implies the need for increment current level of use of chemical fertilizer. The use of oxen power in farm operations such as land preparation, planting and weeding was highly significant in influencing maize productivity. Row planting was a significant variable in positively influencing the productivity of maize. This practice has been applied when farm sizes are relatively large and/ or when farmers use chemical fertilizer. However, farmers who plant maize around homestead and with small farms who do not use chemical fertilizer simply use the traditional broadcasting method of planting. This had a negative consequence on the productivity. On the other hand, the use of hybrid maize variety was highly important in positively affecting maize productivity. However, it has been highly threatened by supply shortage and high seed prices. Farm size was also a key variable influencing the productivity of maize. Extension programs that target farmers with larger farms are more likely to bring about the improvement in productivity. This is consistent with the hypothesis about the relationship between productivity and size.

The technical efficiency of the sample farmers ranged between 0.036 and 1.00. The mean technical efficiency was found to be 40 percent. This revealed that if the average farmer in the sample was to achieve the technical efficiency level of its most counterparts, then the average farmer could realize 60 percent cost saving without any reduction in the level of the output produced. The determinants of technical efficiency identified by the study were agro-ecology, oxen holding, farm size and use of high yielding varieties.

RECOMMENDATIONS

For the improvement of maize productivity and technical efficiency of farmers in the study area, the study recommends the following:

(i) Better utilization of farm labor should be put in place. Policies that motivate and mobilize the rural population especially the youth in agricultural activities should be given due attention.

(ii) Increasing the level use of fertilizer by the farmers through different policy initiatives including improvements in credit service, agro-ecology based maize extension programs and continuous training as well as follow up on the application of improved soil fertility management practices.

(iii) Improving oxen holding of farmers by introducing initiatives such as targeted credit, improved animal health service and technologies that enhance the traction power of the existing oxen.

(iv) Area specific multiplication and provision programs of hybrid maize seed

(v) Increasing farm size per household by either strengthening the resettlement programs or absorbing the underutilized labor in the study areas to off-farm opportunities.

(vi) Creating rural income and expenditure enhancement programs such as employment generation schemes and paid social works.

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REFERENCES

Alvarez A, Arias C 2004. Technical efficiency and farm size: A conditional analysis. *Agricultural Economics,* 30: 241-250.

Amos TT 2007. An analysis of productivity and technical efficiency of smallholder cocoa farmers in Nigeria. *Journal of Social Science,* 15(2): 127-133.

Andreu ML 2008. *Studies on the Economic Efficiency of Kansas Farm*. Ph. D Thesis. Kansas State University.

Angus JF, Bowden JW, Keating BA 1993. Modeling nutrient response in the field. *Plant Soil,* 155(156): 57-66.

Arega D 2003. *Improved Production Technology and Efficiency of Smallholder Farmers in Ethiopia: Extended Parametric and Non-parametric Approaches to Production Efficiency Analysis.* PhD Thesis. University of Pretoria.

Banker RD, Maindiratta A 1988. Non-parametric analysis of technical and allocative efficiencies in production. *Econometrica*, 56(6): 1315-1332.

Belanger G, Walsh JR, Richards JE, Milburn PH, Zaidi N 2000. Comparison of three statistical models describing potato yield response to nitrogen fertilizer. *Agronomy Journal,* 92: 902-908.

Bock BR, Sikora FJ 1990. Modified quadratic plateau model for describing plant responses for fertilizer. *Journal of American Soil Science Society,* 54: 1784-1789.

Charner A, Cooper WW, Rhodes E 1978. Measuring the efficiency of decision making units. *European Journal of Operational Research*, 2: 429-444.

Cheng Y, Lo D 2004. Farm Size, Technical Efficiency and Productivity Growth in Chinese Industry. School of Oriental and African Studies, University of London. *Working paper No. 144.*

Coelli TJ 1995. Recent developments in frontier modeling and efficiency measurement. *Australian Journal of Agricultural Economics*, 39: 219-245.

Coelli TJ, Rao DSP, Battese GE 1998. *An Introduction to Efficiency and Productivity Analysis*. Boston: Kluwer Academic Publishers.

Coelli, TJ, Rao DSP, O'Donnell CJ, Battese GE 2005. *An Introduction to Efficiency and Productivity Analysis.* 2nd Edition. New York: Springer Science and Business Media Inc.

Cooper WW, Seiford LM, Tone K 2006. *Introduction to Data Envelopment Analysis and Its Uses.* New York: Springer Science and Business Media Inc.

Central Statically Agency (CSA), Federal Democratic Republic of Ethiopia 2010. *Agricultural Sample Survey (2009/2010) Report on Area and Production of Crops.* Volume I. Addis Ababa, Ethiopia.

Gould B, Saup W, Klemme R 1989. Conservation tillage. The role of farm and operator characteristics and the perception of soil erosion. *Land Economics*, 65(2): 167-182.

Greene WH 2003. *Econometric Analysis.* 5th Edition. New Jersy: Pearson Education Inc.

Huang TL, Hallam A, Orazem PF, Petterno EM 1998. Empirical tests of efficiency age models. *Economia*, 65: 125-143.

Idiong IC 2007. Estimation farm level technical efficiency in small-scale swamp rice production in Cross River State of Nigeria: A stochastic frontier approach. *World Journal of Agricultural Science*, 3(5): 653-658.

Iraizoz B, Rapun M, Zabaleta I 2003. Assessing the technical efficiency of horticultural production in Navara, Spain. *Agricultural Systems*, 78: 387-403.

Javed M.I, Adil SA, Javed MS 2008. Efficiency analysis of rice-wheat system in Punjab, Pakistan. *Pakistan Journal of Agricultural Sciences*, 45(3): 96-100.

Krasachat W 2003. Technical Efficiencies of Rice Farms in Thailand. A Non-parametric Approach. *Proceedings of Hawaii International Conference on Business*, 18-21 June, 2003, Honolulu.

Maddala GS 1999. *Limited Dependent Variable in Econometrics.* New York: Cambridge University Press.

McCann J 2001. *Maize and Grace. History, Corn and Africa's New Landscapes, 1500-1999*. Boston: Society for Comparative Study and History.

McDonald JF, Moffitt RA 1980. The use of Tobit analysis. *Review of Economics and Statistics,* 62(2): 318-321.

Msuya EE, Hisano S, Nariv T 2008. Analysis of Technical Efficiency of Maize Farmers in Tanzania: The Globalization Era. *Paper presented in the XII World Congress of Rural Sociology of the International Rural Sociology Association*, 6-11 July, Goyang, Korea.

Samuel G 2006. Intensification of Smallholder Agriculture in Ethiopia. Options and Scenarios. *Paper Prepared for the Future Agricultures Consortium Meeting at the Institute of Development Studies*, 20-22 March 2006, Addis Ababa.

Saur J, Frohberg K, Hockmann H 2004. Black-box Frontiers and Implications for Development Policy. Theoretical Considerations. *Development Policy Discussion Paper No. 92*. Centre for Development Research, Bonn, Germany.

Saur J, Tchale H 2006. Alternative Soil Fertility Management Options in Malawi: An Economic Analysis. *Paper presented at the American Agricultural Economics Association Annual Meeting*, Long Beach, California, 23-26 July 2006.