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Analysis of Economic Efficiency of Sesame (Sesamum Indicum L) Production in Babogambel District of West Wollega Zone, Oromia Region, Ethiopia

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Abstract

The aim of the study was to measure the levels of technical, allocative and economic efficiencies of sesame producers and identify factors affecting them in Babogambel district of Oromia Region, Ethiopia. The study was based on cross-sectional data collected in 2016 production season from 124 randomly selected farm households. Stochastic production frontier model was used to estimate technical, allocative and economic efficiency levels, whereas Tobit model was used to identify factors affecting efficiency levels. Accordingly, the mean technical, allocative and economic efficiencies of sample households were 75.16%, 72.95% and 53.95%, respectively. The results indicated that there was substantial amount of inefficiency in sesame production in the study area. Land, labor and oxen were the variables that positively affected the production of sesame. Results of the Tobit model revealed that family size, experience in sesame production and non-farm income, Total cultivated land had effect on technical efficiency. On the other hand, experience in sesame production, family size, extension contact affected soil fertility and education level affected allocative efficiency significantly. Education level, experience in sesame production, soil fertility, extension contact affected economic efficiency significantly. Results indicate that there is a room to increase the efficiency in sesame production of the study area.

Keywords: Allocative efficiency, Babogambel, economic efficiency, Tobit, stochastic,

INTRODUCTION

Sesame is produced in around 75 countries of the world. The production of sesame seeds in the world is dominated by a few countries that lie in the African and Asian continents. The top five sesame producing countries are China, India, Myanmar, Sudan, and Tanzania. Ethiopia is the second top exporter of sesame seed next to India (IEA, 2016). Ethiopia is one of the centers of biodiversity for several oilseeds which can be considered as specialty high value seeds on the international markets. The major sesame seed producing areas in the country are Tigray region, Western and North Western zones, (especially Humera, Tsegede and Welkaite districts); Amhara region, North Gondar zone (specifically Metema, Kuara, West Armachiho, Tach Armachiho and Tegede districts); Oromiya region: Western Wollega (Oda, SirbaAbay, Jarso, Babo-gembel, Gimbi and Manasibu and the surroundings), Eastern Wollega (Gidayana, Diga and Gutin), Horo-guduru (Abedongoro), Keluem Wollega, Jima as well as Illubabor zones; and Benshangul Gumuz region (Assossa, Sherkole, Homsha, Mengie, Kumruk, Kamashi, Aqelo Meti, Yaso, and surroundings) (ECX, 2015). Despite the high oil seed crop productivity variations across the region, the growth rate of productivity is significantly increased within each region except sesame during the same period.

The annual average oil seed crop productivity growth rate was: Neug 11.12%, 8.61% & 4.81% Linseed 12%, -8.45% & 9.36% and Sesame 0.01%, 5.62% & -1.04% in Tigray, Amhara and Oromia regions respectively, Sesame crop productivity shows the list productivity growth among the other oil seed crops in the last ten years in all three major oilseed growing regions of Ethiopia (CSA, 2015). According to CSA (2015), in 2013/14 production year, sesame covered 299,724 ha of land at national level. The total production of sesame in the same year at national level was 2.2 million qt. In the same year, the total productivity of the crop at national level was 7.35qt per ha. From 2013/14 to 2014/15 production season, production of sesame has increased by 27.27% but productivity has decreased by 6.53% at national level.

The same source indicated that in Oromia region, the total area covered by sesame in the production year of 2013/14 was 48,182ha and 379,240qt of sesame have been produced with the productivity of 7.87qt per ha. From 2013/14 to 2014/15, production of sesame has increased by 41.3% but productivity has decreased by 6.6% in Oromia region. Even though there is an effort by some research centers in Ethiopia in variety development and agronomic practices, surprisingly from 1995/96 (1988 E.C) to 2014/15 (2007 E.C) sesame productivity was drastically reduced from 9.8qt per ha to 6.87qt per ha. This implies the research attention that has been given to improve this crop is not comparable with the contribution of this crop in Ethiopian economy for long period of time. Therefore, possible ways should be sought to improve the efficiency of the farmers in Ethiopia.

Babogambel district, which is one of the districts of West Wollega Zone, is known by oilseed production specially sesame and Niger. Out of the total 86400 hectares of land in the district, land used for cultivation occupies 41 percent of it. As sesame is concerned for this study, it occupies 12.1 percent of the total cultivable land of the district. In 2014/15 production year, the total production and productivity of sesame in the district was 27,860.95qt and 7.15qt/ ha respectively (BDARDO, 2015). Among the oil crops of Ethiopia, sesame seed commands a leading position because it is highly adapted to arid and semiarid low land environment and yields well. Accordingly, sesame is the major oilseeds crop in the country in terms of exports next to coffee, accounting for over 85 percent of the value of oilseeds exports (MoARD, 2015). However, the Ethiopian Statistical Agency report of 2014 indicated that the sesame productivity level was 7.35 and 7.87quintals per hectare at national level and in Oromia region respectively. However, it is understood that in 2015 the productivity level of sesame in national and regional level were decreased to 6.87 and 7.3quintals per hectare respectively (CSA, 2015).

Despite of the fact that Babogambel district has high potential for sesame production, the yield has been 7.15quntals per hectare which is below regional average in 2014/15 production season. Its production only increased by .05% and 0.02%in 2014 and 2015, respectively(BDARDO, 2015).This shows as production and productivity of the crop remain in a question for a long period of time in Ethiopia in general and in study area, Babogambel in particular. The general objective of this study was therefore, to analyze economic efficiency of smallholder farmers in the production of sesame in Babogambel district of Western Wollega Zone. Hence, the study was undertaken with the following specific objectives: To estimate the level of technical, allocative and economic efficiencies of sesame production in the study area; and to identify factors affecting technical, allocative and economic efficiencies in the study area.

MATERIALS AND METHODS

Description of the Study Area

This study was conducted in Babogambel district, in West Wollega Zone of Oromia region, Ethiopia, which is found 560km from capital city of Ethiopia (Finfine), and it is located at 120km away from Gimbi (Western Wollega Zone) in east direction, it is bounded by Jarso and Nejo in the east, Manasibu and Kiltukara in the North; Begi in the West, Kondala and Kellem Wollega Zone in the south. The altitude of the district ranges from 1400 to 1615 meters above sea level. The temperature of the district range from 25 – 30 degree centigrade with 1850 millimeters annual average rain fall and 70% of the district is fall under lowland and the left 30% is midland. Agricultural production is the main means of livelihoods for the district. The production season of sesame in the study area starts from the ending of June up to beginning of October.

Types, Sources and Methods of Data Collection

In order to generate sufficient information for this study, both primary and secondary data from different sources were used. Accordingly, secondary data were collected from Babogambel district agricultural department, CSA and different report. Besides, different and relevant published and unpublished reports, bulletins, websites were consulted to generate relevant secondary data on economic efficiency of sesame. The primary data were collected entirely from sample households using a semi-structured questionnaire.

Sampling Technique and Sample Size

Babogambel district was purposively selected for the study because of the presence of large number of sesame producing farmers and its extent of production. To determine the sample kebeles and households, a two stage random sampling procedures was used. In the first stage, three kebeles out of seventeen sesame producing kebeles namely Ambalo-Dila,Malka-Ebicha and Shimal-Tokke were selected randomly.

In the second stage, 124 farm households were selected randomly by lottery method from those who were producing sesame taking into account probability proportional to the size of sesame producers in each sample kebeles. The sample size was determined based on the following formula given by Yamane (1967):

$$n=\frac{N}{1+N(e^2)} \tag{2.1}$$

Where, n is sample size, N is number of Household and e is the desired level of precision. By taking e as 9%, and the total household of 21,783the sample size was 124.

Model specifications and Methods of Data analysis

The stochastic frontier production function was used to estimate the technical, allocative and economic efficiencies of sesame in the study area. The model was specified as:

$$\ln Y_i = \beta_o + \ln \sum \beta_j X_{ij} + \varepsilon_i \tag{2.2}$$

$$\varepsilon_i = v_i - u_i$$

Where,

$Ln(y_i)$ = natural log of output of ith farmer

i = number of farmers in the study

x_i= (k+1) row vector whose frist element is 1 and remaining 'x' elements are log of 'k' input quantities used by ith farm.

$\beta = (\beta_o, \beta_i \ldots\ldots B_k)$, is a (k+1) column vector of unknown parameters to be estimated.

v_i= random error term (ie. random effect)

u_i= error term related with technical inefficiency.

Aigner *et al.* (1977) proposed the log likelihood function for the model in equation (3.2) assuming half normal distribution for the technical inefficiency effects (u_i). They expressed the likelihood function using λ parameterization, where λ is the ratio of the standard errors of the non-symmetric to symmetric error term (i.e. $\lambda = \sigma_u/\sigma_v$). However, Battese and Corra (1977) proposed that the γ parameterization, where $\gamma = \sigma^2_u / (\sigma^2_v + \sigma^2_u)$, to be used instead of λ. The reason is that λ could be any non-negative value while γ ranges from zero to one and better measures the distance between the frontier output and the observed level of output resulting from technical inefficiency.

However, there is an association between γ and λ. According to Bravo and Pinheiro (1997) gamma (γ) can be formulated as:

$$\gamma = \lambda^2 / (1 + \lambda^2) \qquad (2.3)$$

Hence, by following Battese and Corra (1977) the log likelihood function of the model is specified as:

$$\ln(L) = -\frac{N}{2}\left(\ln\left(\frac{\pi}{2}\right) + \ln\sigma^2\right) + \sum_{i=1}^{N} \ln\left[1 - \Phi\left(\frac{\varepsilon_i\sqrt{\gamma}}{\sigma^2}\sqrt{\frac{\gamma}{1-\gamma}}\right)\right] - \frac{1}{2\sigma^2}\sum_{i=1}^{N}\varepsilon_i^2 \qquad (2.4)$$

Where $\varepsilon_i = \ln Y_i - \ln X_i\beta$ is the residual of (2.2); N is the number of observations; Φ(.) is the standard normal distribution; $\sigma^2 = \sigma_v^2 + \sigma_u^2$, and $\gamma = \sigma_u^2 / \sigma^2$ are variance parameters.

The minimization of (2.4) with respect to β, σ^2 and γ and solving the resulting partial derivatives simultaneously, produces the ML estimates of β, σ^2 and γ. The γ parameter is used to test whether the technical inefficiency affects output or not. Likewise, the significance of σ^2 indicates whether the conventional average production function adequately represent the data or not.

Elasticity of production: It is the measure the effect of change in the factor input output. In Cobb-Douglas production function, the regression coefficients stand for the elasticity's of the individual resources (land, labor, seed, fertilizer, herbicide and oxen). The sum of these parameters indicates the nature of returns to scale, i.e., If the sum is equal to 1, it indicates constant returns to scale, if it is greater than 1, it shows increasing returns to scale and if sum is less than 1 it implies that decreasing returns to scale.

Dual cost frontier model: The production function could also be estimated through an alternative form, called dual, such as cost or profit function. Sharma *et al.* (1999) suggests that the corresponding dual cost frontier of the Cobb Douglas production functional form in equation (3.2) can be rewritten as:

$$C_i = C\,(Wi, Y_i^*; \alpha) \qquad (2.5)$$

Where i refers to the i^{th} sample household; C_i is the minimum cost of production; W_i denotes input prices; Y_i* refers to farm output which is adjusted for noise v_i and α's are parameters to be estimated. The economically efficient input vector of the i^{th} household X_{ie} is derived by applying Shepards' lemma (Arega and Rashid, 2005) and substituting the firms input prices and adjusted output level, a system of minimum cost input demand equation can be expressed as:

$$\partial C_i / \partial W_n = X_{ie}\,(W_i, Y_i^*; \alpha) \qquad (2.6)$$

Where n is the number of inputs used. The observed, technically and economically efficient costs of production of the i^{th} farm are then equal to $W'X_i$, $W'X_{it}$ and W'_{ie}; respectively. The minimum cost is derived analytically from the production function, using the methodology used in Arega and Rashid (2005). Given input oriented function, the efficient cost function can be specified as follows:

$$\text{Min} \sum_x C = \sum_{j=1}^{6} X_j W_j \qquad (2.7)$$

Subject to $\quad Y_i^* = \widehat{A} \prod X_j^{\hat{\beta}_j}$

Where $\widehat{A} = \text{Exp}(\hat{\beta}_o)$

The solution for the problem in the above equation is the basis for driving dual cost frontier. Substituting the input demand equations derived using shepherd`s lemma (Eq. 3.8) and Output adjusted for stochastic noise (predicted value of yield) in the minimization problem above, the dual cost function can be written as follows:

$$C(Y_i^*, w) = HY_i^{*\mu} \prod_j W_j^{\alpha_j} \qquad (2.8)$$

Where; $\alpha_j = \mu\hat{\beta}_j$, $\mu = (\sum \hat{\beta}_j)^{-1}$ and $H = \frac{1}{\mu}(\widehat{A} \prod \hat{\beta}^{\beta_j}{}_j)^{-\mu}$

All the Parameters are known; hence we can calculate the minimum (efficient) cost of production.

According to Sharma *et al.* (1999), the above cost measures are used to estimate the technical, allocative and economic efficiencies respectively. We can define the farm–specific technical efficiency in terms of observed output (Yi) to the corresponding frontier output (Yi*) using the existing technology.

$$TE_i = Y_i / Y_i^* \qquad (2.9)$$

The farm specific economic efficiency is defined as the ratio of minimum observed total production cost (C*) to actual total production cost (C).

$EE = C^*/C$ (2.10)

Following Farrell (1957), the AE index can be derived from Equations (3.9) and (3.10) as follows:

$AE = EE/TE$ (2.11)

In this study, a Cobb-Douglas function was fitted to both stochastic production frontiers and cost frontier function of the Sesame farmers using the Maximum Likelihood method. This functional form has been used in many empirical studies.

The production function model for this study is specified as follows;

$\text{Ln } Y = \text{Ln } b_0 + b_1 \ln X_1 + b_2 \ln X_2 + b_3 \ln X_3 + b_4 \ln X_4 + b_5 \ln X_5 + b_6 \ln X_6 + \varepsilon_i$ (2.12)

Where, Y is output of sesame (Qt), X_1 is size of land (hect), X_2 is amount of seed used (Kg), X_3 is the amount of DAP used (kg), X_4 is the number of oxen (MD), X_5 is the amount of labor used (MD), X_6 is the amount of herbicide used (Ltr), and Ln is natural logarithm, $b_0 - b_6$ are coefficients to be estimated, ε_i is composed error term which is also defined as V– U. It is expected a priori that the coefficients of X_1, X_2, X_3, X_4, X_5, X_6, will be positive. The cost frontier function is also specified as;

$\text{LnC} = \ln a_0 + a_1 \ln Px_1 + a_2 \ln Px_2 + a_3 \ln Px_3 + a_4 \ln Px_4 + a_5 \ln Px_5 + a_6 \ln Px_6 + a_7 Y^*$ (2.13)

Where, C is minimum cost of production per sesame farmer, P_1 is the seasonal rent of a hectare of land in the study area (Birr), P_2 is the price of seed per kilogram (Birr) , p_3 is the cost of DAP (Birr), p_4 is the unit cost of oxen (Birr), p_5 is the unit cost of labor (Birr) and p_6 is the unit price of herbicide (Birr) , Y^* is the output of sesame in quintals adjusted for statistical noise, $a_1 - a_6$ are parameters to be estimated, a_0 is the y – intercept. It is expected a priori that the coefficients of Px_1, Px_2, Px_3, Px_4, Px_5 and Px_6 will be positive.

In SPF hypothesis tests can be made using ML ratio test that are not possible in non-parametric models. A number of tests of hypotheses were made in this study using the usual Likelihood Ratio (LR) test given as:

$LR = \lambda = -2\ln[L(H_o)/L(H_1)]$

$\lambda = -2[\ln L(H_o) - \ln L(H_1)]$ (2.14)

Where, λ is the likelihood ratio (LR),

L (H_o) = the log likelihood value of the null-hypothesis,

L (H_1) = log likelihood value of the alternative hypothesis, and ln is the natural logarithms.

All the tests were carried out using generalized likelihood ratio statistics. The test statistics is defined by $\chi 2 = -2\,[L(H_0) - L(H_1)]$, where $L(H_0)$ and $L(H_1)$ are the values of the likelihood function for the model under the null hypothesis, H_0, and the alternative hypothesis, H_1, that are involved.

Identifying the Determinants of Technical, Allocative and Economic Efficiency

This study had adopted the two stage estimation procedure. A two-step economic procedure is used first to estimate efficiency scores and then a Tobit model is used to determine the relationship between the efficiency scores and factors that may influence efficiency indices. The rationale behind using the Tobit model is that there are a number of farms for which efficiency score is approach to one and the bounded nature of efficiency between zero and one. That is, due to absence of fully efficient SPF estimates, the distribution of efficiency measures is no right censoring limit with specified left censoring limit which is below but more approach to minimum efficiency score to include all observation. Estimation with Ordinary Least Squares (OLS) regression of the efficiency scores would lead to biased parameter estimates since OLS assumes normal and homoscedastic distribution of the disturbance and the dependent variable (Greene, 2003). Therefore tobit model was used to estimate determinants that affect production of sesame. According to Green (2003), Tobit (Censored Regression) model is specified as:

$$E_i^* = \sum_j \beta_j X_j + V_i \quad (2.15)$$

$$E_i = 1 \quad if \quad E_i^* \geq 1$$

$$E_i = E_i^* \quad if \quad E_i^* < 1$$

Where E_i is an efficiency score, representing technical, allocative and economic efficiencies; and $V_i \sim N(0, \sigma^2)$ and β_j are the vector of parameters to be estimated, X_j represent various farm variables: X_1= Age of household head

X_2= Level of Education
X_3= Farming Experience
X_4= Family Size
X_5= soil fertility
X_6=Sesame production experience
X_7=proximity to sesame farm
X_8=Number of Oxen
X_9=Total cultivated land
X_{10}= Extension contact
X_{11}=credit access
X_{12}= Sex

and E_i^* is the latent variable.

RESULTS AND DISCUSSION

Descriptive Statistics of Variables Used in the Stochastic Frontier Model

The production function for this study was estimated using six input variables. On average farmers produced 5.13 quintals of sesame, which is the dependent variable in the production function. The land allocated for sesame production, by the sample households during the survey period, ranges from 0.125 to 3 ha with average of 1.012 ha. The average amount of seed that sample households' used was 12.9 Kg. Like other inputs human and animal labor inputs were also decisive, given the traditional farming system in the study area.

Table 1. Descriptive statistics of variables used to estimate the production function

Variable description	Minimum	Maximum	Mean	Std. deviation
Output (Qt)	0.5	19	5.13	3.74
Land (ha)	0.125	3	1.012	0.65
Seed (Kg)	2	42	12.9	7.12
DAP (Kg)	0	200	26.86	38.14
Labor (MDs)	12.5	159.06	50.11	28.74
Herbicide (Lts)	0.375	9	2.85	1.48
Oxen (days)	1.875	40.375	12.26	7.76

Source: Own survey (2016)

To draw some picture about the distribution and level of inputs, the mean and range of input variables is discussed as follows: On average, the total cost of 4021.36 Birr was required to produce 5.13 quintals of sesame. Among the various factors of production, the cost of human labor accounted for the highest share (1760.96 Birr). Following the cost of labor, cost of oxen labor takes major share out of total cost of production which is 621.08 Birr. Among other inputs, cost of seed takes the smallest (158.82 Birr) share out of the total cost of sesame production.

Table 2. Summary statistics of variables used to estimate the cost function

Variable description	Minimum	Maximum	Mean	Std. deviation
Output (Qt)	0.5	19	5.13	3.74
Total cost of production	719.437	10314.6	4021.3	2078.2
Cost of land (Birr)	50	1500	426.84	294.04
Cost of seed (Birr)	24	504	158.82	86.8
Cost of DAP (Birr)	0	3300	575.77	665.02
Cost of human labor (Birr)	437.5	5567	1760.96	1002.4
Cost of Herbicide (Birr)	52.5	1260	425.645	272.82
Cost of oxen labor (Birr)	93.75	2018.75	621.08	389.5

Source: Own survey (2016)

Estimated observed and potential (frontier) level of output

The difference between the actual level and the frontier level of output was computed by estimating the individual and the mean level of frontier output. The mean levels of the actual and frontier output during the production year were 5.13Qt and 7.18Qt/ha, with the standard error of 3.74 and 4.25, respectively. Moreover, paired sample t-test was used on the actual and potential output to compare the difference in the amount of yield between two scenarios. There was a significant difference between potential output and actual output. The mean difference of the actual and the potential output was found to be statistically significant at 1% probability level.

Table 3. Comparison of estimated actual and potential output of sample households

		Potential (frontier) Output		Actual (observed) Output	
Efficiency category	N	Mean	Std. Deviation	Mean	Std. Deviation
0.2 - 0.6999	37	6.5	4.27	3.514	3.13
0.7 – 0.7999	43	7.15	4.26	4.66	3.07
0.8 – 0.8999	23	7.166	3.86	5.92	3.5
0.9 – 0.9999	21	8.48	4.58	8.1	4.46
Overall	124	7.18	4.25	5.13	3.74
Paired sample t-test					t = 13

Econometric Result

This section presents the econometric results of the study. The results of production and cost functions, efficiency scores and determinants of efficiency are discussed successively. Tests of hypotheses for the parameters of the frontier model and production function are conducted using the generalized likelihood ratio statistics, λ.

Table 4.Generalized LR test of hypotheses for parameters of SPF

Hypothesis	df	LH0	LH1	Calc $\chi2$(LR)	Critical X^2	Decision
H_0: CD ($\beta_7 \ldots \beta_{27}=0$)	20	-35.12	-34.14	1.96	31.41	fail to reject
H_0: CD ($\beta_7 \ldots \beta_{12}=0$)	6	-35.12	-37.94	5.64	12.6	fail to reject
H_0: $\mu=0$	1	-53.11	-53.09	0.04	3.84	fail to reject
H_0: $\gamma=0$	1	-48.22	-53.11	9.78	3.84	Rejected
$H_0=\delta_0=\delta_2 \ldots =\delta_{12}=0$	12	-53.11	-35.12	34.64	21.026	Rejected

Source: own computation, 2016

Estimation of production and cost functions

Technical, allocative and economic efficiency levels in sesame production in Babogambel districts were estimated using stochastic frontier production function (SFP). Input variables such as area under sesame cultivation (Land) (ha), oxen (days), labor (MD), quantity of seed(Kg), fertilizer(Kg) and amount of non-selective herbicide chemical(roundup) in liters were used in the model for estimating technical efficiency, while total price of each inputs in birr were used for estimating allocative efficiency.

Table 5.MLE results of the production frontier for the sample households

Variable	Coefficient	Standard error
Constant	0.12	0.47
Land	0.44***	0.1
Seed	0.09	0.08
Dap	0.001	0.00
Oxen	0.21**	0.12
Labor	0.26**	0.10
Herbicide	0.03	0.09
Diagnostic statistics		
Gamma (γ)	0.90***	
Sigma square	0.35***	0.072
Lamda	3.02***	0.11
log_likelihood	53.11	

Note: ** and *** refers to 5% and 1% significance level, respectively.

Source: Own computation (2016)

From the total of six variables considered in the production function, three (Land, labor and oxen) had positive sign and significant effect in explaining the variation in sesame output among farmers and are significant variables in shifting the frontier output to the right or moving along the frontier. This indicated that a unit increase of these variables; increase the level of sesame output. The coefficients of the production function are interpreted as elasticity. Hence, high elasticity of output to land (0.44) suggests that sesame production was highly depending on size of land. As a result, 1% increase in size of land will result in 0.44% increase in sesame production, keeping other factors constant. Alternatively, this indicates sesame production was responsive to labor, land and oxen in the study area. The productions function estimated from stochastic frontier model results: **Ln Y** = **0.12**+ **0.44 ln(land)** + 0.09 ln(seed) + 0.001ln(DAP) + **0.26 ln(labor)**+ **0.21ln(Oxen)**+ 0.03ln (Herbicide) + ε_i

The diagnostic statistics of inefficiency component reveals that sigma squared (σ^2) was0.35 and statistically significant at 1 percent this indicates goodness of fit, and the correctness of the distributional form assumed for the composite error term. Using the formula in equation (3.3) the gamma (γ) was 0.90which was high enough and significant at 1% level. It gives an indication that the unexplained variations in output are the major sources of random errors. It also shows that about 90percent of the variations in output of Sesame farmers are caused by technical inefficiency. It also confirms the presence of the one sided error component in the model; this rendering the use of ordinary least squares (OLS) estimation techniques inadequate in representing the data.

The scale coefficient was calculated to be 1.06, indicating increasing returns to scale. This implies that there is potential for sesame producers to continue to expand their production because they are in the stage I of the production surface, where resource use and production is believed to be inefficient. In other words, a one percent increase in all inputs proportionally will increase the total production by 1.06%. This result is consistent with Fikadu (2004), Amos (2007), Ermias *et al.* (2015) and DOO (2013).

Table 6. Elasticity and returns to scale of the parameters in the production function

Variables	Elasticity
Land	0.444
Seed	0.098
DAP	0.0018
Labor	0.268
Oxen	0.215
Herbicide	0.029
Return to scale	1.06

Source: Own computation (2016)

The dual cost function and derived analytically from the stochastic production function is given as follows: $\mathbf{lnCs_i=0.114 + 0.419lnW_1+ 0.092lnW_2 + 0.0017lnW_3+ 0.204lnW_4 + 0.254lnW_5 +0.028lnW_6 + 0.945lnY_i^*}$Where Cs is minimum cost of producing sesame; W_1 refers to the price of land, W_2 is price of seed; W_3 is price of DAP; W_4 is price of oxen; W_5 is price of labor; W_6 is average price of herbicide chemicals; Y* is. Output of sesame in Quintals adjusted for statistical noise.

In the cost frontier function, all the variables carried the expected positive signs. The coefficients of observed cost of land, cost of seed, labor cost, Oxen cost and cost of herbicide were significant at 1%, while the coefficients of output (Y*) adjusted for statistical noise was significant at 5% level, but cost of DAP were insignificant. This confirmed that more than 54% of respondents were non-user of DAP in the study area, thus cost of DAP is insignificant on cost frontier.

Table 7. MLE of the stochastic cost frontier with observed cost of input used.

Variable	Coefficient	Standard error	t-
Constant	1.9	0.19	9.75***
Log of cost of land	0.356	0.02	17.06***
Log of cost of seed	0.084	0.011	7.28***
Log of cost of Dap	0.00042	0.00	0.73
Log of cost of oxen	0.217	0.017	12.7***
Log of cost of labor	0.214	0.018	11.9***
Log of cost of herbicide	0.042	0.013	3.20***
Output (Y*)	0.01	0.005	1.99**
Diagnostic statistics			
Gamma (γ)	0.982		
Sigma square	0.012	0.0018	
Lamda	7.54	0.012	
log likelihood	173.3		

Note: ** and *** refers to 5% and 1% significance level, respectively.

Source: Own computation (2016)

The gamma (γ) estimate was 0.98 and was significant at 1% level indicating that 98% of the variation in minimum cost was caused by allocative inefficiency. The Coefficient of sigma square (δ^2) was significant at 1% level, and indicated the goodness of fit and correctness of the specified assumptions of the distribution of the compound error term. This result is consistent with the results by DOO and JUM (2013).

Estimation of efficiency scores

The results of the efficiency scores indicate that there were wide ranges of differences in TE, AE and EE among sesame producer farmers. The mean TE of sample households during the survey period was 75.16%. The TE among the households ranges from 25.74% to 98.93%, with standard deviation of 0.1353. Similarly, the mean AE and EE of sample households were 72.95% and 53.95%, respectively. Generally, there is a considerable amount of efficiency variation among sesame producer farmers in all measures of efficiency. This result is consistent with study of Jema (2008),Wondimu (2010), Ermias *et al.* (2015) and mustefa (2014).

Table 8. Descriptive statistics of efficiency score

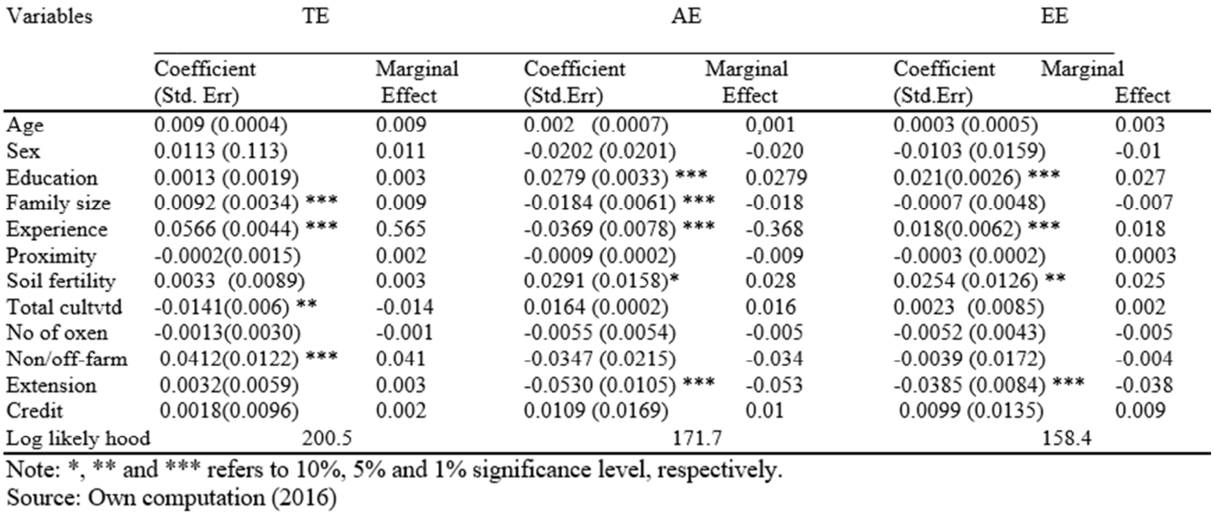
Variable	Obs	Mean	Std. Dev.	Min	Max
AE	124	0.7295	0.133	0.437	0.974
TE	124	0.7516	0.135	0.257	0.989
EE	124	0.5395	0.105	0.239	0.923

Source: Own computation (2016)

Determinants of efficiencies in sample farmers

After determining the presence of efficiency differential among farmers and measuring the levels of their efficiency, finding out factors causing efficiency differentials among farmers was the next most important objective of this study. To see this, the technical, allocative and economic efficiency estimates derived from the model were regressed on socio-economic and institutional variables that explain the variations in efficiency across farm households using Tobit regression model at specified left censoring limit which is below but more approach to minimum efficiency score with no right censoring limit to include all observation.

Table 9.Tobit model estimates determinants for different efficiency measures



Variables	TE		AE		EE	
	Coefficient (Std. Err)	Marginal Effect	Coefficient (Std.Err)	Marginal Effect	Coefficient (Std.Err)	Marginal Effect
Age	0.009 (0.0004)	0.009	0.002 (0.0007)	0,001	0.0003 (0.0005)	0.003
Sex	0.0113 (0.113)	0.011	-0.0202 (0.0201)	-0.020	-0.0103 (0.0159)	-0.01
Education	0.0013 (0.0019)	0.003	0.0279 (0.0033) ***	0.0279	0.021(0.0026) ***	0.027
Family size	0.0092 (0.0034) ***	0.009	-0.0184 (0.0061) ***	-0.018	-0.0007 (0.0048)	-0.007
Experience	0.0566 (0.0044) ***	0.565	-0.0369 (0.0078) ***	-0.368	0.018(0.0062) ***	0.018
Proximity	-0.0002(0.0015)	0.002	-0.0009 (0.0002)	-0.009	-0.0003 (0.0002)	0.0003
Soil fertility	0.0033 (0.0089)	0.003	0.0291 (0.0158)*	0.028	0.0254 (0.0126) **	0.025
Total cultvtd	-0.0141(0.006) **	-0.014	0.0164 (0.0002)	0.016	0.0023 (0.0085)	0.002
No of oxen	-0.0013(0.0030)	-0.001	-0.0055 (0.0054)	-0.005	-0.0052 (0.0043)	-0.005
Non/off-farm	0.0412(0.0122) ***	0.041	-0.0347 (0.0215)	-0.034	-0.0039 (0.0172)	-0.004
Extension	0.0032(0.0059)	0.003	-0.0530 (0.0105) ***	-0.053	-0.0385 (0.0084) ***	-0.038
Credit	0.0018(0.0096)	0.002	0.0109 (0.0169)	0.01	0.0099 (0.0135)	0.009
Log likely hood	200.5		171.7		158.4	

Note: *, ** and *** refers to 10%, 5% and 1% significance level, respectively.

Source: Own computation (2016)

The estimates of the Tobit regression model showed that among 12 variables used in the analysis, family size, total cultivated land, off/non-farm income, and experience in sesame production were found to be statistically significant in affecting the level of TE of farmers. The model revealed that family size, experience in sesame production and non-farm income positively and significantly affected technical efficiency. Total cultivated land had a significant negative effect on technical efficiency. On the other hand, experience in sesame production, family size and extension contact affected allocative efficiency negatively and significantly but soil fertility and education level affected allocative efficiency positively and significantly. Education level, experience in sesame production and soil fertility affected economic efficiency positively and significantly, However, extension contact affected economic efficiency negatively

Education: The coefficient of education is positive for both allocative and Economic efficiencies and significant at 1 percent. Positive and significant impact of education on both types of efficiencies confirms that the importance of education in increasing the efficiency of sesame production. It is a variable that is expected to increase managerial ability and led to good decisions in farming. Because of their better skills, access to information and good farm planning; more educated farmers are better to manage their farm resources and agricultural activities and minimize cost of production than less educated one. Besides this, educated farmers have relatively better capacity for optimal allocation of inputs. In line with this study, research done by Abdul (2003), Arega and Rashid (2005) in Eastern Ethiopia, Ogundari and Ojo (2007), Kehinde and Awoyemi (2009), and Mustefa (2014) found education to influenceallocativeandeconomicefficiencypositivelyandsignificantly.

Family size: The coefficient of family size for technical efficiency is positive and statistically significant at 1 percent significance level. The result is similar to the previous expectation that Farmers those having large family size are more efficient than farmers having small family size, because; family labor is the main input in crop production as the farmer has large family size he would manage crop plots on time and May able to use appropriate input combinations. This is in line with the findings of Mohammed *et al*. (2009), Essa (2011) and Mustefa (2014). In similar manner, the coefficient of family size for allocative efficiency is negative and statistically significant at one percent. This might be because farmers with large family size had less good capacity for optimal allocation of resources. This result is in line with the results of Okoruwa*et al.*(2006).

Sesame production experience: The coefficient of experience is positive as expected for both TE and EE significant at 1 percent. This indicated that increased farming experience may lead to better assessment of importance and complexities of good farming decision, including efficient use of inputs. Unexpectedly, experience in sesame production was found to have a negative and significant relationship with allocative efficiency in study area. Wilson *et al.* (1998) also found a negative relationship between experience and efficiency in potato production in UK, implying that farmers with fewer years of experience achieved higher levels of efficiency. Rahman (2002) also reported similar results for Bangladesh rice farmers and Ermias *et al.*(2015) also reported for Salamego sesame farmers in Ethiopia. The reason might be those with little experience are likely to seek out for new technology, unlike those with experience or are better at managing their resources.

Total cultivated land: Total cultivated or farm land was found to have significant and negative impact on TE. This might be due to the fact that the increased land size reduces technical efficiency by creating shortage of family labor, management and other resources that should have been available at the same time for sesame production but on the different product like noug, maize and sorghum in the study area. This result is in line with the results of Coelli *et al.*(2005),Jema(2008)

Off/non-farm income: The positive and significant coefficient of the off/non-farm income in technical efficiency suggests that the income obtained from such non-farm activities could be used for the purchase of agricultural inputs and augments financing of household expenditures which would entirely dependent on agriculture. This could be due to the fact that most of the non-farm activities (butchery, grinding mills, handicraft, and selling of local drinks) performed by the sample households do not compete with time allocated for farm activities and the availability of off/non-farm income shifts the cash constraint outwards and enables farmers to make timely purchases of those inputs which they cannot provide from on farm income. The result is consistent with Jema (2008),Hasen (2011), Abebayehu (2011) and Mustefa (2014).

Soil fertility: Soil fertility had a significant and positive impact on allocative and economic efficiencies, as expected. This implies that fertility of land is an important factor in influencing the level of efficiency in the production of sesame. In other words, farmers with fertile farm were more efficient than farmers with less fertile farm. The result is consistent with that of Fekadu (2004) and Ermias*et al.* (2015).

Extension contact: Unexpectedly, extension contact was found to have a negative and significant relationship with allocative and economic efficiency of farmers. This might be due to the fact that the involvement of extension workers in many non-extension activities such as credit applications processing, input distributions, and collection of loans. Moreover, during the survey, most farmers explained that they do not have new skills and information they learn from development agents and they inform that even if there are development agents who agree with the farmers concern, most of them are disregarding their primary activity and shift to other activity. The result is consistent with Jema (2008) and Ermias*et al.*(2015).

CONCLUSION

This study analyzed the technical, allocative and economic efficiencies and factors that explain the variation in efficiency among sesame producer farmers in Babogambel district of West Wollega zone, Oromia, Ethiopia. The study area was selected purposively based on the potential of sesame production in the zone.

In this study both primary and secondary data were used. Primary data were collected through household survey from a sample of 124 households using a semi-structured questionnaire. Secondary data were collected from relevant sources to supplement the primary data. Data analysis was carried out using descriptive statistics and econometric techniques.

The Cobb-Douglas stochastic frontier production and its dual cost functions were estimated from which TE, AE and EE estimates were extracted. Result of the production function indicated that Land, labor and oxen were limiting constraints, with positive sign as expected. The positive coefficients of these variables indicate that, increased use of these inputs will increase the production level to greater extent. The average TE, AE and EE values of the sample households were 75.16, 72.95 and 53.95%, respectively. This implies that farmers can increase their sesame production on average by 24.84% if they were technically efficient. Similarly, sesame producers can reduce current cost of inputs, on average, by 28.05% if they were allocatively efficient. The result also indicated that if these farmers operate at full efficiency levels, on average they could reduce their costs of production by 46.05% and still produce the same level of output. In the other part of the analysis, relationships between TE, AE, and EE, and various variables that were expected to have effect on farm efficiency were examined. This was relied on Tobit regression techniques, where TE, AE, and EE were expressed as functions of 12 explanatory variables.

An important conclusion stemming from the analysis of the efficiency of sesame production is that, there exists a considerable room to enhance the level of technical, allocative and economic efficiency of sesame producer farmers. The implication is that, there will be considerable gain in production level or reduction in cost of production if introduction and dissemination of agricultural technologies is coupled with improving the existing level of efficiency. Moreover, the study contributes to improve farm revenue, welfare and generally helps agricultural as well as economic development.

RECOMMENDATIONS

The policy implications of this analysis are that efficiency estimates indicate both the distribution of the farmers' efficiency and its socio-economic determinants. Thus, the results of the study give information to policy makers on how to improve farm level efficiency of sesame production and identify the determinants for specific efficiency types. The study results revealed that there is a considerable variability in all efficiencies and efficiency score of sample household in the production of Sesame in the study area. This indicated that in the long run improving the existing level of technical, allocative and economic efficiency of farmers alone may not lead to significant increment in the level of sesame. So in the long run it needs attention to introduce other best alternative farming practices and improved technologies in order to change the lives of farmers. The policy makers should give due emphasis to increase the level of efficiencies. This is because the use of improved technologies is expensive since it requires large capital. In addition, farmers have serious financial problem since they are subsistence farmers. Thus, the following policy recommendations are forwarded based on the result of the study.

Education was very important factor that contributed positively to the improvement of allocative and economic efficiency. So, the government should give more attention to provide educational service for all to attain educated farmers in order to increase efficiency and agricultural productivity of the country in the long run.

Fertility of sesame farm was found to be related to allocative and economic efficiency of farmers positively. Therefore, development programs should give due emphasis to improve and maintain the fertility of land through awareness creation and introduction of technologies that improve and maintains fertility so that the efficiency of the farmers increases.

The result of the finding also indicated that, unexpectedly, extension contact was found to affect allocative and economic efficiency of sesame producer farmers negatively. Despite the justification given by this study, it needs further study why it appears to affect efficiency negatively.

Even though experience in sesame production was found to affect allocative efficiency negatively, it had a positive impact on technical and overall efficiency. This indicates that increased farming experience may lead to better assessment of importance and complexities of good farming decision, including efficient use of inputs. Thus, the government should facilitate the infrastructure (especially road) to improve the market network of sesame producer which encourages the farmers to produce effectively and supply their products to the market with low transportation cost that increase farmers experience in the long run.

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REFERENCES

Aigner, D.J. and Chu, S.F. (1968). On Estimating the Industry Production Function. *American Economic Review* 58(4): 826-839.

Aigner, D.J., Lovell. K.C.A. and Schmidt, P.S. (1977). Formulation and Estimation of Stochastic Models. *Journal of Econometrics* 6: 21-37.

Ajibefun, I. A., Battese, G. E. and Daramola, A. G. Determinants of Technical Efficiency in Smallholders' Corps Farming in Oyo state Nigeria: Application of Frontier Production function. *Quarterly Journal of International Agriculture,* 41(3): 226-240

Bravo-Ureta, B.E. and Rieger, L. 1991. Dairy Farm Efficiency Measurement Using Stochastic Frontiers and Neoclassical Duality. *American Journal of Agricultural Economics,* 73: 421-428.

Charnes, A., W.W. Cooper and E. Rhodes. 1978. Measuring the Inefficiency of Decision Making Unit. *European Journal of Operational Research*, 2: 429–44.

Cobb, C. W. and Douglas.P.H. 1928. A Theory of production. *American Economic Review* 18: 139-165.

Coelli, T. J. and Perelman.S. 1999. A Comparison of Parametric and Non-parametric Distance functions: With Application to European Railways. *European Journal of Operational Research,* 117: 326-339.

CSA. 2015. Statistical Report on Area and Crop Production. Addis Ababa, Ethiopia.

Dawit Alemu and Meijerink.G.W. 2010. Sesame Traders and the ECX: An Overview with Focus on Transaction Costs and Risks, VC4PPD Report #8, Addis Ababa.

DOO. and JUM. Mgbada. 2013. Technical and Economic Efficiencies in Poultry Production in Imo State, Nigeria. (http://creativecommons.org/licenses/by/3.0)

Ermias Mokonon, Endrias Geta and Belaineh Legesse. 2015. Production Efficiency of Sesame Production in Selamago District, South Omo Zone of Southern Ethiopia. *Current research in agricultural science*, 2(1): 8-21. *Journal homepage*:

Jema Haji. 2008. Economic Efficiency and Marketing Performance of Vegetable Production in Eastern and Central Parts of Ethiopia. Doctoral Thesis. Acta Universitatis Agriculture Sueciae (SLU)Uppsala, Sweden.

Jema Haji and H. Andersson. 2006. Determinants of efficiency of vegetable production in smallholder farms: The Case of Ethiopia. *Journal of Food Economics,* 3(3): 125 -137

Kopp. R.J and Diewert. E.W. 1982. The Decomposition of Frontier Cost Function Deviations into Measures of Technical and Allocative Efficiency. *Journal of Econometrics,* 19: 319-331.

Kumbhakar. S.C. and C.A.K. Lovell. 2000. Stochastic Frontier Analysis. Cambridge University Press, Cambridge. United Kingdom.

Lovell. C.A.K. 1993. Production Frontiers and Productive Efficiency. In H. Fried. C.A.K. Lovell and S. Schmidt, The Measurement of Productive Efficiency. Techniques and Application, Oxford University Press.

Mustefa Bati. 2014. Economic Efficiency in barley production : the case of chole district, east arsi zone, oromia national regional state, ethiopia Thesis Presented to School of Graduate Studies of Haramaya University.

Sharma. K.R. P. Leung. and H.M. Zaleski.1999. Technical, Allocative and Economic Efficiencies in Swine Production in Hawaii: A Comparison of Parametric and Non-parametric Approaches. *Agricultural Economics*, 20: 23-35.

Okoruwa, V.O., O.O. Ogundele and B.O. Oyewusi. 2006. Efficiency and Productivity of Farmers in Nigeria: A Study of Rice Farmers in North Central Nigeria. Poster Paper Prepared for Presentation at the International Association of Agricultural Economists Conference, Gold Coast, Australia.

Shepard, R.W. 1970. Theory of Cost and Production Functions, Princeton University Press, Princeton.

Strock, H., Bezabih Emana, Berhanu Adenew, A. Borowiecki and Shimelis Wolde Hawariate. 1991. The Role of New Varieties and Chemical Fertilizer under Risk: The Case of Smallholders in Eastern Oromiya, Ethiopia. Ph.D. Dissertation, Department of Horticulture, University of Hannover, Shaker Verlag, Germany.

Torkamani, J. and H.J. Brain. 1996. A study of Economic Efficiency of Iranian Farmers in Ramjerd district. Application of Stochastic Programming Department of Agricultural Economics, College of Agriculture Shiraz university, Shiraz, Iran.

Tobin. J. 1958. Estimation of Relationships for Limited Dependent Variables. *Econometrica,* 26: 24–36.

V.B. Taru, I.Z.Kyagya, S.I.Mshelia and E.F.Adebayo. 2008. Economic efficiency of resource use in Groundnut production in Adamawa state of Nigeria. *World Journal of Agricultural Sciences,* 4 (S): 896-900.

Wilson. P. and Hadley.D. 1998. Measuring and Explaining Technical Efficiency in UK Potato Production. *Journal of Agricultural Economics,* 49(3):294-305.

Yamane .T.I. 1967. Statistics: An Introductory Analysis 2nd Edition. NewYork, Harper and Row.

APPENDICES

Appendix 1.Technical efficiency score of the sample household

1	0.722131	43	0.763136	85	0.670004
2	0.46469	44	0.731643	86	0.78514
3	0.642236	45	0.640791	87	0.795345
4	0.954289	46	0.622577	88	0.903177
5	0.489136	47	0.770695	89	0.766362
6	0.93172	48	0.722225	90	0.702595
7	0.554825	49	0.2574	91	0.690211
8	0.809759	50	0.747753	92	0.941941
9	0.645833	51	0.699337	93	0.54698
10	0.564012	52	0.520546	94	0.803018
11	0.874462	53	0.65655	95	0.78612
12	0.740373	54	0.743392	96	0.752979
13	0.643127	55	0.731834	97	0.926307
14	0.835062	56	0.428632	98	0.974712
15	0.691455	57	0.721663	99	0.934868
16	0.77239	58	0.79545	100	0.820138
17	0.881659	59	0.527923	101	0.567096
18	0.736715	60	0.745384	102	0.851907
19	0.738353	61	0.795065	103	0.859522
20	0.728775	62	0.797348	104	0.871462
21	0.930398	63	0.634599	105	0.821385
22	0.443059	64	0.683862	106	0.442937
23	0.851113	65	0.733404	107	0.777004
24	0.962936	66	0.849049	108	0.666048
25	0.70726	67	0.688578	109	0.929118
26	0.821016	68	0.709907	110	0.752563
27	0.539761	69	0.828022	111	0.979117
28	0.763851	70	0.636062	112	0.803683
29	0.772443	71	0.910936	113	0.830683
30	0.806454	72	0.942106	114	0.867397
31	0.731838	73	0.722476	115	0.673894
32	0.989326	74	0.948039	116	0.677737
33	0.901202	75	0.63204	117	0.796324
34	0.960417	76	0.722701	118	0.685482
35	0.932482	77	0.82356	119	0.771758
36	0.909741	78	0.632259	120	0.907798
37	0.765267	79	0.715553	121	0.79117
38	0.83639	80	0.470339	122	0.937038
39	0.796242	81	0.624159	123	0.721955
40	0.724394	82	0.707646	124	0.626672
41	0.673222	83	0.812522		
42	0.803976	84	0.763136		

Average = 75.16%

Appendix 2.Allocative efficiency score of the sample households

1	0.845395	43	0.739413	85	0.772188
2	0.834567	44	0.757682	86	0.503432
3	0.964457	45	0.733396	87	0.834189
4	0.609555	46	0.83282	88	0.697285
5	0.876092	47	0.823136	89	0.838512
6	0.61303	48	0.896713	90	0.705384
7	0.824244	49	0.93233	91	0.77091
8	0.808013	50	0.823814	92	0.641379
9	0.769414	51	0.828546	93	0.789065
10	0.938405	52	0.81678	94	0.560405
11	0.603718	53	0.666544	95	0.605031
12	0.772768	54	0.755375	96	0.749782
13	0.754447	55	0.675367	97	0.769075
14	0.629347	56	0.88931	98	0.657608
15	0.653835	57	0.781642	99	0.634422
16	0.928368	58	0.912908	100	0.605627
17	0.548869	59	0.933166	101	0.813334
18	0.887485	60	0.82994	102	0.90777
19	0.752929	61	0.841881	103	0.690854
20	0.586022	62	0.830739	104	0.727689
21	0.437664	63	0.751451	105	0.578019
22	0.926712	64	0.896712	106	0.824715
23	0.92719	65	0.680969	107	0.638593
24	0.589697	66	0.810854	108	0.456718
25	0.861554	67	0.608663	109	0.572004
26	0.445787	68	0.870125	110	0.779687
27	0.666278	69	0.661101	111	0.528486
28	0.58426	70	0.530825	112	0.562682
29	0.866518	71	0.738215	113	0.715141
30	0.779634	72	0.682534	114	0.610275
31	0.785714	73	0.52157	115	0.845089
32	0.562558	74	0.726057	116	0.929385
33	0.762827	75	0.695096	117	0.923958
34	0.644978	76	0.764872	118	0.919682
35	0.471239	77	0.717972	119	0.806383
36	0.45185	78	0.719902	120	0.636446
37	0.584294	79	0.750593	121	0.705526
38	0.617395	80	0.973828	122	0.720577
39	0.441997	81	0.914194	123	0.721388
40	0.857519	82	0.596942	124	0.745718
41	0.565424	83	0.532509		
42	0.883874	84	0.739413		

Average =72.95%

Appendix 3.Economic efficiency score of the sample households

1	0.610486	43	0.564272	85	0.517369
2	0.387815	44	0.554353	86	0.395265
3	0.619409	45	0.469954	87	0.663468
4	0.581692	46	0.518494	88	0.629772
5	0.428528	47	0.634387	89	0.642603
6	0.571173	48	0.647628	90	0.495599
7	0.457311	49	0.239982	91	0.532091
8	0.654296	50	0.616009	92	0.604141
9	0.496913	51	0.579433	93	0.431603
10	0.529272	52	0.425172	94	0.450015
11	0.527929	53	0.437619	95	0.475627
12	0.572136	54	0.56154	96	0.56457
13	0.485205	55	0.494256	97	0.712399
14	0.525544	56	0.381186	98	0.640979
15	0.452098	57	0.564083	99	0.593101
16	0.717062	58	0.726172	100	0.496698
17	0.483915	59	0.49264	101	0.461239
18	0.653823	60	0.618624	102	0.773336
19	0.555927	61	0.66935	103	0.593805
20	0.427078	62	0.662389	104	0.634153
21	0.407202	63	0.47687	105	0.474776
22	0.410588	64	0.613227	106	0.365297
23	0.789143	65	0.499426	107	0.49619
24	0.56784	66	0.688455	108	0.304196
25	0.609342	67	0.419112	109	0.53146
26	0.365999	68	0.617708	110	0.586764
27	0.359631	69	0.547406	111	0.51745
28	0.446288	70	0.337638	112	0.452218
29	0.669335	71	0.672466	113	0.594056
30	0.628739	72	0.643019	114	0.52935
31	0.575015	73	0.376822	115	0.5695
32	0.556553	74	0.68833	116	0.629879
33	0.687461	75	0.439328	117	0.92345
34	0.619448	76	0.552774	118	0.630426
35	0.439422	77	0.591293	119	0.622332
36	0.411067	78	0.455164	120	0.577765
37	0.447141	79	0.53709	121	0.558191
38	0.516383	80	0.45803	122	0.675208
39	0.351936	81	0.570603	123	0.52081
40	0.621182	82	0.422424	124	0.46732
41	0.380656	83	0.432675		
42	0.710614	84	0.564272		

Average = 53.95%

Appendix4. Conversion factors for man equivalent and adult equivalent

	Man Equivalent		Adult Equivalent	
Age group (years)	Male	Female	Male	Female
<10	0	0	0.6	0.6
10-13	0.2	0.2	0.9	0.8
14-16	0.5	0.4	1.0	0.75
17-50	1.00	0.8	1.0	0.75
>50	0.7	0.5	1.0	0.75

Source: Storck *et al.* (1991)

Appendix5.Conversion factors used to estimate tropical livestock unit equivalents

Animal category	**TLU**
Calf	0.25
Weaned Calf	0.34
Donkey (Young)	0.35
Donkey (adult)	0.70
Camel	1.25
Heifer	0.75
Sheep and Goat (adult)	0.13
Caw and Ox	1.00
Sheep and Goat young	0.06
Mule	1.10
Chicken	0.013

Source: Storck *et al.* (1991)

Appendix 6. Multicollinearity test for variables in the SPF model

No.	Variable	VIF	(1/VIF)
1	Land	4.31	0.2322
2	DAP	1.14	0.8778
3	Labor	4.17	0.2400
4	Seed	2.26	0.4425
5	Oxen	4.10	0.2441
6	Herbicide	2.24	0.4457
Mean VIF		3.04	

Source: Own computation (2017)