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Latt, Aung Ko
Laboratory of Farm Management, Division of Agricultural and Resource Economics, Department of Agricultural and Resource Economics, Graduate School of Bioresource and Bioenvironmental Sciences, Kyushu University,

Hotta, Kazuhiko
Faculty of Agriculture, Kyushu University

Nanseki, Teruaki
Faculty of Agriculture, Kyushu University

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Analysis of Technical Efficiency of Monsoon Rain–fed Sesame Production in Myanmar: A Stochastic Frontier Approach

Aung Ko LATT[1], Kazuhiko HOTTA[2] and Teruaki NANSEKI[2]

Laboratory of Farm Management, Division of Agricultural and Resource Economics, Department of Agricultural and Resource Economics, Graduate School of Bioresource and Bioenvironmental Sciences, Kyushu University, Fukuoka 812–8581, Japan
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This study was designed to estimate the level of technical efficiency of sesame farmers in Myanmar. The primary cross–sectional household survey data for rain–fed sesame production in 2008 rainy season collected from the randomly selected samples of 115 farmers were used in the analyzing model. A stochastic frontier production function was applied in a single–stage process using FRONTIER–4.1 computer program to estimate technical efficiency and to know the factors affecting the sesame yield. The results showed that technical efficiency indices range from 54 to 97 percent for sample farmers with an average of 85 percent. This indicates that there is a scope for further increasing sesame production by improving resources use efficiency.

INTRODUCTION

Edible oil is the second most important commodity in daily diet of people after rice in Myanmar. Moreover, oil crops are third in importance to rice and pulses and beans in respect to area sown to crops in Myanmar. Sesame (*Sesamum indicum*) is the most extensive and traditional edible oil crop among the principal oil crops such as groundnut, sunflower, niger, mustard and oil palm. Sesame occupied about 49% of the seven year average (2001/02–2007/08) of area sown to the principal oil crops, 7.28 million acres. Sesame is grown for oil consumption as it is high in oil contents and farmers also derive a substantial proportion of their cash income from this crop in the region. Sesame has a premier place in the production of oilseeds in Myanmar and has export potentials in accordance with the global figures.

It has been realized that the country's edible oil production is still lack of self–sufficiency for the domestic requirements. Consequently, to bridge the gap between supply and demand, several amounts of palm oil are being imported annually. Therefore, the current status of the oil crops sub–sector has important negative impacts for farmers, consumers and national economy. A lack of productivity growth is one of the oil crops, including sesame, sub–sector constraints. Increasing sesame farmers' productivity is required not only for net foreign exchange cost saving but also for export earnings. To increase crop production, production efficiency improvement becomes one of the suitable approaches for developing country.

This study was therefore carried out with the following objectives: 1) to estimate the effects of inputs used on sesame yield and the level of responsiveness of yield to these inputs, 2) to estimate the technical efficiency in given inputs used among the sesame farmers and 3) to identify some socio–economic characteristics of farmers and farm specific characteristics that may affect the technical inefficiency.

DATA AND METHODOLOGY

The production data used in the econometric analysis were primary cross sectional survey data which were collected from 115 monsoon rain–fed sesame farmers in Magway Township, Central Dry Zone of Myanmar. Sesame farmers were selected using random sampling method. Technical Efficiency analysis used 2008 rainy season main harvest sesame cropping year household data. The survey was conducted during September and October 2009 and data collection was carried out through face–to–face interviewing of sample farmers by using a structured questionnaire.

The traditional concept of productive efficiency, as proposed by Farrell (1957), has two components: technical (or physical) efficiency and allocative (or price) efficiency. Technical efficiency refers to the ability of a firm to achieve the maximum attainable level of output from a given set of production inputs while allocative efficiency refers to a farm's (firm) ability to use the production inputs in the optimal combination, given their respective prices and given production technology. Economic efficiency or overall efficiency is the product of technical and allocative efficiency. Hence, in order to be economically efficient, a farm must be both technically and allocatively efficient.

Proposed Stochastic Frontier Production Function

The stochastic frontier production function was independently and originally proposed by Aignar, Lovell and Schmidt (1977) and Meeusen and Van den Broeck (1977). This model can take into account for technical inefficiency in production, and but they can also take into

[1] Laboratory of Farm Management, Division of Agricultural and Resource Economics, Department of Agricultural and Resource Economics, Graduate School of Bioresource and Bioenvironmental Sciences, Kyushu University, Fukuoka 812–8581, Japan

[2] Faculty of Agriculture, Kyushu University

* Corresponding author (E–mail: nanseki@agr.kyushu–u.ac.jp)

account for disturbance terms representing exogenous random shocks beyond the control of producers and other noise in the data together with the combined effects of unspecified input variables in the production function. In developing countries, since crops production is operating under the various uncertainties, the present study employed a stochastic production frontier approach.

An appropriate formulation of stochastic frontier model in terms of a general production function for the ith production unit is as the followings:

$$Y_i = f(X_i;\ \beta_i) + \varepsilon_i\ (\varepsilon_i = V_i - U_i) \quad (1)$$

Where, Y_i is the production of i–th farm, X_i is a vector of k inputs used by i–th farm and β_i is vector of unknown parameter to be estimated and ε_i is an error term made up of two components, V_i and U_i. Where, V_i is random variable error associated with random factors such as measurement errors and other statistical noise in production and exogenous factors beyond the farmers' control, and V_i is assumed to be independently and identically distributed (iid) as N (0, σ_v^2), and independent of U_i. U_i is non–negative random variable associated with farm–specific factors which would affect technical efficiency in the production and U_i is assumed to be independently distributed as truncation (at zero) of the normal distribution with mean, μ and variance, σ_u^2. However, U_i can also have other distributions such as half–normal, exponential or gamma, Aigner *et al.* (1977), Meeusen and Van den Broeck, (1977) and Kebede (2001). The original specification of U_i assumed to be half–normal (N (0, σ_u^2)) has been applied over the past decades. Moreover, FRONTIER 4.1 program cannot accommodate exponential or gamma distribution, Coelli (1996).

In this study, following the studies of Battese *et al.* (1996), Battese and Coelli (1995), Dey *et al.* (2000) and Idiong (2007), U_i is assumed to be distributed as truncation (at zero) of the normal distribution with mean μ_i and variance σ_u^2 (N |(μ_i, σ_u^2)|), where

$$\mu_i = Z_i\ \delta_i \quad (2)$$

Where, Z_i is a 1 × e vector of farm/farmers specific variables that may cause inefficiency and δ_i is a e × 1 vector of unknown parameters to be estimated and then, farm/farmers level stochastic production frontier that represents the maximum feasible output (Y_i^*) can be expresses as

$$Y_i^* = f(X_i;\ \beta_i) \exp(V_i) \quad (3)$$

Y_i^* is the highest predicted output and equation (1) may be rewritten using equation (3) as

$$Y_i = Y^*_i \exp(-U_i) \quad (4)$$

And then, Technical Efficiency of the i^{th} farm can be estimated as,

$$TE_i = Y_i / Y^*_i = Y^*_i \exp(-U_i) / f(X_i;\ \beta_i) \exp(V_i)$$

$$= \exp(-U_i) \quad (5)$$

This means the difference between observed and frontier output is embedded in the U_i. If U_i is equal to 0, then Y is equal to Y^* and the production is on the frontier and the farm is technically efficient. If U_i is greater than 0, the production will lie below the frontier and the farm is technically inefficient (Dey *et al.*, 2000 and Idiong, 2007).

As presented in Battese and Coelli (1993), the technical efficiencies are predicted using the predictor that is based on the conditional expectation of exp (–U_i). The technical efficiency of a farmer is between zero and one and is inversely related to the inefficiency effect (Coelli and Bettese, 1996).

The β and δ coefficients are estimated together with variance parameters which are expressed in terms of:

$$\sigma_s^2 = \sigma_v^2 + \sigma_u^2$$

$$\gamma = \sigma_u^2 / \sigma_s^2$$

The Maximum Likelihood Estimates (MLEs) of equation (1) provides consistent estimators for β, γ, and σ_s^2 parameter, where, σ_s^2 explains the total variation in the dependent variable due to random shocks (σ_v^2) and due to technical inefficiency (σ_u^2) together, Abedullah *et al.* (2006). Gamma (γ) parameter represents the share of inefficiency in the overall residual variance with values in interval 0 and 1, Coelli *et al.* (2005), Idiong (2007) and Abedullah *et al.* (2006). If γ is equal to 0, all deviations from the frontier are due to noise, while γ is equal to 1 means all deviations are due to technical inefficiency, Coelli *et al.* (2005).

Empirical Stochastic Frontier Production Function

Since stochastic frontier production models were proposed by Aigner, Lovell and Schmidt (1977) and Meeusen and Van den Broeck (1977), there has been a vast range of their applications in literature. The two most popular functional forms for stochastic frontier literature are the Cobb–Douglas and the translog production function. However, the Cobb–Douglas functional form has been most commonly used in the empirical estimation of frontier models. Its most attractive feature is its simplicity. A logarithmic transformation provides a model which is linear in the logs of inputs and hence easily lends itself to econometric estimation (Coelli, 1995).

Moreover, the Cobb–Douglas functional form has been widely applied in farm efficiency analyses[1]. Despite its well–known limitations, Bravo–Ureta and Pinheiro (1997) chose the Cobb–Douglas functional form for their study because the methodology employed requires that the production function be self–dual. Therefore, following the literature, the Cobb–Douglas functional form was chosen for Stochastic Frontier Analysis in this study.

In the production function, five inputs of production, seed rate, farm yard manure, urea, human labor and animal power are included because these inputs are the conventional inputs used in crop production in the study area. Therefore, the stochastic frontier production function for sesame farmers is specified by

$$\text{Ln } Y_i = \beta_0 + \beta_1 \text{Ln } X_{i1}, + \beta_2 \text{ Ln } X_{i2} + \beta_3 \text{ Ln } X_{i3} + \beta_4 \text{ Ln } X_{i4} + \beta_5 \text{Ln } X_i 5 + V_i - U_i \quad (6)$$

Where, the subscript i indicates the i–th farmer in the sample, Ln refers to natural logarithm, β_0 is constant and β_s is unknown parameters to be estimated. Y is sesame yield of farm (kg per acre), X_1 is seed rate used of farm (kg per acre), X_2 is farm yard manure (FYM) used (cartloads per acre), X_3 is urea fertilizer used (kg per acre), X_4 is labor used (man days per acre) and X_5 is animal power used (oxen–pair days per acre). V_i are random errors term and U_i are technical inefficiency effects as explained in equation (1).

The stochastic frontier model for sesame farmers was estimated on per acreage basic by using the computer program, Frontier 4.1 written by Coelli (1996). Abedullach, *et al.* (2006) gave the reasons for estimating on per acreage basic that it is intuitively simpler to directly interpret efficiency on a per unit area as opposed to per filed plot basic and farm size is collinear with other variables included in the model.

The technical efficiency of production for the i–th farm is defined as the ratio of observed output to the corresponding maximum feasible output associated with no technical inefficiency is described by

$$TE_i = \exp(-U_i) = \frac{\text{Observed output}}{\text{Maximum feasible output}}$$

After obtaining farm specific technical efficiency, the sources of the inefficiency were identified by making appropriate analysis. Moreover, investigating the sources of technical inefficiency are particular interests of researchers who analyzed the technical efficiency of crop production. However, Coelli and Battese (1996) mentioned that the expected signs on the δ–parameters in the inefficiency model are not clear in all cases. They gave an example as the age of farmers could be expected to have positive or a negative effect upon the size of the inefficiency effects. The older farmers are likely to have had more experience and hence have less inefficiency. However, they are also likely to be more conservative and thus be less willing to adopt new practices, thereby perhaps having greater inefficiencies in agricultural production.

The literature of previous studies indicates that socio–economic and demographic characteristics of farmers such as age and education of farmers, farming experiences, credit and extension assets, etc. and farm characteristics such as land size and soil fertility, etc. would determine the technical efficiency or inefficiency. In this study, the following model is used to study the relationship between the explanatory variables and the level of technical efficiency.

$$TIE_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 \quad (7)$$

TIE_i = technical inefficiency predicted by model itself

δ_0 = constant

Z_1 = Farmers' operated Farm Size (in acres)

Z_2 = education level of farmers as dummy (if farmer has middle and above educational level, $Z_2 = 1$ and otherwise, $Z_2 = 0$)

Z_3 = farmers' age (in years)

Z_4 = soil conditions demonstrated by the farmer as dummy (if 50% and more than 50% of farmers' cropping fields are in good and moderate soil, $Z_4 = 1$ and otherwise, $Z_4 = 0$)

δ_s = unknown scalar parameters

In this study, following Battese and Coelli (1995), the parameters of the stochastic production frontier and inefficiency effect models are jointly estimated in a single–stage by using the maximum likelihood estimation method. They criticized about a two–stage analysis in which the first stage involves the specification and estimation of the stochastic frontier production function and the prediction of the technical inefficiency effects under the assumption that these effects are identically distributed. The second stage involves the specification of a regression model for the predicted technical inefficiency effects, which contradicts the assumption of identically distributed inefficiency effects in the stochastic frontier. Coelli and Battese (1996) and Rahman, S. and Rahman, M. (2008) also used the single stage approach in their stochastic frontier analysis.

RESULTS AND DISCUSSION

Summary Statistics of the variables used in the stochastic frontier analysis

Table 1 shows the detailed summary statistics of the output and input variables gathered from 115 sesame farmers to be involved in the stochastic frontier analysis. The average sesame yield was 258.96 kg per acre with a standard deviation of 51.63 that indicates that the large variability of yield among the farmers. On average, human labor including both family and hired labors 64.09 man–days per acre were applied on sesame production. The maximum rate was 104.4 and the minimum was 44.5 man–days per acre. The animal or draught power used for land preparation, FYM application and tillage or inter cultivation was measured by oxen–pair days per acre. The minimum of 3.75 and maximum of 11 oxen–pair days were used by sample farmers with the average of 5.79 oxen–pair days per acre. The amounts of animal labor and human labor used show that a peculiar characteristic of agricultural farming where mechanization is wholly absent in the study area.

[1] The statement can be supported by the empirical literature reviewed completed by Battese (1992), and by Bravo–Ureta and Pinheiro (1993), Kebede (2001), Abedullah, *et al.* (2006). Moreover, different studies concluded that choice of functional form might not have a significant impact on measured efficiency levels (Good *et al.* (1993) and Ahmed and Bravo–Ureta (1996).

Table 1. Summary statistics for variables used in the stochastic frontier production function

Variables	Unit	Mean	Standard Deviation	Maximum	Minimum
Variables for production function model					
Yield	kg/ac	258.96	51.63	374.03	125.95
Seed (X_1)	kg/ac	6.48	0.44	8.31	5.44
FYM (X_2)	cartloads/ac	6.45	2.18	15	2.68
Urea (X_3)	kg/ac	21.12	6.64	36.36	4.62
Labor (X_4)	man–days/ac	64.09	12.33	104.4	44.5
Animal Power (x_5)	oxen–pair days/ac	5.79	1.18	11	3.75
Variables for inefficiency model					
Farmers' operated Farm Size (Z_1)	acre	12.25	7.75	36.5	2
Farmers' Education Level (Z_2)	dummy	0.57	0.50	1	0
Farmers' age (Z_3)	years	44.75	11.26	72	22
Soil conditions (Z_4)	dummy	0.97	0.18	1	0

1ha = 2.47 acres
Source: Survey data, 2009

Estimation of Production Frontier and Technical Efficiency

The estimations of stochastic frontier production function of the selected rain–fed sesame farmers are described in Table 2. The results of both of the Ordinary Least Square (OLS) and Maximum Likelihood Estimations (MLEs) for the Cobb–Douglas production function as described in equation (6) are reported.

The lower section of Table 2 reports the results of testing the hypothesis for the present of technical inefficiency effects among the sample farmers. The study revealed that the MLEs of key parameter γ (Gamma) was 0.802 and highly significant at 1 percent level. This is consistent with the theory that the γ–value must be between zero and one as mentioned in methodology section. This implies that 80 percent of the variation in sesame yield is attributed to technical inefficiency and 20 percent is due to the stochastic random. It also confirms that the technical inefficiency effects are likely to be significant in the stochastic frontier model and that the traditional average production function (OLS) with no technical inefficiency effect is not an adequate representation of the data, Battese *et al.* (1996) and Idiong (2007).

Furthermore, the general Likelihood Ratio (LR) test was also used to test the presence of technical inefficiency

Table 2. Ordinary Least Square and Maximum Likelihood Estimates of the Cobb–Douglas Stochastic Frontier Production Function

Variables	OLS Estimations		MLEs	
	Coefficients	t–ratios	Coefficients	t–ratios
Constant	3.364***	6.224	3.800***	8.126
Seed	–0.155ns	–0.651	–0.074ns	–0.356
FYM	0.111*	1.783	0.103*	1.965
Urea	0.209***	4.857	0.177***	4.518
Labor	0.405***	4.353	0.329***	3.596
Animal Power	–0.024ns	–0.219	–0.018ns	–0.181
Variance Parameter				
$\sigma_s^2 = \sigma_v^2 + \sigma_u^2$			0.044**	1.987
(Gamma) $\gamma = \sigma_u^2 / \sigma_s^2$			0.802***	6.619
LR–test of one sided error			13.748	
$\chi^2_{(6,0.95)}$ (mix Chi–square distribution)			11.911	
Log likelihood Function	46.828		53.702	
No. of observation				115

*,**, *** are significant at 10%, 5%, 1% level respectively and ns is not significant

Source: Own estimates

effects. Null hypothesis or restricted model in which the total variation of output due to technical inefficiency is zero that is γ=0. Alternative hypothesis is general stochastic frontier model in where no restriction and thus γ=0.

LR = –2 {log likelihood (H_0) – log likelihood (H_a)}

The likelihood ratio test has a mixed Chi–square (χ^2_R) distribution with R equal to the number of parameters assumed to be zero in the null hypothesis or the number of parameters excluded in the unrestricted model, Rahman (2003) and Kolawole (2006). Null hypothesis (H_0) is to be rejected if LR test is greater than the critical Chi–square table value (LR > χ^2_R).

In this study, the null hypothesis that technical inefficiency effects are absent that is

$H_0 = \gamma = \delta_0 = \delta_1 = \delta_2 = \delta_3 = \delta_4 = 0$ in the model. The value of log–likelihood function for the unrestricted stochastic frontier production model was 53.702 and the value of log–likelihood function for restricted or ordinary least square model was 46.828. Therefore, the calculated generalized likelihood ratio test to be LR = –2 * (46.828 – 53.702) = 13.748. This value is also estimated by Frontier 4.1 model itself and reported as the "LR test of one sided error". To take the critical value, the degrees of freedom or the number of parameters assumed to be zero in the null hypothesis, R is equal to 6 in this study.

The value of Likelihood Ratio test exceeds the critical value taken from Kodde and Palm (1986, Table 1) (LR statistic 13.748 > $\chi^2_{(6,\ 0.95)}$ =11.911). This table was used in several studies analysed by Coelli, *et al.* (2005), Abedullah, *et al.* (2006) and Idiong (2007). So, the null hypothesis of no technical inefficiency effects among the sesame farmers is rejected at the 5 percent significant level in favor of the presence of technical inefficiency effects among the sample farmers. This also implies that the presence of Cobb–Douglas stochastic frontier model for the adequate representation of data.

Among the signs of coefficients of five variables in equation (6) when estimated with OLS and MLE, the estimated coefficients of seed rate and animal or bullock power were negative but they were not significant. This implies that seed rates and animal power used do not affect the sesame yield significantly. However, the negative signs of seed rate and animal power on sesame yield may be due to inefficient used and improper used or overused of these inputs.

Hassan and Ahmad (2005) also found that the coefficient for wheat seed variable on wheat production in Pakistan with negative sign. Tun Win (2004) found that the coefficient of seed rate was negatively related to yield of cotton farmers in Myanmar. In this study, the negative sign of seed rate on yield may be due to farmers' overused of seed rate. During the survey, every farmer used to store sesame from the previous crop year to use as seeds for the next cropping season. So, they used their own seed and they don't need to pay any purchasing charge for seeds and it would enhance farmers to use excessive amount of seed rate.

The estimated coefficients for animal or drought power also showed negative sign but no significant. It also conforms to previous studies in India reported by Battese and Coelli (1995) and Coelli and Battese (1996). They mentioned that the reason for the negative elasticity for bullock labor may be due to the fact that the bullocks are often used more extensively in years of poorer rainfall (for weed control, levy bank improvements, etc.) when yields are lower. Thus quantity of bullock labor may be acting as an inverse proxy for rainfall. Tun Win (2004) also investigated that the significantly negative effects of draught power on the yield of cotton farmers in Myanmar. He concluded that draught power can be supposed due to both unsystematic use and overused.

In this study, the finding for the negative relationship of animal power to sesame yield may be due to unsystematic and overused. In the study area, 95.65 percent of farmers used their own oxen and cows for draught power and only 4.35 percent of farmers have no own animals. So, the farmers don't need to pay any hiring charge for animal power. Hence, it is likely that animal power could be overused among sample farmers.

The coefficients of other variables such as FYM, labor and urea fertilizer were positive sign in both OLS and MLE and significant at 10 percent level for FYM and 1 percent level for both labor and urea, respectively.

Inputs elasticity and Responsiveness of yield to inputs used

The elasticity of each variable input was determined to estimate the responsiveness of yield to inputs. The results of study showed that the sesame yield has the highest responsiveness to labor, followed by the urea fertilizer and FYM. It suggests that the contribution of labor man–days is dominant with elasticity of 0.33. It implies that a one percent increase in the use of labor man–days will lead to a 0.33 percent increase in sesame yield. The large coefficient of this variable is suggested that farmers used an appreciable amount of human labors in the cultivation process and hence the contribution of this variable to increased yield was considerable. Moreover, the increase in sesame yield may be the results of better weeding and proper production practices for harvesting and thrashing and winnowing.

Other important inputs were urea fertilizer and FYM. A one percent increase in urea would increase sesame yield about 0.18 percent. One percent increase in FYM will lead to 0.10 percent increase in sesame yield.

Technical Efficiency Level of Sample Farmers

The frequency distributions of technical efficiency of sample farmers are reported in Fig. 1. The minimum technical efficiency was 54 percent and the maximum was 97 percent while the mean technical efficiency was 85 percent. According to efficiency distributions, about 73.04 percent of farmers attained more than 80 percent of technical efficiency level, while none had below 50 percent level of efficiency.

The 85 percent of average technical efficiency estimated in this study is nearly the same as that found by

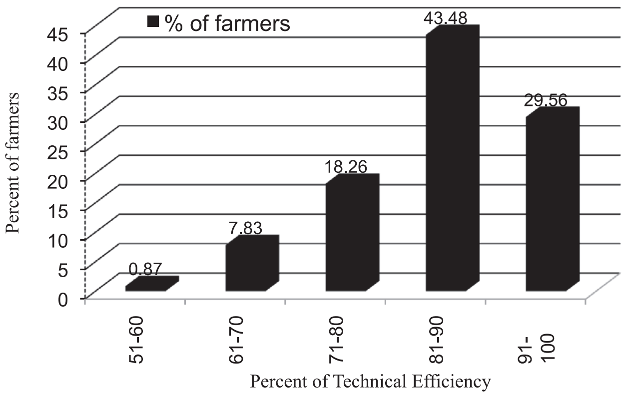

Fig. 1. Distributions of the farm specific technical efficiency of individual farmers.
Source: Own estimates

Abedulllah, *et al.* (2006) for potato farmers (84 percent) in Punjab, Pakistan. To provide a basis comparison for the technical efficiency measures, Table 3 presents mean technical efficiency indices reported in other researches that have estimated on cross–sectional data from developing countries by using stochastic frontier production function.

Sources of technical inefficiency

The analyzing of the sources of technical inefficiency is also needed in order to investigate the variation of technical efficiencies among the sesame farmers. By using the specification of equation (7), the study attempted to capture determinants of technical efficiency. The Maximum Likelihood Estimates of determinants of technical efficiency of sample farmers are depicted in Table 4. It should be note that since the explained variable in the inefficiency model is the mode of technical inefficiency, a negative sign on a parameter inefficiencies means that the associated variable reduces technical inefficiency or has a positive effect on efficiency, while a positive sign increases technical inefficiency or has a negative effect on efficiency.

The results indicated that the coefficient of farmers' operated farm size, educational level, age and soil conditions have expected signs. However, only soil condition as dummy variable was found to be statistically significant at 10 percent level.

The coefficient of farmers' operated farm size variable had positive relationship with inefficiency, but it was not significant. If farmers have large farm size, they may have many field plots and then they may have some difficulties to reach all important production enhancing inputs to each plot. It means that probably because the managerial ability on large farms becomes more complex. This result is in line with that of Tun Win (2004) on cotton in Myanmar and Bravo–Ureta and Pinheiro (1997) on peasant farming in Dominican Republic. Coelli and Battese (1996) mentioned that the claim which is frequently made for developing country agriculture, that smaller farmers tend to be more efficient in production than larger farmers.

The negative sign for education of the farmer is consistent with our expectation, but it was also statistically insignificant. This is probably because education would enhance farmers to adopt and utilize the improved technologies as well as their innovativeness. Battese and Coelli (1995), Coelli and Battese (1996) and Abedullah,

Table 3. Comparison of Average Technical Efficiency from various studies using Stochastic Frontier Production Function

Author	Country	Crops	Mean TE (%)
This study	Myanmar	Sesame	85
Abedullah, *et al.* (2006)	Pakistan	Potato	84
Hassan and Ahmad (2005)	Pakistan	Wheat	94
Idiong, I.C. (2007)	Nigeria	Rice	77
Thanda Kyi and M. von Oppen (1999)	Myanmar	no fertilizer use on rice (small, medium, large scale) farmers	(88 , 92, 93)
	Myanmar	fertilizer use on rice (small, medium ,large scale) farmers	(97 , 90, 92)

Table 4. Maximum Likelihood Estimates of Technical Inefficiency of Sesame Farmers

Variables	Coefficients	Standard Errors	t–ratios
Constant	0.060	0.602	0.099
Farmers' operated farm size	0.037 [ns]	0.071	0.527
Farmers' education level	–0.091 [ns]	0.089	–1.020
Farmers' age	0.069 [ns]	0.157	0.443
Soil conditions	–0.313 [*]	0.176	–1.785

*is significant at 10 percent level and ns is not significant
Source: Own estimates

et al. (2006) found that farmers with greater year of schooling tends to be less technically inefficient.

The coefficient of farmers' age had positive sign on inefficiency and it was also not significant. The older farmers are technically less efficient than younger farmers. It may be due to the older farmers may like to use the old and traditional cultural practices and they may not be easily to adopt new practices and modern inputs. Moreover, younger farmers may be more active in present agricultural practicing than older farmers. This result is consistent with the finding of Battese and Coelli (1995), Idiong (2007), Brovo–Ureta and Pinheiro (1997). However, Coelli and Battese (1996) found that the mixture signs of age of India farmers on crop production inefficiency in three places. The older farmers tend to have more efficient than younger farmers in Aurepalle and Kanzara, but the reverse is true in Shirapur in India.

The dummy for soil conditions was only one statistically significant variable among the determinants of inefficiency. Rahman (2003) reported that soil fertility, an inherent capacity of the cultivable land, is also an important factor in promoting farmers' welfare. His study results revealed that Bangladesh rice farmers located in fertile regions perform significantly better than those in less fertile regions. In this study, soil conditions variable had negative sign on technical inefficiency and had 10 percent significant level. It implies that if the farmers have more good and moderate soil conditions on their cropping field plots, they are more technically efficient. This may be due to the following reasons: if farmers have bad soil on their fields, they wouldn't want to use high cost effective inputs in order to avoid risks from bad soil conditions as a result in sesame yield would decrease. Consequently, it will reduce technical efficiency. Or, even though farmers use enough inputs such as fertilizer and FYM, the sesame plants could not absorb these inputs effectively on the bad soil. Nevertheless, this calls for study on the history of the plot and plot–specific physical characteristics such as soil pH, soil texture and cation exchange capacity (CEC) of soil, etc. to get better understanding in the study area.

CONCLUSIONS AND RECOMMENDATIONS

According to the empirical literature recently completed by researchers, measurement of technical efficiency has been one of the most important issues of farming business for efficient use of resources including land, labor, and capital. This study was carried out to predict the level of technical efficiency of sesame farmers and to explain variations in technical efficiency among farmers by identifying socio–economic characteristics and farm characteristics.

In the frontier production function, the estimated coefficients for farm yard manure, labor and urea fertilizer were found to positively and significantly affect on sesame yield. Therefore, the increase of these inputs use would lead to increase sesame yield. The study showed that the sesame yield has the highest responsiveness to labor, followed by the fertilizer and FYM. It suggests that the contribution of labor man–days in sesame yield is dominant factor with elasticity of 0.33. Therefore, sesame seems to be labor intensive crop for better weeding, for timely harvesting and for proper winnowing and thrashing.

The result of mean technical efficiency 85 percent further shows that there is a scope for the farmers to increase their sesame yield by improving their resources use efficiencies with the current technology. The results indicated that the coefficient of farmers' operated farm size, educational level, farmers' age and soil conditions had expected signs on the technical efficiency. The dummy variable for soil condition was found to be statistically significant at 10 percent level. So, the technical efficiency would be increased by improving soil fertility of farmers' cropping field plots. However, the farm specific characteristic variable used in this analysis was only based on the evaluation of soil condition as demonstrated by the sample farmers themselves. The history of field plots and the detailed specific physical characteristics of soil conditions such as soil pH, cation exchange capacity (CEC) of soil, and soil texture and so on in the study area were not included in this study. In the future study, it would be required to investigate the detailed soil fertility index in the study area.

Given the empirical findings, the suggestions and recommendations are proposed as the followings: the balance use of FYM and urea fertilizer would enhance sesame yield per acre. Therefore, the procurement and distribution of urea fertilizer may be the possible and appropriate way to improve sesame productivity, and then, it will also improve farmers' technical efficiency.

In the short run, programs designed to educate rural households through introducing farmers' training school systems and/or giving proper extension services with equipped skills. It could assist farmers to be better decision makers of their farms and it could have an impact on increasing the level of technical efficiency and hence sesame productivity.

Many of the farmers achieving high and consistent yields and then obtaining high technical efficiencies can be used effectively to demonstrate the benefits of good farming practices, including input use adjustments and undertaking soil conservation practices in order to reduce the gap between the most technically efficient and the least technically efficient farmers.

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