Sources of Technical Efficiency Among Smallholder Maize Farmers in Babati District,Tanzania

Michael .R. Baha
School of Business Studies and Economics, University of Dodoma, Tanzania
Correspondence: Michael R.Baha, School of Business Studies and Economics. University of Dodoma, Box 395, Dodoma, Tanzania.
E- mail: bahamic@gmail.com

Abstract
Decrease in maize yield per hectare in Tanzania for the past three years was noted. This decline in yield has been attributed to many factors. Using a cross sectional data obtained through a multistage sampling technique the production efficiency and its determinants among maize crop farmers in the district were examined. A purposive sampling technique was used to select four wards under maize production with a simple random sampling used to select six villages out of the four wards. Stratified sampling was to select 122 farmers who cultivated maize in the study area. Stochastic frontier model determined the sources of inefficiency among farmers in the study area. The mean technical efficiency was found to be 62.3% suggesting that an estimated 37.7% of the inefficiency in maize production in study area results from combination of both technical and allocative inefficiency. The study concludes that, in order to increase efficiency farm size, formal education, number of plots owned by a farmer, frequency of contacts with extension officers, use of insect sides, and the use of hand hoes or otherwise are important factors.
Keywords: Smallholders, Maize, Production efficiency, stochastic frontier, Tanzania.

1. Introduction

Maize is one of the important food crops in Tanzania. It accounts for more than 75% of the cereal consumption making it one of the strategic crops for food security in the country (Msuya, 2009). The crop provides about 60% of dietary calories to the Tanzanian population (Kaliba, *et al*., 1998). The crop is widely cultivated in the country due to reliable climatic conditions. Maize is grown in almost every region in Tanzania, but highly performing in two agro-ecological zones which include southern and western highlands and the semi – arid lands in the country (WB, 1994).

Despite being widely cultivated and the role it plays as a food crop in the country, its yield per hectare has been decreasing. The available data indicate that the average crop yield per hectare in the country has decreased from 1 4071.24 kg/ha in 2007/08 production season to 1 122.536kg/ha in 2009/10 production season (FAO, 2011).

The situation has continued to be worse in major producing regions (with exception of Rukwa region where the average yield per hectare has been increasing); data available indicate that yield per hectare has been decreasing in the same period from 1 823.2kg/ha to 1 265.3kg/ha in Mbeya region, 1584.4kg/ha to 15065.7kg/ha in Ruvuma region, 1556.3kg/ha to 1231.7 in Iringa region and 1530.2kg/ha to 13363kg/ha in Manyara region (MAFC, 2011).

Babati district which is the main crop producing district in Manyara region has also not been outstanding on this; the crop yield per hectare has been showing the same trend despite the increase in area under the crop from 35070 hectares to 35280 hectares in 2006/07 and 2009/10 seasons respectively (URT, 2011). The yield per hectare has been decreasing continuously from 1362.5kg/ha in 2006/07 to 1124.8kg/ha in 2008/09 (URT, 2011).

Maize yield decrease is a pervasive problem, which threatens not only the economic well being of the farmers but also the efforts by the government to ensure food security (URT, 2011). This implies that if special attention is not paid to reverse the situation, the country stands a chance of facing severe food insecurity and negative outcomes from rural poverty alleviation efforts by the government through *Kilimo Kwanza*. It follows that, clarifying questions like what is the level of efficiency of maize farmers in the study area. What are the factors affecting maize production efficiency in the study area is imperative. These are the important policy issues that need to be understood by policy makers and project planners on the ground for achieving country objectives and millennium development goals.

It follows that this study provides an understanding of the aforementioned questions, by filling in the information gaps on the sources and level of efficiency in the District. Consequently, this study was designed to generate this information by the research conducted in Babati District.

2. Methodology

2.1 The Theoretical Model

A production function explains the technical relationship between the inputs and resulting outputs. If estimated empirically from data on observed outputs and input usage, it shows that the average level of outputs which be produced from a given level of inputs (Schmidt, 1985). Streams of studies have estimated the relative contributions of the factors of production through estimating production functions at either the individual level

or aggregate level. These include Cobb-Douglas production functions in fishing industry by Hannesson in1993
An implicit assumption of production functions is that all firms are producing in a technically efficient manner, and the representative firm therefore defines the frontier. Variations from the frontier are thus assumed to be random, and are likely to be associated with factors of production which are not measured. Contrary the estimation of the production frontier assumes that the boundary of the production function is defined by "best practice" firms. It therefore indicates the maximum potential output for a given set of inputs along a ray from the origin point. Some white noise is accommodated, since the estimation procedures are stochastic, but an additional one-sided error represents any other reason firms would be away from (within) the boundary. Observations within the frontier are deemed "inefficient", so from an estimated production frontier it is possible to measure the relative efficiency of certain groups or a set of practices from the relationship between observed production and some ideal or potential production (Greene, 1993).
A general stochastic production frontier model can be given by:
$\ln q_j = f(\ln x) + v_j - u_j$ Where q_j is the output produced by firm *j*, x is a vector of factor inputs, v_j is the stochastic (white noise) error term and u_j is a one-sided error representing the technical inefficiency of firm *j*. Both v_j and u_j are assumed to be independently and identically distributed with variance σ_v^2 and σ_u^2 respectively.

2.2 The Empirical Model

Data on maize smallholder farmers in Babati District are considered for an empirical application of the technical efficiency model for this paper. The model proposed a stochastic frontier production function, which has firm effects assumed to be distributed as a truncated normal random variable, in which the inefficiency effects are directly influenced by a number of variables. Given the objectives this study the Cobb-Douglas production functions and the stochastic frontier is applied and thus expressed as:

$$\ln(Maizeout) = \beta_0 + \beta_1 \ln(Labour) + \beta_2 \ln(Land) + \beta_3 \ln(Material) + V_i - U_i \quad \ldots\ldots\ldots \quad (i)$$

Where:

$\ln$ Denotes Natural logarithms;
$Maizeout$ Total amount of maize harvested in 2009/2010 season expressed in tons;
$Labour$ Both family and hired labour utilized in various farm activities expressed in man-day equivalents;
$Land$ Land area under maize cultivation in the 2009/2010 season expressed in hectares;
$Material$ Expenditures on intermediate materials (seeds, fertilizer, hiring tractor and ox-plough) expressed in Tanzanian shillings
β_i's Unknown parameters to be estimated;
V_i Represents independently and identically distributed random errors $N(0, \sigma_v^2)$. These are factors outside the control of the smallholder; and
U_i Represents non-negative random variables which are independently and identically distributed as $N(0, \sigma_u^2)$ i.e. the distribution of U_i is half normal. $|U_i| > 0$ reflects the technical efficiency relative to the frontier production function. $|U_i| = 0$ for a farm whose production lies on the frontier and $|U_i| > 0$ for a farm whose production lies below the frontier.

Knowing that farmers are technically inefficient might not be useful unless the sources of the inefficiency are identified. Thus, in the second stage of this analysis we investigate farm- and farmer-specific attributes that have impact on maize farmers' technical efficiency. The inefficiency function can be written as:

$$U_i = \delta_0 + \delta_1 Noforma + \delta_2 Hhsize + \delta_3 Plonnumber + \delta_4 Distplot + \delta_5 Gender + \delta_6 Nocoext + \delta_7 Traseva + \delta_8 Credito + \delta_9 Usefert + \delta_{10} Useinsect + \delta_{11} Hhoe + \delta_{12} Maizeland_i \ldots\ldots\ldots \quad (ii)$$

Where:

$Noforma$ Dummy variable for smallholder level of education, assuming a value of 1 if the farmer has no formal education and 0 if otherwise;
$Useinfer$ Dummy variable showing value of 1 if the smallholder indicated to have used fertilizers, otherwise zero;
$Useinsec$ Dummy variable showing value of 1 if the smallholder indicated to have used agrochemicals, otherwise zero;

Hhsize Household size, (number of people staying together and utilizing scare resources together)
Plonumber Measure land fragmentation (number of plots owned by smallholder under maize cultivation);
Distplot Distance to the plots from homestead expressed in Km;
Hanhoe Dummy variable showing value of 1 if the smallholder indicated to have used a hand hoe, otherwise zero;
Traseva Dummy variable showing value of 1 if the smallholder indicated to have used traditional maize seed variety, otherwise zero;
Nocoext Dummy variable showing value of 1 if the smallholder indicated has never had contact with extension officers, otherwise zero;
Maizlan Land area under maize cultivation in the 2009/2010 season expressed in hectares;
Gender Gender Dummy variable showing value of 1 if the smallholder is a male, otherwise zero;
Credito Dummy variable showing value of 1 if the smallholder has obtained any form of agricultural input credit, otherwise zero;
W_i An error term that follows a truncated normal distribution; and
δ_i's Inefficiency parameters to be estimated

The C-D production frontier function defined by equation (iv) and the inefficiency model defined by equation above will jointly estimated by the maximum-likelihood (ML) method using FRONTIER 4.1 (Coelli 1996). The FRONTIER software uses a three-step estimation method to obtain the final maximum-likelihood estimates. First, estimates of the α -parameters are obtained by OLS. A two-phase grid search for γ is conducted in the second step with α -estimates set to the OLS values and other parameters set to zero. The third step involves an iterative procedure, using the Davidon-Fletcher-Powell Quasi-Newton method to obtain final maximum-likelihood estimates with the values selected in the grid search as starting values.

2.2 The Data

The study was conducted in Babati District, which is one of the five districts in Manyara Region, located below the Equator between 3^0 and 4^0 latitude and longitude 35^0 and 36^0 of Greenwich. Neighbouring districts are Monduli in the North, Karatu in the Northwest, Mbulu in the West, Hanang in the Southwest, Kondoa in the South and Simanjiro in the East. The district population is estimated to be 303 013 people in 2002 of which 156 169 are male and 146 844 (URT 2002). The study area was regarded best for studying sources of technical efficiency as farmers from the district primarily rely on maize production for their livelihoods, although in recent years, the study area has experienced some expansion of non-farm activities. Increasing population growth and density has also led to fragmentation of landholdings for some families so that the distribution is not homogeneous hence the difference in farm plots. Therefore, most of the farmers in the study area operate as smallholders or sharecroppers. Furthermore accessibility of the area and good agronomic practices were also main drivers for selection of this study area.

Selection of wards and villages for the study was done with staffs' assistance from the office of the District Agricultural and Livestock Development Officer (DALDO) through listing of the respective wards and villages basing on accessibility, good agronomic practices and land management program which is still operating in the district.

Babati district has 18 wards; four wards were selected from each district as follows, Dareda, Duru, Galapo and Mamire. A total of 6 villages were selected for the survey (Table 1). There after stratified random sampling was carried out on each ward for selection of respondents who participated in the study *i.e.* people who own maize farm plots at different sizes.

Table 1: Villages Selected from the Study Area

District	Ward	Type	Village
	Mamire	Rural	Mamire
	Galapo	Mixed	Galapo
Babati			Orongadida
	Dareda	Rural	Bermi
			Dareda Kati
	Duru	Rural	Duru

3.0 Result and Discussion

3.1 Production frontier and Technical efficiency

3.2 Hypothesis Testing and Model Robustness

Before proceeding to examine the parameter estimates of the production frontier and the factors that affect the production efficiency of the maize farmers, this study investigated the validity of the model $((i)\ and\ (ii))$ used in the analysis. Tests of null hypotheses for the parameters in the frontier production functions and in the inefficiency models were performed using the generalized likelihood-ratio test statistic defined by: $\lambda = -2(\log[L(H_0) - \log(H_1)])$ where $L(H_0)$ and $L(H_1)$ denote the values of the likelihood function under the null (H_0) and alternative (H_2) hypotheses, respectively. If the null hypothesis is true, the LR test statistic has an approximately a chi-square or a mixed chi-square distribution with degrees of freedom equal to the difference between the number of parameters in the unrestricted and restricted models.

First the null hypothesis which specifies that there are no technical inefficiency effects in the model was tested *i.e.* $H_0 = \gamma = \delta_0 = \delta_1 = ...\delta_{18}$ .The hypothesis was rejected as gamma parameter (Table 7) is 0.94 and significant at 5 percent probability level, which means about 94 percent of the disturbance term is due to inefficiency. Thus, the inclusion of the technical inefficiency term is a significant addition to the model. In addition, a stochastic translog production frontier was estimated as a test of robustness in the choice of functional form. The form of this model encompasses the Cobb-Douglas form, so test of preference for one form over the other can be undertaken by analyzing significance of cross terms in the translog form. The ML estimates of the translog production frontier are given in Table 3.

Table 2: Parameter Estimates of the C-D Production Frontier

		OLS		MLE	
Variables	Parameters	Coefficient	t-ratio	Coefficient	t - ratio
Constant	β_0	-6.8873***	-2.7844	-7.0936***	-3.6963
Ln(Mandays)	β_1	0.07014	0.7093	0.1393**	1.7581
Ln(Land)	β_2	0.4427**	1.8701	0.3293**	1.8643
Ln(Materials)	β_3	0.5204***	2.6825	0.55***	3.6064
	σ^2			1.3967	
	γ			0.94	
Log – likelihood		-143.1195		-129.255	
LR - Test of the one-sided error				27.73	

*, **, ***Significant at 10, 5, and 1 percent respectively

Table 3: MLE for Parameters of the Stochastic Frontier and Inefficiency Model

Variables	**Parameters**	**Coefficient**	**Standard error**	**t-ratio**
Frontier Model				
Constant	β_0	-88.6749***	1.1766	-75.3668
Ln(Mandays)	β_1	1.2323	2.7624	0.4461
Ln(Land)	β_2	-8.2751***	2.2736	-3.6396
ln(Material)	β_3	12.7257***	2.4241	5.2497
$\ln Mandays^2$	β_4	-0.1193*	0.1037	-1.1504
$LnLand^2$	β_5	-0.1171	0.2591	-0.4518
$LnMaterial^2$	β_6	-0.5728***	0.1609	-3.5594
LnMandays*LnLand	β_7	-0.1919	0.2731	-0.7029
LnMandays*LnMaterials	β_8	0.1522	0.1735	0.8771
LnLand*LnMaterial	β_9	0.8733**	0.3788	2.3056
Inefficiency Model				
Constant	δ_0	-1.6821**	0.9698	-1.7344
Noforma	δ_1	-0.1818	0.9816	-0.1852
Hhsize	δ_2	0.25894***	0.0928	2.7901
Plonnumber	δ_3	-1.6603***	0.4796	-3.4616
Distplot	δ_4	0.2322***	0.0898	2.5867
Gender	δ_5	2.0357***	0.7228	2.8163
Nocoext	δ_6	-0.2179*	0.1344	-1.6209
Traseva	δ_7	0.7066*	0.4649	1.5196
Credito	δ_8	1.3414**	0.5783	2.3197
Usefert	δ_9	1.4414**	0.8008	1.7999
Useinsec	δ_{10}	-3.2638***	0.1167	-2.7961
Hhoe	δ_{11}	-0.1682**	0.9698	-1.7344

*, **, ***Significant at 10, 5, and 1 percent respectively

Table 3, shows that only coefficient of a constant, land, material, mandays square, material square and product of land and material shows significant effect on output. But the coefficient of a constant, land, mandays square, material and Material Square are negative. Ten of the parameters in the inefficiency model showed significant effect on inefficiency. Furthermore, all cross products have *t*-values less than one or close to zero except the product of land and material. This suggests that there are only interactions between these later variables. Robustness of the estimated models can also be indicated by the value of the log-likelihood function.

The model that best fits the data is the one with a higher log-likelihood function. The values of the log-likelihood function for the estimated models are -143.1195 and -129.255 for C-D model and translog model respectively. Given that the C–D frontier model best fits the data the study conclude it to be more appropriate than translog model specification.

The second null hypothesis which is tested is H_0: $H_0 = \delta_1 = ...\delta_{11}$ implying that the farm-level technical inefficiencies are not affected by the farm - farmer-oriented variables, policy variables and/or socio-economic variables included in the inefficiency model. This hypothesis is also rejected, implying the variables present in the inefficiency model have collectively significant contribution in explaining technical inefficiency effects for the maize farmers. The results of a likelihood ratio test (LR = 27.73) confirms that farmers' low production efficiency mainly relate to the variance in farm management

3.3 The Production Efficiency and Distribution

The distribution of production efficiency of maize farmers in the study area is presented in Table 11. Farmers technical efficiency vary from 0.008 to 0.92 with the average production efficiency score is 62.3% implying that the average farm producing maize could increase production for about 37.7% by improving their technical and allocative efficiency. This average TE does not differ significantly with that of 60.6% of Kiteto and Mbozi as presented by Msuya, (2008) and that of Weir (1999) and Weir and Knight (2000) find mean efficiency levels of about 55% among Ethiopian cereal crop producers. The observed wide variation on production is not surprising, similar variation in production efficiency in maize farmers are also observed in from Kenya and Malawi with the mean technical efficiency of 49% (range of 8 to 98%) and 46.23% (with a range of 8.12 to 93.95%) respectively. Despite the observed variation in production efficiency, more than 36% of farmers have less than 60% efficiency level; hence most of farmers seem to be skewed towards production efficiency of less than 60%. However, the results indicate there is a room for increasing production by improving technical and allocative efficiency for maize farmers in the study area. The volatile distribution of efficiency indexes among smallholder maize farmers are depicted by Figure 8

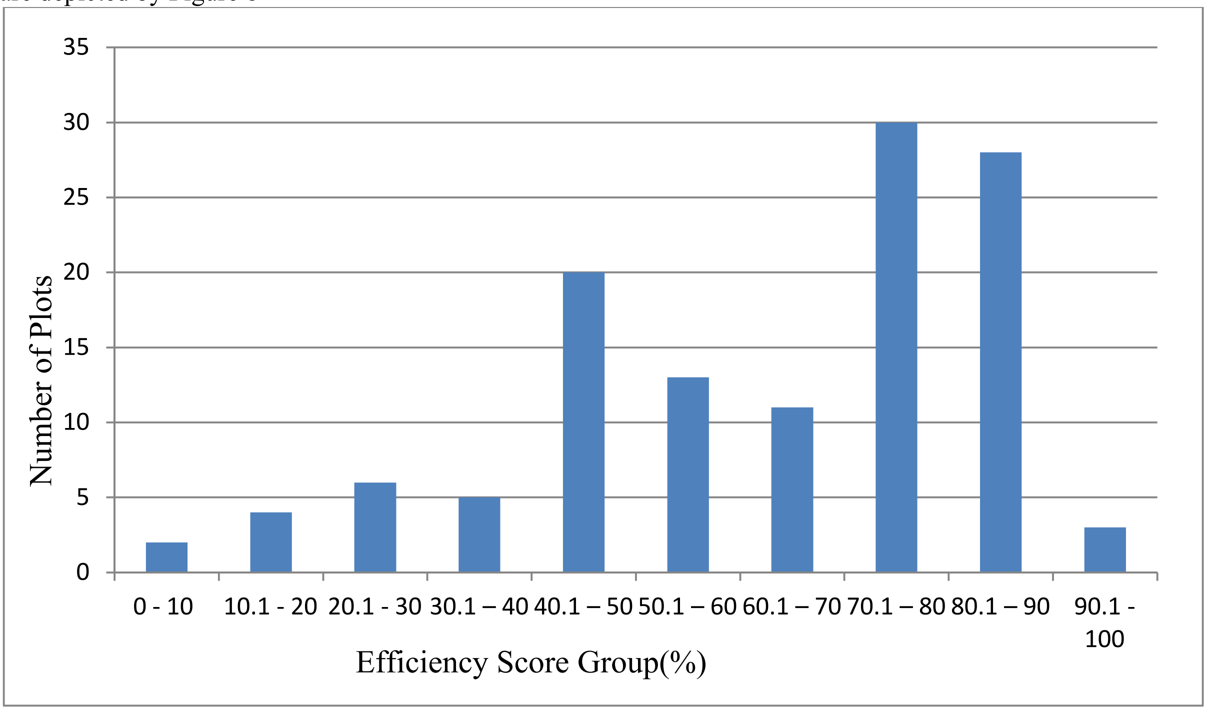

Figure 1: The Distribution of Efficiency indexes among smallholder maize farmers

3.4 Determinants of Inefficiency

This section reports on sources of inefficiency also estimated in the model. A negative sign on a coefficient inefficiencies means that the variable increases technical efficiency and a positive effect on productivity, while a positive sign reduces technical efficiency. The results on Table 4 reveal that the number of plots owned, number of contacts with extension officer, means of land acquisition, use of insect sides, the use of hand hoes dummy variables and the area under maize production have a negative sign and therefore increase technical efficiency. These results appear plausible. To interpret the coefficients it is recommended to use marginal effect (Battese and Coelli, 1993).

Table 4: Inefficiency Model

Variables	Parameter	Coefficients	Standard error	t- ratio
Constant	δ_0	-1.9908**	1.0951	-1.8179
Noforma	δ_1	-0.4073	1.2358	-0.3296
HHsize	δ_2	0.3087***	0.0953	3.2402
Plonnumber	δ_3	-1.9369***	0.3084	-6.2797
Distplot	δ_4	0.3066***	0.0907	3.3798
Gender	δ_5	2.0867***	0.6255	3.3363
Nocoext	δ_6	-0.2414**	0.1264	-1.9089
Traseva	δ_7	0.8874*	0.549	1.6163
Credito	δ_8	1.3399***	0.544	2.4629
Usefert	δ_9	2.2294*	0.8443	2.6406
Useininsect	δ_{10}	-2.9224***	0.83	-3.5209
Hhoe	δ_{11}	-1.9906**	1.0951	-1.8179
Maizeland	δ_{12}	-0.4595**	0.2441	-1.8822

*, **, ***Significant at 10, 5, and 1% respectively

Results on gender (sex) show male farmers were more efficient. This is contrary to results by Masterson (2007) and Tchale and Sauer (2007) who found gender to have no significant impact on efficiency but similar to the results by Msuya *et al,* (2008) among maize farmers in Tanzania and Kibaara (2005) among maize smallholders in Kenya. Consequently, this work is evidence to the ongoing debate on the role of gender in maize farmers' efficiency by providing more results showing how gender has a significant impact on efficiency.

The coefficient for use of agrochemicals variable is negative and statistically significant. This implies that, farmers who use agrochemicals are more efficient compared to farmers who do not spray their farms. However, coefficient for the use of fertilizers variable is positive and statistically significant at 10% level of significance. This implies that smallholders who use fertilizers are less efficient compared to those who do not use fertilizers. This is contrary to the current influence and subsidization policy by the government of fertilizers to the farmers.

The estimated coefficient of house hold size is positive and significant at 1% level of significance. This implies that maize farmers with more family size tend to be technically efficient in maize production. This result is not exceptional but similar to the results by Oyewo, (2011) for maize farmers in Oyo State who found more family size tend to be technically efficient.

The negative but insignificant coefficient for lack of formal education variable indicates that farmers' education is less important factor in enhancing agricultural productivity in the study area similar to the results by Chirwa (2007) in southern Malawi maize farmers. An explanation to this is that, maize is mainly produced for subsistence using traditional methods and the education of farmers does not play a role in the optimal combination of inputs. However these results are unlike the results by Msuya (2008), for maize farmers in Tanzania who found the opposite. The coefficients for credits and plot distance from the homesteads also have similar sings as this of lack of formal education.

Another result found to be interesting is that; estimated coefficient for the use of traditional seed variety is positive and significant at 10% level of significance. This implies that farmers who use traditional seed varieties are less efficient compared to those who use improved seeds. The results of similar nature were also found by Chirwa, (2007) to maize farmers in Southern Malawi.

4. Conclusion and recommendation

The main objective of the paper was to determine the sources of Production efficiency among maize farmers in Babati, Tanzania. The study used Stochastic production frontier functions were in the analysis. Using comprehensive survey data obtained from 122 maize farms in 2010 the study obtained production efficiency with wide variation among maize farmers in the district. The mean level of efficiency for maize farming is 0.623 indicating that there remains considerable scope to increase maize production by improving both technical and allocative efficiency.

The farm-specific variables used to explain inefficiencies indicate that those farmers who have farming experience, number of farm plots they own, contacts with extension officers , those who had hired or bought land, the ones who use hand hoe and insect sides to be more efficient. Due to the gap of 37.7% inefficiency level, resulting from the above mentioned factors there is a need for proper policy to eliminate this gap. Increasing farm plot size, strengthening extension services, extension materials and farmers training were therefore found to improve efficiency if increased .

In view of the major findings of the study and the above conclusions, the following recommendations are drawn. More efforts should be intensified on the part of extension agents in training and provision of extension materials to the farmers so as to boost their efficiencies in maize production, also results of better researches of improved agronomic practices should be extended to the farmers in this area by the extension agents. The extension services can be intensified by promoting the linkage between farmers, researchers and extension personnel. This will facilitate the flow of information from the researchers to the farmers and vice versa, which is important for the development of relevant technologies. An efficient extension system will ensure proper communication between farmers and researchers, which is important for the developed technologies to reach the end users, and for the researchers to have a clear knowledge of farmers' needs. To achieve this target, the government should enhance the support provided to extension agents and agricultural researchers.

The study confirmed that efficiency can be increased by increasing farm plot size in the study area with the current level of inputs used. This should be done by emphasizing favorable environment for increasing farm sizes among farmers to ensure transformation from agriculture sector dominated by very small farms to agriculture dominated by plausibly large farms. The relative increase in farm plot size will not only increase the food security in the country but also stimulate efforts by the government to move its citizens out of absolute poverty. Given the escalating prices of inorganic fertilizers (taking the bigger share of the agriculture sector budget in the country), alternatives such as integrated soil fertility management which reduces the effective costs of soil fertility management options are recommended.

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