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Farm Level Efficiency of Crop Production in the Central Highlands of Ethiopia

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Abstract The gap between demand for and supply of food can be minimized by improving productivity either through introduction of modern technologies, reallocation of resources or improving the efficiency of production. It is however almost impossible to increase production by bringing more land and capital resources as they are very limiting in the rural parts of the developing world. Wheat, faba bean (horse bean) and lentil are the three most important crops in the central highlands of Ethiopia and enhancing the farm level efficiency of their production is a crucial component of the food security strategy of the government. This study aims at analyzing level and determinants of production efficiency of these crops by smallholder farmers in North Shewa zone. The study generated data from 480 randomly selected smallholder farmers in the 2015/16 production season. The study estimated, technical, allocative and economic efficiencies using Data Envelopment Analysis technique. The results showed that mean technical, allocative and economic efficiencies were 77%, 69% and 53%, respectively, indicating a substantial inefficiency in the production of these important crops. Analysis of determinants of efficiency using a double-bounded Tobit model indicates that age, education, off/non-farm income, livestock holding, credit access, extension contacts, market distance, distance to all weather road and average farm plots distance significantly affect efficiency of production. The findings of the study show that the production efficiency of these crops can be significantly improved through increased integration of the crop and livestock subsystems, investment of basic education and infrastructure, and improvement of the agricultural extension system and the rural credit services.

Keywords: *allocative efficiency, economic efficiency, technical efficiency, data envelopment analysis*

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1. Introduction

Agriculture in Ethiopia accounts for 85% of employment, about 36.7% of the annual GDP and 85% of the foreign earnings [1]. The issue of improving agricultural productivity has always been among the key development agenda of the Ethiopian government due to, among others, considerable increase in population and food price [2]. Given fixed or declining supply of agricultural land, labor and other inputs, economic growth in countries like Ethiopia can hardly depend only on agriculture.

Crop production in North Shewa Zone of central Ethiopian highlands is constrained by technical, economic and environmental factors. These factors made the productivity of wheat, faba bean and lentil very low. The existence of production inefficiency at farm level, lack of and inexistence of improved production technologies are accountable for the low productivity of selected crops, among others [3]. Yet, there is no any reliable data or information on the level of productivity and/or efficiency per unit of the limiting factors.

Most of the previous empirical efficiency studies in Ethiopia [4-10] are limited to either the estimation of technical efficiency; focused on land renting and sharecropping efficiency; or they analyzed specific crop production efficiency. However, this study differs from the previous studies is that it analyzed both technical, allocative and economic efficiency on multiple crops.

Currently, access to improved agricultural technologies and farm inputs is a long-lasting challenge Ethiopian farmers have been living with. Hence, measuring level of production efficiency and the extent of resource use inefficiency given the existing technology and input levels is critically important. Therefore, a question arises as to how farmers are using or combining the available scarce resources to produce the maximum output and sources of inefficiency differentials among farm households. These are key issues whose investigation can be useful for the formulation of policies to strengthen and improve the efficiency of crop production in the study areas. This research focuses on taking a step towards filling the above mentioned problems by collecting cross-sectional data from smallholder farmers of central highlands of Ethiopia. Hence, this research aimed at measuring technical, allocative and economic efficiencies levels and their determinants for the three key crops in the study areas.

2. Methodology

2.1. The Study Areas

The study was conducted in Moretna Jiru, Basona Worena and Menz Gera Mdr districts in the central highlands of Ethiopia. Administratively, the districts are located in North Shewa zone of the Amhara region (Figure 1).

North Shewa zone is one of the ten administrative zones in Amhara region. The zone shares borders with south Wollo zone in the north, with Afar regional state in the east, and Oromiya regional state in south and west. The zone has an estimated total population of about 1934759 of which 50.5% are male and the remaining 49.5% are female - with an estimated area of 15954.5 km^2 and population density of 121 people per km^2 [11].

Crop production and livestock rearing are the major sources for the households' economy. The soil in most places is black and vertisol with clay loam texture in some areas. Farmers use draft power for land preparation and other crop production activities that require traction power. The Zone receives an annual rainfall ranging 900-1100 mm. The landscape of the area is predominantly uneven and broken with plain patches of land scattered all over the place.

2.2. Data Sources, Collection and Sampling Techniques

Both primary and secondary data sets were used for this study. Primary data were collected from farmers through an interview with the help of pre-tested semi-structured questionnaire during 2015/16 cropping season. Moreover, focus group discussions were held to capture the communal wisdom on the production of these crops. Secondary data were collected from published and unpublished sources to complement the primary data.

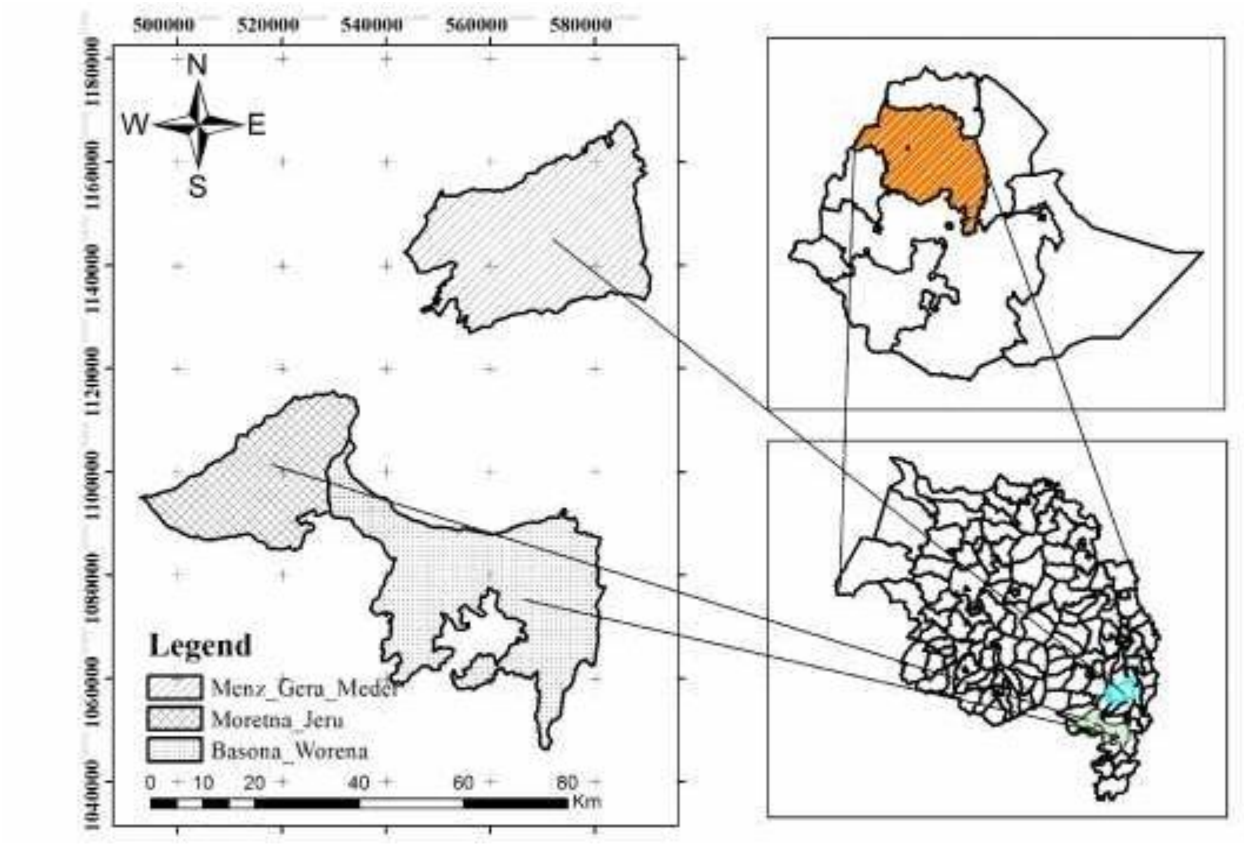


Figure 1. Map of the study areas

Table 1. Distribution of Sample Farm Household Heads by District and Kebele

Districts	Total households	Sample households		*Kebeles*	Total households	Sample households	
		No.	%			No.	%
Basona Worena	27176	142	29.6	Gudoberet	896	74	15.4
				Keyit	825	68	14.2
Moretina Jiru	35764	187	39.0	Mangudo	964	94	19.6
				Weyramba	913	93	19.4
Menz Gera Mdr	28870	151	31.4	Gragn	1084	79	16.4
				Tsehaysina	943	72	15.0
Total	91810	480	100		5625	480	100

Source: ZADO, 2014, respective *kebeles'* records and survey results.

Three stage random sampling method was used to select sample households. In the first stage, three districts were selected based on wheat, faba bean and lentil production potential and importance of agricultural research and extension interventions. The second stage involved a random selection of two *kebeles*[1] from each district and the third stage involved random selection of households from each selected kebele with probability proportional to size (Table 1).

The sample size for the study is determined based on the following formula [12].

$$n = \frac{z^2 pqN}{e^2(N-1) + z^2 pq} \quad (1)$$

Where n is the desired sample size, **Z** is the inverse of the standard cumulative distribution that corresponds to the level of confidence with the value of 1.96, p is the estimated proportion of an attribute present in the population and q = 1-p. N is the size of the total population from which the sample is drawn. Assuming large population but the variability is not known in the proportion about the inputs use, p = 0.5 is considered as suggested by [13] to get the desired minimum sample size of ≈480 households at 95 % confidence level and ±4.5 % precision (**e**).

2.3. Methods of Data Analyses

2.3.1. Efficiency Analysis

There are different ways of measuring and analyzing production efficiency. Broadly, the approaches are categorized as parametric and non-parametric. The parametric methods assume that the maximum output that a producer can obtain is determined both by the production function and by random external factors such as luck or unexpected disturbances in a related market and are mainly econometric modeling based and are derived from the broad set of models known as stochastic frontier models.

The non-parametric models, in contrast to the specification of stochastic frontier models, assume the deviation of an observation from the theoretical maximum is attributed solely to the inefficiency of the firm and are mostly based on mathematical programming methods known as data envelopment approach (DEA).

There have been several studies that have analyzed data with both DEA and parametric, deterministic frontier estimators. In both studies, the authors do not observe radical differences in the results with the various procedures. That is perhaps not surprising since the main differences in their specifications concerned functional form-Cobb-Douglas for the parametric models, piecewise linear for the nonparametric ones. The differences in the inferences one draws often differ more sharply when the statistical underpinnings are made more detailed in the stochastic frontier model. In sum, the evidence is mixed, but it does appear that quite frequently, the overall picture drawn by DEA and statistical frontier based techniques are similar.

[1] It is the lowest administrative unit in the country.

Reference [14] first introduced DEA and it has served as the corner stone for all subsequent developments in the nonparametric approach. As discussed in [15], DEA has several advantages; i.e., it does not require a prior specific functional form for the production frontier, it can handle multiple outputs and inputs. Furthermore, it also does not require the distributional assumption of the inefficiency term [15].

The disadvantage of DEA, compared to the parametric methods, is that DEA attributes all deviations from the frontier to inefficiency and post-estimation hypothesis testing is not possible. To alleviate this problem, bootstrapping methods was used. In this study, DEA-based clustering with input-oriented Constant Returns to Scale (CRS) model is used to estimate the efficiency measures using DEAP Version 2.1 computer programing as described in [16]. Determinants of inefficiency were identified using double-bounded Tobit model.

I. Technical efficiency (TE) estimation

Technical efficiency is the efficiency in converting inputs to outputs. It exists when it is possible to produce more outputs with the fixed inputs available (output-orientated) or to produce a given level of output with less input (input-orientated). The input-oriented constant returns to scale (CRS) DEA frontier for the calculation of technical efficiency (TE) is given by the solution to the linear programming problem of the form

$$\begin{aligned} & Min_{\phi\lambda} \quad \phi \\ & subject \quad to: \\ & \qquad -y_i + Y\lambda \geq 0 \\ & \qquad \phi x_i - X\lambda \geq 0 \\ & \qquad \lambda \geq 0 \end{aligned} \quad (2)$$

Where x_i and y_i are input and output vectors of the i^{th} farmer, respectively, X is an /m x n input matrix and Y is an s x n output matrix representing data for all n farmers in the sample, ϕ is a scalar, and λ is an n X 1 vector of constants. ϕ is always less than or equal to one. Based on [17] definition, a value of one indicates a point on the frontier and hence the existence of a technically efficient farmer. The DEA model (2) has an intuitive interpretation. The problem takes the i^{th} farmer and then seeks for the amount by which the input vector, x_i, can be reduced and still attain the same output level.

II. Economic efficiency (EE) estimation

Assuming identical input prices, in order to investigate the economic efficiency or cost efficiency, the input orientated cost minimization DEA is specified as follows:

$$\begin{aligned} & Min_{\lambda,\phi_{EE}} \quad \phi_{EE} \\ & subject \quad to: \\ & \qquad y_i + Y\lambda \geq 0 \\ & \qquad \phi_{EE} c_i - C\lambda \geq 0 \\ & \qquad \lambda \geq 0 \end{aligned} \quad (3)$$

Where c is a scalar representing cost or budget level, and C is a row vector of observed costs. Intuitively, the problem takes the i^{th} farmer and then seeks for the amounts by which the input cost, c_i, can be reduced and remain on the production frontier.

III. Allocative efficiency (AE) estimation

Allocative efficiency can be estimated as the ratio of economic efficiency and technical efficiency as:

$$AE = \frac{EE}{TE}. \quad (4)$$

2.3.2. Double-bounded Tobit Model

The Tobit model is used to identify determinants of production inefficiency at farm household level. Inefficiency takes values between 0 and 1. The modeling requires limited dependent variable specification and hence double-bounded Tobit model is employed.

Thus, following [18], the study adopted the double-bounded Tobit model which specified as follows:

$$U_i^* = \beta_0 + \sum_{j=1}^{k} \beta_j Z_{ij} + \mu_i,$$

$$U_i = \begin{cases} 1 & if \quad U_i^* \geq 1 \\ U_i^*, & if \quad 0 < U_i^* < 1 \\ 0 & if \quad U_i^* \leq 0 \end{cases} \quad (5)$$

Where: i refers to the i^{th} farm in the sample; U_i is efficiency scores representing technical, allocative and economic efficiencies of the i^{th} farm. U_i* is the latent variable, β_j are parameters of interest to be estimated and μ_i is random error term that is independently and normally distributed with mean zero and common variance δ^2 of ($\mu_i \sim N(0, \delta^2)$). Z_{ij} are socioeconomic, institutional and demographic variables that are expected to affect efficiency scores.

3. Results and Discussion

3.1. Households Characteristics

The average age of the sample household heads was found to be 43.41 years with a standard deviation of 11.16. Of the total sample farmers, about 15% were aged 30 or less years and only about 5% were older than 64 years. The majority of the household heads (80%) were found in the range of 31 and 64 years of age. The average family size of the sample households was 5.16 persons, which is larger than the rural national average (5.04), the regional average (4.50), and comparable with zonal average of 4.19 persons per household respectively [19,20]. The household heads' education level (years), farming experience (years), labour supply (Adult equivalent) and dependency ratio have mean values of 4.05, 19.20, 3.27 and 0.76 respectively and there is significant difference among the districts as shown in Table 2.

Table 2. Descriptive Statistics of Household Characteristics between Districts (N=480)

variables	Total	Districts			χ^2 or F-test
	Mean (Std.)	Basona Worena	Moretina Jiru	Menz Gera Mdr	
Male headed household (%)	96.5	95.8	95.2	98.7	0.197
Age of the household head (Year)	43.41(11.16)	43.77(10.15)	44.16(11.33)	42.14(11.82)	1.470
Farming experience (Year)	19.20(11.08)	19.69 (10.90)	20.22(10.99)	17.46(11.22)	2.810*
Formal education level of household head (Year)	4.05(3.47)	4.04 (3.22)	3.74 (3.66)	4.45 (3.46)	1.737
Formally educated family members (Number)	4.49 (1.51)	4.16 (1.38)	4.63 (1.62)	4.62 (1.43)	5.163***
Family size (Number)	5.16(1.57)	4.75(1.50)	5.32(1.69)	5.35(1.39)	7.245***
Labour supply (Adult equivalent)	3.27 (1.41)	3.32 (1.47)	3.43 (1.53)	3.03 (1.15)	3.360**
Dependency ratio	0.76(.59)	0.58(0.49)	0.74(0.57)	0.96 (0.63)	16.64***

Note: Values in parentheses (Std.) are Standard deviations.
Source: Computed from survey data (2015)

Table 3. Descriptive Statistics of Major Wealth Indicator Variables (N=480)

Variables	Mean (Std.)	Gini-coefficient
Total own farm land holding (ha)	1.14 (0.57)	0.28
Livestock holding (TLU)	4.72 (2.26)	0.25
Income from sale of selected crops (Birr/year)	8628.01 (11019.09)	0.62
Income from all crops sales (Birr/year)	11099.20 (13389.08)	0.59
Income from all live animals sales (Birr/year)	8836.13 (9240.40)	0.52
Income from animals products sales (Birr/year)	1102.55 (2193.59)	0.77
Income from off/ non-farm activities (Birr/year)	1712.60 (3295.94)	0.79

Source: Author's computation from sample survey data (2015)

3.2. Socio-economic Characteristics

Households in the study areas have average farmland size of about 1.14 hectare, which is comparable to the national average (1.14 ha) and smaller than the regional (1.21ha) and zonal average (1.40 ha) [19]. Moreover, about 5.6% of sample farmers were landless and about 37.7% of the sample farmers owned land less than 1.00 ha. In terms of crop land cover, wheat was the first covering 33.3% followed by lentil (25.3%), faba bean (18.5%) and others (22.8%) of the total farm land cultivated (1.62ha) in 2015 main cropping season.

In the study areas, land holding, livestock holding and income from sales of crops and livestock are considered as key indicators of the wealth of the households among others. The Gini-coefficient showed low level of inequality among the sample households with respect to own farm land holding and livestock holding. However, there was a high level of inequality among farm households in other wealth indicators (Table 3).

Yield of selected crops was computed based on total grain output per unit of land for those who produce the crop and expressed in quintal (100 kg) per hectare of land (qt/ha). Hence, the average yields were 24.21, 15.52 and 11.24 qt/ha for wheat, faba bean and lentil, respectively. The average yield levels are slightly lower than the national average of 25.43, 18.93 and 13.89 qt/ha, in order, in 2015 main production season [19]. Moreover, yield is by far below the research field/potential yield of 44-50, 30-40 and 17-25 qt/ha for wheat, faba bean and lentil, respectively. This implies that there is low level of yield and potential resource use inefficiency in the study areas.

Comparing across the three districts, households in Moretna Jiru district have the highest mean yield for wheat (32.41qt/ha) and faba bean (18.19 qt/ha) whereas households in Menz Gera Mdr district have the highest mean lentil yield (11.81qt/ha). There was a statistically significant difference in wheat and faba bean yield between districts, respectively. However, there was no significant difference in lentil yields between districts during 2015 main production season.

3.3. Descriptive Statistics of Data for Efficiency Measurement

3.3.1. Input-Output Measures

The size of land (both own, rented in and shared in) used for production of the three crops was measured in hectare and its cost was approximated by its rental value. The output of a given crop for a household was aggregated as the sum of all outputs obtained from different plots of that crop regardless of variety differences. Therefore, a household in the study areas produced on average 1329.93 kg of wheat, 435.70 kg of faba bean and 451.63 kg of lentil in 2015 main production season (Table 4).

Table 4. Descriptive Statistics of Input-Output Variables

Variables	Input output variables	Mean (Std.)
Wheat	Wheat Output (kg)	1329.93 (999.56)
Fbean	Faba bean output (kg)	435.70 (243.29)
Lentil	Lentil output (kg)	451.63 (418.57)
Land	Land for selected crops (ha)	1.00 (0.54)
DAP	Quantity of DAP fertilizer (kg)	165.80 (165.59)
Urea	Quantity of Urea fertilizer (kg)	122.97 (128.67)
Fchem	Quantity of field chemicals (lt)	0.52 (0.93)
Labor	Labor (Family, exchange and Hired) (man-day)	64.67 (32.41)
Oxen	Oxen power (oxen-day)	9.93 (5.37)
Wtsed	Quantity of wheat seed (kg)	89.09 (55.86)
Fbsed	Quantity of faba bean seed (kg)	51.73(33.29)
Ltsed	Quantity of lentil seed (kg)	35.92 (32.18)

Source: Author's computation from sample survey data (2015).
Note: Values in the parentheses are standard deviations.

Table 5. Distribution of Technical, Allocative and Economic Efficiencies (N=480)

Efficiency	TE	%	AE	%	EE	%
0.00 – 0.10	-	-	-	-	-	-
0.11 – 0.20	-	-	-	-	5	1.00
0.21 – 0.30	4	0.80	1	0.20	44	9.20
0.31 – 0.40	17	3.50	11	2.30	78	16.30
0.41 – 0.50	41	8.50	33	6.90	105	21.90
0.51 – 0.60	53	11.00	85	17.70	88	18.30
0.61 – 0.70	62	12.90	123	25.60	82	17.10
0.71 – 0.80	76	15.80	121	25.20	44	9.20
0.81 – 0.90	60	12.50	82	17.10	18	3.80
0.91 – 1.00	167	34.80	24	5.00	16	3.30
Operating below mean	237	49.37	227	47.29	264	55.00
Operating above mean	243	50.63	253	52.71	216	45.00
Mean	0.769		0.693		0.533	
Std. Deviation	0.202		0.139		0.180	
Minimum	0.271		0.322		0.189	
Maximum	1.000		1.000		1.000	

Source: DEA results from sample survey data (2015).

3.3.2. Estimation of Efficiency Scores

The average technical efficiency level of production of these crops is 77% and ranges from 27% to 100% (Table 5). This indicates that if the average farmer in the sample was to achieve the technical efficiency level of its most efficient counterpart, then the average farmer could realize a 23% increase in output by improving technical efficiency with existing technology. Among the sample farmers, 119 were fully technically efficient farmers. The average allocative efficiency level was about 69% with six fully efficient farmers. This means that if the average farmer in the sample was to achieve the allocative efficiency level of its most efficient counterpart, then the average farmer could save 31% of their current cost of inputs by using the right inputs and outputs mix given input costs and output prices.

The average mean economic efficiency level of sample households was 53% and six farmers were fully efficient. This means that if the average farmer in the sample was to achieve the economic efficiency level of its most efficient counterpart, then the average farmer could experience 47% increase output by improving the technical and allocative efficiency with the existing technology.

3.4. DEA-Based Clustering Efficiency Scores

Based on variance difference from centroid values, five mutually exclusive clusters were formed using dendrograms through allocation of observations on the degree of belongingness and cut-off size. As shown in Table 6, there were considerable similarities within a cluster and differences between clusters. As indicated in Figure 2, the height of the vertical lines and the range of the (dis)similarity axis give visual clues about the strength of the clustering. Long vertical lines at the top of the dendrogram indicate that the groups represented are well separated from one another and vice versa.

Table 7 summarizes cluster group by efficiency scores and clusters distribution in the study districts. Using the average efficiency scores as comparison criteria, the five cluster groups were found to be significantly different from each other. Generally, $G_3 > G_2 > G_4 > G_5 > G_1$ in efficiency performance.

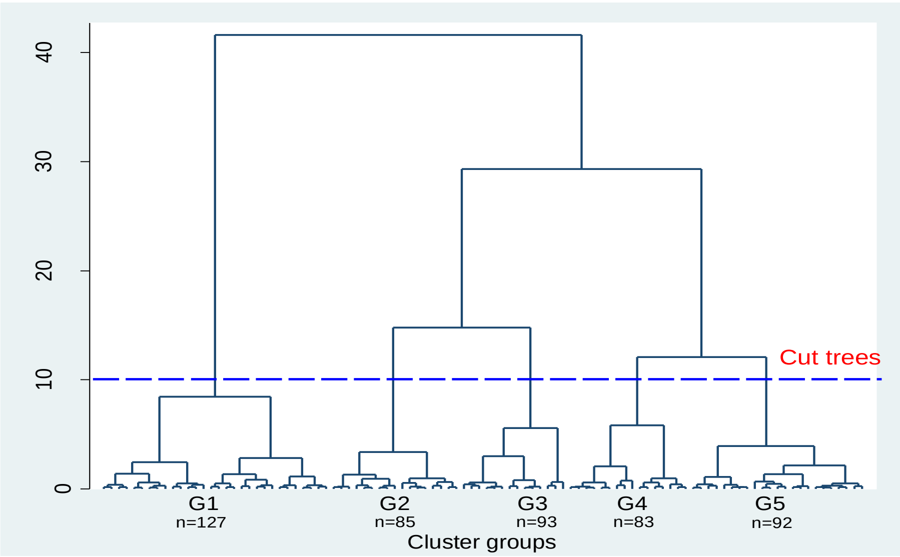
Considering across the study areas, Moretna Jiru district performed better in selected crops production efficiency followed by Bassona Worena district. There was significant difference (p<1%) in efficiency scores among the districts.

One-sample mean comparisons show that on average smallholder farmers are not technically, allocatively and economically efficient ($P < 1\%$), which means average level of efficiency scores are significantly different from unity. Hence, the result showed that there existed substantial inefficiency in the production of the selected crops in the study areas. The average levels of efficiencies of this study were comparable to those from other studies done in Ethiopia [3,7,21,22,23].

Table 6. Variance Decomposition for the Optimal Cluster Formation/ Classification

	Absolute	Percentage			
Within-cluster	0.018	19			
Between-clusters	0.074	81			
Total	0.092	100			
Descriptions / Clusters	G_1	G_2	G_3	G_4	G_5
Households number in each cluster	127	85	93	83	92
Percentage (%)	27	18	19	17	19
Within-cluster variance	0.016	0.017	0.019	0.018	0.019
Average distance to centroid	0.112	0.119	0.118	0.122	0.123

Source: Author's computation from efficiency scores of the survey data (2015).



Source: Author's computation from efficiency scores of the survey data (2015).

Figure 2. Dendrograms for hierarchical cluster analysis of efficiency scores (N=480)

Table 7. DEA-Based Clustering Efficiency Scores by Districts

Groups	%	E. scores	Total efficiency scores by group			Districts' level efficiency scores by group					
						Basona Worena		Moretina Jiru		Menz Gera Mdr	
			Mean (Std.)	Min	Max	Mean (Std.)	% group [% district]	Mean (Std.)	% group [% district]	Mean (Std.)	% group [% district]
G1 n=127	27	TE_1	0.51 (0.103)	0.271	0.717	0.53(0.092)	28 [25]	0.56 (0.070)	24 [16]	0.46 (0.101)	47 [40]
		AE_1	0.72 (0.101)	0.459	0.941	0.73 (0.072)		0.82 (0.079)		0.66 (0.085)	
		EE_1	0.37 (0.098)	0.189	0.573	0.38 (0.074)		0.46 (0.057)		0.30 (0.079)	
G2 n=85	18	TE_2	0.77 (0.744)	0.624	0.922	0.75 (0.085)	19 [12]	0.76(0.069)	74 [34]	0.83 (0.135)	7 [4]
		AE_2	0.81 (0.051)	0.713	0.930	0.80 (0.052)		0.82 (0.051)		0.75 (0.046)	
		EE_2	0.62 (0.066)	0.508	0.770	0.61 (.066)		0.62 (0.061)		0.62 (0.108)	
G3 n=93	19	TE_3	0.99 (0.023)	0.909	1.000	0.99 (0.019)	35 [23]	0.98(0.036)	57 [28]	0.99 (0.021)	8 [5]
		AE_3	0.81 (0.087)	0.691	1.000	0.82 (0.101)		0.81 (0.080)		0.75 (0.085)	
		EE_3	0.80 (0.093)	0.650	1.000	0.81 (0.105)		0.79 (0.092)		0.74 0.091)	
G4 n=83	17	TE_4	0.97 (0.044)	0.825	1.000	0.98 (049)	43 [25]	0.97 (0.037)	27 [12]	0.96 (0.044)	30 [16]
		AE_4	0.55 (0.099)	0.332	0.687	0.52 (0.097)		0.60 (0.097)		0.53 (0.096)	
		EE_4	0.54 (0.098)	0.302	0.674	0.52 (0.103)		0.58 (0.091)		0.51 (0.092)	
G5 n=92	19	TE_5	0.74 (0.079)	0.549	0.888	0.74 (0.064)	23 [15]	0.79 (0.060)	20 [10]	0.72 (0.089)	58 [35]
		AE_5	0.58 (0.077)	0.360	0.733	0.56 (0.074)		0.62 (0.062)		0.56 (0.077)	
		EE_5	0.43 (0.080)	0.225	0.569	0.42 (0.064)		0.49 (0.055)		0.41 (0.086)	
Total N=480	**100**	$\mathbf{TE_T}$	**0.77 (0.202)**	**0.271**	**1.000**	**0.81 (0.201)**	**30 [100]**	**0.82 (0.160)**	**39 [100]**	**0.67 (0.215)**	**31 [100]**
		$\mathbf{AE_T}$	**0.69 (0.139)**	**0.322**	**1.000**	**0.68 (0.148)**		**0.77 (0.111)**		**0.61 (0.107)**	
		$\mathbf{EE_T}$	**0.53 (0.180)**	**0.189**	**1.000**	**0.55 (0.184)**		**0.62 (0.142)**		**0.41 (0.142)**	

Source: Author's computation from efficiency scores of the survey data (2015).
Note: Values in (Std.), % group and [% district] are standard deviation, proportion from group and proportion from district, respectively.

Table 8. Descriptive Statistics of Variables Hypothesized to Influence Efficiencies (N=480)

Variables	**Variables description**		**Mean**	**Std.**
	Continuous variables			
Age	Age of the household head (Years)		43.41	11.16
Education	Household head education level (Years)		4.05	3.47
Family size	Household family size (adult equivalent)		4.90	1.58
Livestock	Livestock holding (TLU)		4.72	2.26
Extension contact	Extension contacts (Days per production year)		19.09	14.70
All weather road	Distance to all weather road (km)		1.34	1.46
Nearest market	Distance to nearest market (km)		6.73	3.80
Farm plots	Average distance to the selected crops plots (km)		1.88	1.28
	Dummy variables	**Response**	**Frequency**	**Percent**
Sex	Sex (Male =1, Female=0),	Male	463	96.5
		Female	17	3.5
Credit	Credit access (Yes=1, No=0)	Yes	270	56.3
		No	210	43.7
Off/non-farm income	Off/non-farm income (Yes=1, No=0)	Yes	193	40.2
		No	287	59.8
Cooperative	Coop. membership (Yes=1, No=0)	Yes	453	94.4
		No	27	5.6

Source: Author's computation from sample survey data (2015)
Note: Std.: Represents standard deviation.

3.5. Determinants of Efficiency of Selected Crops Production

The results obtained from DEA model showed the existence of substantial inefficiencies of selected crops production and that there are efficiency variations among farmers. In order to identify key determinants of the efficiency of technical, allocative and economic efficiency scores are separately regressed on selected variables using double bonded Tobit model [24]. Table 8 presents descriptive statistics of variables that influence efficiencies in selected crops production.

Model diagnosis showed that normality assumption and multicollinearity were not a problem. However, there was some evidence of heteroscedasticity and hence all the estimation were done using robust standard error specifications [25].

Analysis of the determinants of efficiency differentials among farm households using a double bounded Tobit model indicates that education, participation in off/non-farm activities and livestock holding were positively and significantly affect technical efficiency whereas market and distances to all weather road have negative and significant effect on it. Credit access and extension contacts were found to be positively and significantly affecting allocative efficiency while age, off/non-farm activities, market, distances to all weather road and average farm plots distances have negative and significant effect on it. Education and livestock holding were found to be positive and significantly affecting economic efficiency whereas distances from market, all weather road and farm plots were found to be negatively and significantly affect economic efficiency (Table 9). Age of the household head has a negative and significant effect on AE of selected crops production at 10% level of significance. Though older farmers are expected to have greater access to productive resources, these farmers may be in a position to experience much with their traditional farming practices and usually risk averse than younger farmers. The same results were obtained in the studies of [26,27].

Education of the household head has a positive and significant effect on TE and EE of selected crops production at 1% and 5% statistical levels. This suggests that better educated household heads can understand agricultural instructions easily, have higher tendency to adopt improved production technologies, have better access to information and be able to apply technical skills. Thus, a one-year increase in educational attainment level of the household head increases the probability and level of the expected value of TE and EE by about 1.2 and 1.0% with an overall increase in the probability and levels of efficiency by 0.9 and 0.6%, respectively. This result is in line with other studies like [7,28,29,30].

Livestock holding has a positive and significant effect on TE and EE in selected crops production. Farmers who own large number of livestock were technically and economically more efficient than those who own less number of livestock. This is because livestock provides draught power, manure and is a source of income that can be used to purchase the necessary agricultural inputs. These results are in agreement with the findings of [7,8,9,22].

Credit is an important element in agricultural production systems. Credit increases farmer's efficiency as it temporarily solves shortage of working capital. The study found positive and significant effect of rural credit on AE of farmers. Studies by [27,29,31] found similar results. Extension contacts also have a positive and statistically significant effect on allocative efficiency at 5% level of statistical error. These results are consistent with the findings of [7,27,31].

Market distance is another variable affecting TE, AE and EE significantly and negatively at 1% level of statistical error. An increase in market distance by one kilometer would decreases the probability and level of the expected value of TE, AE and EE by about 2.1, 0.9 and 2.4% with an overall decrease in the probability and levels of efficiencies by 1.7, 0.6 and 1.3%, respectively. Similar results were found in the works of [3,21,29].

Distance to all weather road is used as proxy for accessibility of transportation to markets. The study discovered that it has a negative and statistically significant effect at 1%, 5% and 10% levels of statistical error on TE, AE and EE, respectively. As the distance to all weather increases, it is expected that the transaction cost of acquiring inputs or time taking products to markets increases and hence undermines the incentive to produce. Similarly, farm distance also has a negative and statistically significant effect at 1% and 5% levels of statistical error to AE and EE scores.

Table 9. Tobit Regression Results on Technical, Allocative and Economic Efficiency of Selected Crops Production and Their Marginal Effects. (Dependent Variables: Technical, Allocative and Economic Efficiency) (N=480)

Variables	Technical Efficiency			Allocative Efficiency			Economic Efficiency		
	Coefficient (Std.)	**Marginal effects**		**Coefficient (Std.)**	**Marginal effects**		**Coefficient (Std.)**	**Marginal effects**	
		Total change	Expected change		Total change	Expected change		Total change	Expected change
Age (Years)	0.001 (0.001)	0.001	0.001	-0.001* (0.001)	-0.001	-0.002	-0.001 (0.001)	-0.0004	-0.001
Education (Years)	0.009*** (0.003)	0.009	0.012	0.002 (0.002)	0.002	0.003	0.005** (0.002)	0.0055	0.010
Livestock (TLU)	0.012** (0.006)	0.012	0.015	0.001 (0.003)	0.001	0.001	0.008* (0.004)	0.0078	0.015
Credit (Dummy)	-0.015 (0.024)	-0.015	-0.019	0.023* (0.013)	0.023	0.033	0.016 (0.016)	0.0158	0.030
Extension (No. days)	0.000(0.001)	0.000	0.000	0.001*(0.000)	0.001	0.001	0.001 (0.001)	0.0005	0.001
Off-farm income (Dummy)	0.045* (0.023)	0.045	0.057	-0.039*** (0.013)	-0.039	-0.056	-0.002 (0.017)	-0.0018	-0.004
Market distance (km)	-0.017*** (0.003)	-0.017	-0.021	-0.006*** (0.002)	-0.006	-0.009	-0.013*** (0.002)	-0.0126	-0.024
All weather road (km)	-0.027*** (0.006)	-0.027	-0.035	-0.008** (0.004)	-0.008	-0.012	-0.011* (0.005)	-0.0107	-0.020
Farm plots distance (km)	-0.005 (0.009)	-0.005	-0.007	-0.014*** (0.005)	-0.014	-0.020	-0.015** (0.006)	-0.0148	-0.028
Constant	0.792*** (0.090)			0.855*** (0.058)			0.639*** (0.069)		
Log likelihood	-96.7214			273.5525			156.9983		
F (12,468), Pr > F	7.56***			4.80***			6.05***		

Note: ***, ** and * indicate the level of significance at 1, 5 and 10 percent, respectively.
● Only significant variables are presented in the table. Values in parentheses (Std.) are robust standard errors.

Marginal effects value in cell explain $\frac{\partial E(y)}{\partial x_j}$ (total change) and $\frac{\partial E(y^*)}{\partial x_j}$ (Expected change).

Source: model results.

4. Conclusion and Recommendations

This study examined production efficiency levels and identified inefficiency factors for selected crops production by smallholder farmers in three districts of North Shewa zone, Amhara region. For this purpose, cross sectional data derived from a randomly selected sample of 480 smallholder farmers in the year 2015 production season was used.

DEA results showed that the mean technical, allocative and economic efficiencies were 77%, 69% and 53% respectively, indicating a substantial level of inefficiencies in the production of selected crops. Analysis of determinants of efficiency using Tobit model indicates that though aged farmers have accumulated resources they tend to be less responsive to innovations and changes, whereas, younger farmers do and are more efficient. The level of education of the household head, livestock holding, credit and extension contact emerge as an important factors in enhancing efficiencies of selected crops production. The study also revealed that distances from market, all weather road and farm plots significantly decrease all efficiency scores.

Hence due attention should be given to improve the productivity of livestock through the provision of improved breed, better health service, improved feed and other necessary supports. Government should give due attention on provision of basic education so that farmers can understand agricultural instructions easily and have better access to product information and use the available resources more competently. Strategies should emphasize on strengthening the existing agricultural extension service through provision of on job training, upgrading the educational level, non-overlapping and consistent responsibilities of extension workers are supreme for improving farming technique with technological innovations in the study area. Moreover, expansion of infrastructures and credit services should take in to consideration.

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