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Analysis of Smallholder Farmers' Technical Efficiency of Maize Production: The Case of Fogera District, South Gondar Zone, Ethiopia

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Abstract
Ethiopian agriculture is characterized by low productivity. As a result, the country has been a scene of poverty and persistent food insecurity. To solve this problem studying the level of technical efficiency becomes more important. The main inspiration of efficiency and productivity studies are the need to investigate and understand the forces that drive maize technical efficiency in order to analyze. Therefore, this study was conducted in Fogera district of South Gondar zone to measure the level of technical efficiency and identify socio-economic factors affecting the efficiency of smallholder farmers in maize production. A three-stage sampling technique was employed to select 120 maize growing smallholder farmers. Stochastic production functions were employed to estimate technical efficiency levels. The estimated results showed that the mean level of technical efficiency of maize producers was 73%. The estimated gamma parameters (discrepancy ratio γ), which measures the relative deviation of output from the frontier level due to inefficiency, was about 84%. The estimated stochastic production frontier (SPF) model also indicates that DAP, Urea and maize plot size are significant determinants of maize production level. The estimated SPF model together with the inefficiency parameters shows that education, improved seed and credit access were found to determine technical efficiencies of farmers positively while participation in off-farm income, slope and fragmentations were found negative relationship with technical efficiency. Hence, emphasis should be given to more on timely supply of DAP, Urea, improved seed and socioeconomic significant variables such as education, credit access and slope to improve farmers' efficiency in production of maize.
Keywords: Technical efficiency, Maize production, stochastic frontier, Fogera district
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INTRODUCTION

Background of the Study

The economy of Ethiopia is largely based on agriculture, agriculture accounts for 46.6% of the gross domestic product (GDP) contributions, 80% of exports earnings, 85% of total employment and 70% of industrial raw materials supplies (CSA, 2014). According to World Bank, (2014), Agricultural productions are dominated by smallholder farmers that operate on farms of less than one hectare. In the highlands, the average landholding has fallen from 0.5 ha in the 1970s to only 0.2 ha by 2014 and accompanied by a lower marginal productivity of labor that is estimated to be close to zero. As many as 4.6 million people need food assistance annually. Yet agriculture is the country's most promising resource.

Maize was originated in America and it is the world's third most important food crop next to rice and wheat. It was introduced to Ethiopia during the late 16th or early 17th century (FAO, 2014). Since, Ethiopia is one of the world's centers of genetic diversity in crop germplasm produces more of maize than any other crops (CSA, 2014). Maize is Ethiopia 's staple crop and is widely grown in most part by smallholder farmers throughout the country. In 2012/13, maize production was 42 million qt, 40% higher than teff and 75% higher than wheat production. With an average yield of 17.4 qt per hectare (equal to 32 million qt grown over 1.8 million hectares) from 2010 to 2013, maize has been the leading cereal crop in Ethiopia since the mid-1990s in terms of both crop yield and production (Rashid et al., 2010). Maize is a major crop in South Gondar areas of Amhara region of Ethiopia. Farmers grow maize mainly to make different traditional food items like corn flour, porridge, bread, corn meal, for brewing beverage alcohol, livestock feed, corn oil and ethanol production (Geta et al., 2013).

For the Fogera district, enhancing the total production and productivity is not an option rather it is a must and give the first priority. The measurement of efficiency has remained an area of important research where resources are scanty and opportunities for developing by inventing or adopting better technologies are dwindling (Alemayehu, 2010). Therefore, this study was intended to measure the technical efficiency of maize producer smallholder farmers and identify its determinant factors in the Fogera district.

Concepts of Technical Efficiency

Technical efficiency is the ability of a firm to obtain maximal output from a given set of inputs and technology. When technical efficiency is defined in terms of maximum output from a given bundle of measured inputs, only those farmers who are technically efficient is operate on the production frontier. Firms are efficient and whatever inefficiency comes in the process of production is due to external shocks or statistical noise which is entirely beyond their control (Nyagaka, 2010).

Productive efficiency consists of technical and allocative efficiency. Technical efficiency of a producer is a comparison between observed and optimal values of its outputs and inputs. It refers to the ability to avoid wastage either by producing as much output as technology and input usage allow or by using as little input as required by technology and output production (Kilic et al,. 2009). Technical efficiency has, therefore, both an input conserving and output promoting argument. It is assumed that technical efficiency ranges between zero and one, if TE = 1 implies that the firm is producing on its production frontier and is said to be technically efficient. 1–TE is therefore the largest proportional reduction in input that can be achieved in the production of the output. Allocative efficiency deals with the extent to which farmers make efficiency decisions by using inputs up to the level at which their marginal contribution to production value is equal to the factor cost. Allocative efficiency is related to the ability of a firm to choose its input in a cost minimizing way. Technical and allocative efficiencies were components of economic efficiency. Economic efficiency is concerned with the realization of maximum output in monetary term with the minimum available resources (Farrell and Lovell, 1985).

Maize is the global leading cereal in terms of production, with 1,016 million metric tons produced on 184 million hectares globally. Different types of maize are grown throughout the world, with one important difference being color. Maize kernels can be different colors ranging from white to yellow to red to black. Maize is produced globally across temperate and tropical zones and spanning all continents. The subtropical maize in the low- and middle-income countries that provide 64% of total maize production and where maize plays a key role in the food security and livelihoods of millions of poor farmers (FAO, 2014). Currently, Ethiopia is the fourth largest maize producing country in Africa, and first in the East African region. However, the efforts directed at improving maize production over the years, low productivity remains a major challenge in agricultural sub-sector. Hence, the average national on farm level yields of 21 qt per ha compares unfavorably with on farm field trial yields of 50-60 qt /ha and on research field yield 80-110 qt/ha (Dawit et al., 2010). As a result, technical efficiency in maize production is necessary in order to determine the extent of the gains that could be obtained by improving performance in agricultural production with a given technology (Kpotor, 2012).

MATERIAL AND METHODS

Description of the Study Area

Fogera district is located in South Gondar zone of Amhara National Regional State at about 625 km from Addis Ababa and 55 km from the regional capital, Bahir Dar. It is one of from 106 districts as of the Regional State. Woreta is the capital of the district. Geographically, the district is located from 110 58 N latitude and 370 41 E longitude. The district is bordered by Libo Kemkem district in the North, Dera district in the South, Lake Tana in the West and Farta district in the East. The district is divided into 29 rural keble Administrations and 5 urban kebeles (FWADO, 2015/16). Based on 2007 national census conducted by the Central Statistical Agency of Ethiopia (CSA, 2014), Amhara Region has a population of 17,214,056 of which 8,636,875 were men and 8,577,181 were women. The total land of the district is 117,414 ha. The current land use pattern includes 44% cultivated land, 24% pasture land, 20% water bodies and the rest for others. The mean annual rainfall is 1216.3 mm, with Belg and Meher cropping seasons. The main crops grown in the area include wheat, maize, teff, barley, sorghum, onion and rice (FWADO, 2015/16).

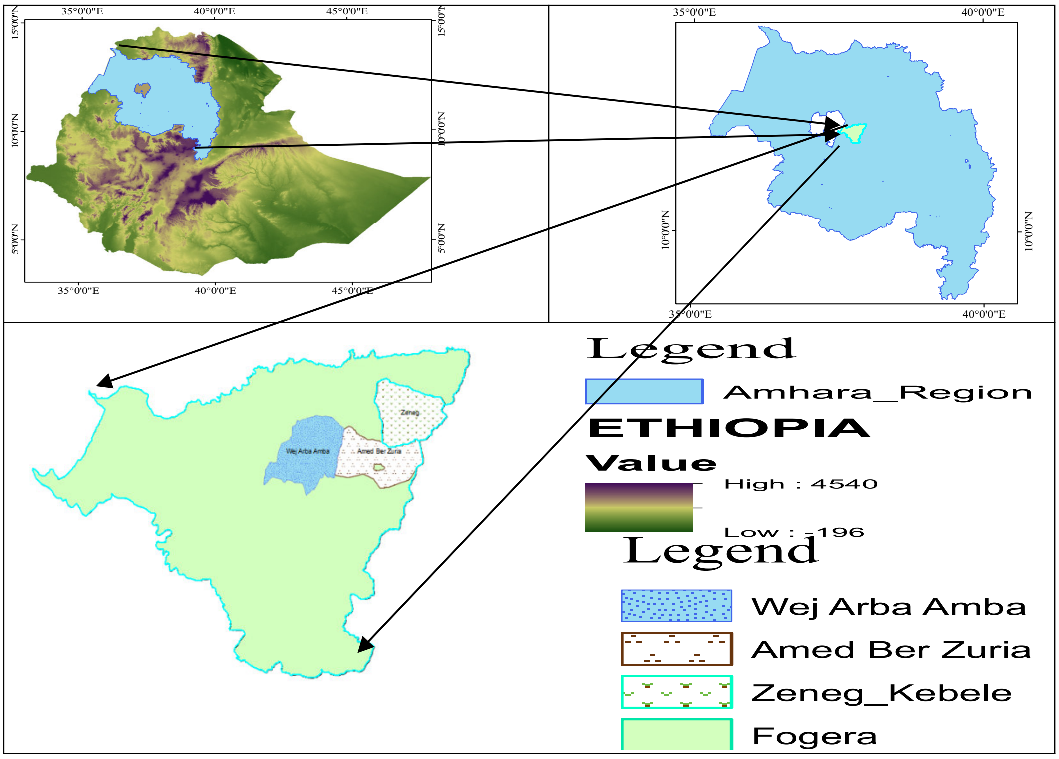

Figure **1:** Map of the Study Area

Sampling Techniques and the Data
Three stage sampling technique were employed to select 120 sample smallholder farmers. Fogera district consists of 24 rural and 5 urban Kebles Administrations (KAs). In the first stage, out of the total 24 rural (KAs) that participated in maize production of 2015/16 cropping season in the district, 12 Kebeles were selected using purposive sampling technique which were maize cultivation was carried extensively. In the second stage, 3 Kebeles namely Alember zuria, Woj Arba Amba and Zeng were selected using simple random sampling technique. In the third stage, based on a complete list of names of all maize producer smallholder farmers obtained from FWAO, 40, 52 and 28 sample smallholder farmers were selected from Alember zuria, Woj Arba Amba and Zeng, respectively using probability proportional to size (PPS) technique. The existing kebeles share similarities in topography, mixed crop production system and use of technology. The study applied a simplified formula provided by Yamane, (1969) to determine the required sample size at 95% confidence level, degree of variability 0.5 and level of precision 9% are recommended in order to get a sample size which is represent a true population.

As sources of information both Primary and secondary data was collected. To collect primary data from the sample smallholder farmers, semi structured interview schedule was employed. To facilitate the task of data collection, enumerators was recruited from the study areas and was trained. Interview schedule was pretested with the enumerators for one day to ensure that wording and coding matched field situation. The data pertaining to output obtained and quantity of various inputs used in maize production was collected. That is to say, data was collected on input-output variables such as output obtained in quintal, labor (MDE), oxen (ODE), plot size in ha., fertilizer in kg and seed in kg. In addition, demographic, socio-economic and institutional data such as age, sex, level of education, access to credit, family size, soil fertility, maize plot slope, maize seed varieties and total livestock (TLU) was collected. Secondary data related to maize production trend and input supply was collected to clarify and support analysis and interpretation of primary data. In addition, secondary data was also obtained from reports of similar studies and information's documented at various office levels of FWAO and other district agricultural office. An important literature on technical efficiency was also accessed from the internet and university of Gondar library.

Data Analysis Methods: A stochastic frontier approach was applied to estimate the level of technical efficiency of smallholder farmers. In general, Agricultural production is likely to be affected by random shocks (white noise) such as drought, weather, pest infection, fires, diseases (rusts). Furthermore, measurement errors are likely to be high because of many farmers were smallholders in whose farm operations were managed by family members, keeping accurate records is not always a priority (Coelli and Battese, 2006). In such a condition where random shocks and measurement errors are high, a model that accounts for the effect of noise is more appropriate to choose. Thus, the stochastic efficiency decomposition methodology is chosen as more appropriate for this study. Therefore, the general stochastic frontier model developed independently by Aigner et al., (1977) and Meeusen, (1977) in which an additional random error, vi, is added to the non-negative random variable μ_i, the SFP function model can be written as:

$$\ln Y_i = \beta_o + \ln \sum_{j=1}^{n} \beta_i X_{ij} + \ln \sum_{k=1}^{m} \alpha_k Z_{ik} + Exp^{e_i} \qquad (1)$$

$\ln Y_i$ -represents yield of maize output of the i^{th} maize producer smallholder farmer; X_{ij} -refers to j^{th} farm input variables used for maize crop produced on i^{th} plot and similarly Z_{ik} denotes k^{th} inefficiency explanatory variables; ß and α stands for the vector of unknown parameters to be estimated; $e_i= v_i-u_i$ which is the residual random term composed of two elements v_i and u_i The v_i is a symmetric component/ disturbance error term and permits a random variation in output due to factors such as weather, omitted variables and capture events beyond the control of farmers. The other component, u_is, is non-negative random variable and reflects the technical inefficiency relative to the stochastic frontier.
The technical efficiency effects model (Coelli and Battese, 2006) in which both the stochastic frontier and factors affecting inefficiency are estimated simultaneously is specified as:

$$\ln(OUTP) = \beta_0 + \beta_1 \ln(AREA) + \beta_2 \ln(LAB) + \beta_3 \ln(SEED) + \beta_4 \ln(UREA) + \beta_5 \ln(DAP) + \beta_6 \ln(OXPW) + \beta_7 \ln(HERB) + v_i - [\, \delta_0 + \delta_1 Educ + \delta_2 Age + \delta_3 Famsiz + \delta_4 FrmSz + \delta_5 Slope + \delta_6 TLU + \delta_7 Offarinc + \delta_8 SeedVar + \delta_9 Credit + \delta_{10} Fragmt + \delta_{11} Ownshp + w_i]$$
(2)

Where: ln-the natural logarithm, OUTP - total output of maize obtained from the i^{th} plot (in quintal); AREA - maize plot size (in hectare); LAB - amount of labor (in man day equivalent); SEED - amount of maize seed (in kg); UREA/DAP - amount of UREA/DAP fertilizer (in kg); OXPW - amount of draught power (in oxen day); HERB - amount of herbicide (in litter). Where the inefficiency variables used in the above model were defined as follows: Educ - years of formal education; Age- age of the smallholder farmer; Famsiz - total number smallholder farmer members; FrmSz- total land size; Slope - is a maize plot slope; TLU - tropical livestock unit; Offainc- off-farm activity; SeedVar- improve seed; Credit- credit access; Fragmt- fragmentation of maize plots; Ownshp- ownership of maize plots; β_i- vector of unknown parameters and δ_i- Parameter vector associated with inefficiency effect to be estimated and w_i - Error term.

As stochastic frontier method requires a prior specification of the functional form a log likelihood ration test indicated that Cobb-Douglas production function is the best functional form for this study. The one-stage estimation procedure of the inefficiency effects model together with the production frontier function was used in the study. The two-stage procedure produces inconsistency in the assumption (Coelli and Battese, 2006). Moreover one-stage procedure is the most commonly used method in the analysis of technical efficiency. Thus one-stage procedure was selected for this study. TE can be estimated using the computer program, FRONTIER version 4.1 and it is a single purpose package specifically designed for the estimation of stochastic production frontiers.

RESULTS AND DISCUSSION

Econometric Results

The maximum likelihood estimate of the parameters of the stochastic production frontier was estimated using Frontier 4.1 version computer program. Before estimation of technical efficiency and analysis of its determinants, variance inflation factor (VIF) for the continuous variables and contingency coefficient (CC) for the discrete variables were examined to check the problem of serious multi-co linearity. The values of VIF for all variables entered into the model were below 10, which indicate the absence of multi-co linearity among the explanatory variables. Regarding the categorical variables, results have shown that there was no multi-co linearity problem among variables. The validity of the model used for the analysis was investigated. The Cobb-Douglas and the Trans-log functional forms were the most commonly used stochastic frontier functions in the analysis of technical efficiency in production. As a result, the Cobb-Douglas production functions select the appropriate specification.

The parameters were estimated simultaneously with those involved in the model for the inefficiency effects. Table 1 presents the results of both the OLS and ML estimates as well as inefficiency model result. The results of the Cobb-Douglas Stochastic Production Frontier model showed that maize plot, the amount of seed, urea, DAP and pre-harvest oxen power had positive and significant effect on the level of output. This means that, the increase in these inputs would increase output of maize (Table 1).

Table 1. Maximum likelihood, OLS estimate and technical inefficiency determinants for Cobb-Douglas production function

Variable	Parameter	Ordinary least squares		Maximum likelihood estimate	
		Coefficient	t-ratio	Coefficient	t-ratio
Constant	β_0	-0.401	-0.8817	0.435	1.455
LnArea	β_1	0.365	3.0561***	0.230	2.196**
LnLabor	β_2	0.018	0.7476	0.017	0.944
LnSeed	β_3	-0.789	- 1.7041**	-0.962	- 2.257**
LnUrea	β_4	0.643	4.4792***	0.503	5.766***
lnDAP	β_5	0.799	1.7318**	0.966	2.269**
lnOxen power	β_6	0.149	1.3292	0.203	2.190**
lnHerbicide	β_7	0.017	0.1909	-0.038	-0.558

Inefficiency effect model				
Variables	Parameter	Coefficients	Standard error (SE)	t-ratio
Constant	σ_0	0.696	0.352	1.98**
Education	σ_1	-0.345	0.150	-2.29**
Age	σ_2	-0.006	0.004	-1.33
Family Size	σ_3	0.006	0.031	0.21
Total Land	σ_4	-0.062	0.138	-0.449
Slope	σ_5	0.267	0.141	1.89**
TLU	σ_6	-0.002	0.022	-0.08
Off farm Activity	σ_7	0.359	0.159	2.25**
Improved Seed	σ_8	-0.539	0.193	-2.79***
Credit	σ_9	-0.256	0.142	-1.80**
Fragmentation	σ_{10}	0.278	0.172	1.62*
Ownership	σ_{11}	0.015	0.133	0.12
Sigma-squared	σ^2	0.108	0.034	3.14***
Gamma	Γ	0.84	0.118	7.15***
LL		1.27		
Mean Efficiency		0.73		
Returns to scale		0.94		
Total sample size	N	120		

*,**and *** represents significance at 10%,5% and1% probability levels, respectively
Source: Computed from Field Survey Data, 2015/16

As shown in Table 1, the parametric coefficients or partial elasticity of significant input variables were 0.23 for area, 0.5 for urea, 0.96 for DAP, and 0.2 for oxen power. These values indicated the relative importance of each factor in maize production. Otherwise, a 1% increase in the use of land, urea, DAP and oxen power will result 0.23%, 0.5%, 0.96%, and 0.2% increase in the efficiency level of maize output, respectively. The coefficient parameters summation of the partial elasticity 0.94 showed that maize production in the study area was operated at decreasing returns to scale. Therefore, an increase in all production inputs by 1% will increase maize yield by less than 1%.

Efficiency scores

Both diagnostic statistics of inefficiency component sigma squared (σ^2) and gamma (γ) were statistically significant, respectively and showing the existence of significant variation from the frontier function. Sigma squared indicates goodness of fit, and the correctness of the distributional form assumed for the composite error term. The estimated value of gamma (γ) was 0.84 which indicates that 84% of total variation in farm output is due to technical inefficacy while the remaining 16% was as a result of the effect of the disturbance term.

The TE analysis revealed that technical efficiency score of sample smallholder farmers varied from 28% to 95%, with the mean TE level being 73%, it can be deduced that 27% of the output was lost due to the inefficiency in maize producing system or in the inefficiency among the sampled smallholder farmers or both combined. These provided opportunity for improving maize output by investigating factors that influence efficiency in order to improve the productivity of maize in the study area. Likewise, on average, output can be increased by at least 27% while utilizing existing resources and technology given the inefficiency factors were fully addressed.

Determinants of Technical efficiency

The focus of this analysis was to provide an empirical evidence of the determinants of productivity variability/inefficiency gaps among smallholder farmers in order to improve the existing level of efficiency in the study area. Most literatures used to analyze determinants of efficiency rather than inefficiency. However, the only difference between them is only on the interpretation (Solomon, 2014). Merely having knowledge that smallholder farmers were technically inefficient might not be useful unless the sources of the inefficiency were identified. Thus, in the second stage of this analysis, the study investigated farm and smallholder farmer specific attributes that had impact on smallholder farmers' technical efficiency.

The parameters of the explanatory variables in the inefficiency model were simultaneously estimated in a single stage estimation procedure using computer program, FRONTIER 4.1. The inefficiency variables in the study were classified under three categories. These were the socio economic and demographic factors (education, age and family size), resource related factors (total farm size, slope of land, livestock holdings, off-farm income activities, improved seed variety, maize plot fragmentation and ownership of land), and the credit access as an institutional factor. The dependent variable of the model was inefficiency and the negative signs implied that an increase in the explanatory variable would decrease the corresponding level of inefficiency (i.e. improvement of efficiency), and the positive sign is interpreted inversely.

Table 1 above showed that the coefficients of explanatory variables in the technical inefficiency model results estimates. Accordingly, the negative and significant coefficients of education, improved seed and credit access indicated that improving these factors contribute to reducing technical inefficiency. Whereas, the positive and significant variables of slope, off-farm income and fragmentation, affected the technical inefficiency positively that increase in the magnitude of these factors aggravated the technical inefficiency levels.

Education: is important to increase the managerial capacity of the smallholder farmer's in decision making. The results showed that smallholder farmers with more years of formal and informal schooling were more efficient than their counterparts. As expected, education affects the technical inefficiency effect of maize production significantly and negatively at 5% level of significance. The negative sign implies that smallholder farmers that were more educated tends to be more efficient in agricultural production than the less educated ones. Education enhances the acquisition and utilization of information on improved technology by the smallholder farmers. Similar results had been reported in Getachew and Bamlak, (2014); Wondimu, (2013); Agerie, (2013); Shumet, (2011); Beckhman et al., (2010). In general, more educated smallholder farmers were better able to generating off-farm income, utilize credit access, slope and fertility management, adopt improved technologies and purchased the appropriate quantities of inputs such as improve seed, DAP, Urea, and planting materials much faster than their counterparts. This result was consistent with the findings of Abdulai and Huffman, (2000) which established that an increase in human capital will augment the productivity of smallholder farmers.

Improved seed: The coefficient of the dummy variable representing use of improved seeds was statistically significant and negatively appeared at 5% level of significance as expected. The negative sign of the estimated coefficients of improved seeds had important implications of positively contributes on the technical efficiency of the maize producer smallholder farmers in the study area. It means that the tendency for any maize producer smallholder farmers to increase the production depend on the type and quality of improved seed available at the right time of sowing. This is because of improved maize seed would be so many advantageous like high yielding, disease resistant and produce at a minimum cost. Despite the gains in technical efficiency, about 37.5% of the smallholder farmers used improved seeds. This is probably because of high prices for improved seeds, making them unaffordable credit and education access to the study area of maize producer smallholder farmers. The other maize producer smallholder farmers use recycled seeds. This was in agreement with the findings of (Solomon 2014; Rudra et al., 2014; *Geta* et al., 2013; Hassen et al., 2012).

Access to Credit: The coefficient of credit recipient has consistent with the previous expected negative sign and statistically significant effect on technical inefficiency at 5% level of significance. The negative sign shows that credit recipient are more efficient than their counterpart of non-recipient. This implies that access to credit is a significant factor in enhancing efficiency of maize producer smallholder farmers in the study area. These findings can be attributed to the fact that credit permits a sample smallholder farmer to enhance efficiency by overcoming liquidity constraints. Hence, use of credit access ensures timely acquisition and use of agricultural inputs such as improved seed, DAP, Urea, herbicide, education and implement farm management decisions on time and these results increased production of efficiency. This suggests that availability of credit is an important factor for attaining a higher level of technical efficiency. Technically inefficient sample smallholder farmers can possibly get more efficient in the short run by facilitating access to credit. This empirical result is supported by the findings of Musa et al., (2014); Kwabena et al., (2014); Bekele, (2013); Shumet, (2011); Biforin et al., (2010) found positively and statistically significant relationship between credit and efficiency. If production credit is invested on the farm, it is expected that this will lead to higher levels of output. Thus, access to credit is more likely to lead to an improvement in the level of technical efficiency.

Slope of maize plot: Slope has strong influence on the long-term characteristics and viability of the farming system. This implies that the steeper plot is more vulnerable to erosion than the plain plot. Hence, on the steep slope plots under continuous cultivation and with little fertility maintenance, soil fertility deteriorates overtime. This leads to the decline of the productivity of farm land. Thus, the slope of maize plot was hypothesized to have a negative effect on the technical efficiency of the smallholder farmers. It was found to be an important explanatory variable of technical efficiency of maize producer sample smallholder farmers (Table 1). The results showed that the steep slope of maize plot was contributed positively and significantly to increase technical inefficiency at 5% level of significance. This implies that the steeper maize plot is more vulnerable to erosion than the plain plot or determines efficiency negatively. This is the result of no well-organized soil conservation activities which protect flooding. In this case, steep maize plots were vulnerable to erosion damage and they were likely infertile compared to plain maize plots. This result is in full agreement with (Ruth, 2011; Alemayehu, 2010 and Wondimagegn, 2010).

Off farm income: Off-farm income had a positive and statistically significant effect on technical inefficiency at 5% level of significance. This implied that for the Fogera maize producing smallholder farmers the inefficiency the coefficient of off-farm income variable was positive, indicating that the smallholder farmers who were engaged in generating off-farm income tended to exhibit lower technical efficiency levels in maize production. The negative relationship is attributed to the fact that off-farm income activity reduce that is invested their full concentrations in farming activity of higher productivity or involvement in off-farm activity are accompanied by reallocation of time away from farm related activities to generating income, such as adoption of new technologies, slope and fertility management, and gathering of technical information that is essential for enhancing production efficiency. This finding was in agreement with that of (Teklemariam, 2014; Bealu et al., 2013; Hassen et al., 2012; Shumet, 2011).

Land Fragmentation: The variable represents the number of parcels of maize land (number of maize plots), on which the smallholder farmer grows maize. It was hypothesized that a smallholder farmer with a greater number of maize plots is more inefficient than a farmer with more consolidated area. The reason is that as the number of maize plots operated by the smallholder farmer increases, the smallholder farmer was unable to distribute labor resources for different activities. Moreover, the smallholder farmers that have large number of maize plots would be wasted their time in moving between plots. The number of maize plot (fragmentation) used on the inefficiency model was appeared positive sign and statistically significant at 10% level of significance with consistent the previous hypothesized expectation (Table 12). This implied that, smallholder farmers that have large number of fragmented maize plots have the higher probability of wasting time of by moving different maize plots or unable to distribute labor resources, which results to decrease the efficiency of maize production. Furthermore, this result is congruent to with (Kifle, 2014; Getachew and Bamlak, 2014; Bekele, 2013; Beckhman et al., 2010).

Marginal Effects of inefficiency variables

The estimated parameters on the inefficiency model presented in Table 1 only indicated the direction of the effects that the variables had on inefficiency levels (where a negative parameter estimate shows that the variable reduces technical inefficiency). In contrast, the marginal effect presented on Table 2 below indicates the effect of inefficiency variables on technical efficiency level. According to Coelli and Battese, (2006), quantification of the marginal effects of inefficiency variables on technical efficiency was done by partial differentiation of the technical efficiency predictor with respect to each variable in the inefficiency function. The marginal effects were calculated by the STATA command mfx.

Table 2. Marginal effect of efficiency variables among sample household heads

variables	dy/dx	Std. Err.	z	Change in TE in %
Education	0.108**	0.062	3.73	10.8
Slope	- 0.041*	0.064	-2.64	4.1
Off farm income	- 0.071*	0.061	2.16	7.1
Seed Variety	0.072*	0.060	2.21	7.2
Credit	0.276**	0.076	3.59	27.6
Fragmentation	- 0.353***	0.068	5.14	35.3

*,**,*** implies significant at 10% and 5% and 1% probability level, respectively

Source: Computed from Field Survey Data, 2016/17

Table 2 shows the marginal effect of the efficiency measuring variables (this table is interpreted differently, a positive sign indicate an increase in TE). Producers who use improved maize seed are 7.2% more efficient than those that do not, ceteris paribus. Therefore, in order to increase the yield, they probably need to improve the quality of maize seeds rather than the quantity of seed. The marginal change (gain in TE) for an additional year of school is 10.8%. This indicated that for considered smallholder farmers an increase in the year of school, on average will increase the technical efficiency by 10.8 %. In contrast the marginal effect (-0.041) of slope of maize plot for technical efficiency indicated that, an increase in slope of maize plot, on average his technical efficiency will decrease by 4.1%. The marginal effect for credit can be interpreted as, if a smallholder farmer gained credit access, the smallholder farmers technical efficiency will increase on average by 27.6 % higher than those smallholder farmers who did not receive any credit access. Finally, participation in off-farm income earning activity and fragmentation of land reduces technical efficiency by 7.1% and 35.3 % than those they did not participate in off-farm activity and having fewer fragments, respectively. This result is in full agreement with Wondimu, (2013) and Endrias et al., (2013).

CONCLUSION AND POLICY IMPLICATION

The main aim of this study was to analyze determinants of technical efficiency of smallholder farmer maize production system in Fogera district. This was achieved by measuring the efficiency of smallholder farmers and identifying the determinant factors of technical efficiency that influence technical efficiency of maize production. The study area has crop-livestock mixed farming system. The major cereal crops grown based on the area and quantity proportion are maize, teff, rice and finger millet (on ascending order). Production of maize by smallholder farmers in Fogera district plays a vital role in alleviating poverty, since maize is the staple food in the District.

The results obtained from the SPF estimation showed that inefficiency was present in maize production among smallholder famers. Sufficient evidence of positive relationship between maize productivity and higher use of intermediate inputs such as DAP, Urea and maize plot utilization were practiced. In addition, technical efficiency increased with the increased in education, credit and improved maize seed whereas slope, off-farm participation and fragmentation decreased efficiency. Thus, it was needed in a priority basis to invest in public education to explore credit access and supply improved seed for the farm operation.

In general, an important conclusion stemming from this study is that, there exists a considerable room to reduce the level of technical inefficiency of maize production in the Fogera district. Thus, integrated development efforts that will improve the existing level of input use and policy measures towards decreasing the existing level of inefficiency will have paramount importance in improving the food security of the study area.

Based on the above results, the following important recommendations were given: The study confirmed that there is an indication of a great potential for maize productivity improvement in utilizing the existing experiences of few better off smallholder farmers. The positive and statistical significance of major traditional inputs such as maize plot, DAP, Urea and oxen-days show the importance of conventional inputs in smallholder farmers implying better access and use of these inputs could lead to higher maize production and productivity in the study area. Enhancing the productivity of these factors of production is necessary. As a result; Policy interventions should focus more on timely supply of DAP, Urea and good quality of improved seed to improve farmers' efficiency in production of maize.

Education Improvement also found to be a very and should be taken into account in the measure of technical efficiency. Hence, the government should have designed capacity building programs should be arranged and executed in order to capacitate the smallholder farmers development project through vigorous grass-root level extension work, farmers' active participation, on-farm demonstration and trials and proper guidance of the farmers should be increased in the study area.

Slope of maize plot should be recommended that soil and water conservation (land management practice) measures practice should be done in order to maintain at least the existing fertility status of the steep maize plot in the short run. credit facilities also are necessary to empowers smallholder farmers to purchases inputs that they cannot afford from their own resources, which enhance production and productivity of maize. Reduction in the interest rate and bureaucracies will then improve technical efficiency of maize production.

In general, the existence of higher technical inefficiency in the study area indicates that integrated development efforts that will improve the existing level of input use and policy measures that will decrease the existing level of inefficiency of smallholder farmers will have great importance in improving the living standard of smallholder farmers at large. Given limited resources, it would be wise and obviously better for the government and other concerned parties (like NGOs) participating in developmental activities to encourage development endeavors towards improving the level of efficiency of smallholder farmers in the study area.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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