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Technical efficiency of smallholder farmers in red pepper production in North Gondar zone Amhara regional state, Ethiopia

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Abstract

Indtroduction: Currently, Ethiopia is following an agricultural development-led industrialization strategy with a major goal of helping agriculture grow so that it can encourage growth in other sectors of the country's economy. However, it is characterized by low productivity due to technical and socioeconomic factors. To improve this problem, integration of modern technologies with improved level of efficiency becomes more crucial. Therefore, this study tries to fill the gap by investigating efficiency variations and factors affecting technical efficiency of red pepper production in North Gondar zone Amhara regional state, Ethiopia.

Methods: By using multistage sampling, cross-sectional data were collected from 385 systematically selected households. Stochastic frontier Cobb–Douglas production was estimated.

Result and conclusion: The results of the analysis revealed that a mean technical efficiency of red pepper was 78.80% (ranging from 16 to 94.9%). This implies that red pepper producers can reduce current level of input application by 21.2% given the existing technology level. The estimated stochastic production frontier (SPF) model also indicates that land, seed, chemical, oxen and labor are significant determinants of red pepper production level. The estimated SPF model together with the inefficiency parameters shows that age, education status, land size, land fragmentation, extension service, credit access and market information were found to statistically and significantly affect the level of TE of red pepper farmers in the study area. Hence, emphasis should be given to improve the efficiency level of those less efficient farmers by adopting the practices of relatively efficient farmers in the area so that they can be able to operate at the frontier. Specifically the concerned body should provide adult and vocational education for the farmers and create opportunities for farmers with lower technical efficiency to have experience and best practices sharing with those that scored efficiency scores close to one.

Keywords: Technical efficiency, Red pepper, Stochastic frontier, Cobb–Douglas and North Gondar zone

1 Introduction

In many developing countries including Ethiopia, agriculture plays a vibrant role in promoting economic growth and development. The importance of agriculture in Ethiopia is evidenced by its share in GDP (43%), its employment generation (80%), share of export (70%) and providing about 70% of raw material for the industries in the country in 2012/13 (UNDP 2013). Furthermore, 90% of the poor earn their livelihood from this sector (Yu et al. 2011). Thus, it is not surprising that policy action in Ethiopia is largely based on influencing the dynamism of the agricultural sector.

However, Ethiopian agriculture is characterized by low productivity due to technical and socioeconomic factors. Mostly the farmers with the same resources are producing different per hectare output, because of management inefficiency inputs, limited use of modern agricultural technologies, obsolete farming techniques, poor complementary services such as extension, credit, marketing, and infrastructure; poor and biased agricultural policies in developing countries like as Ethiopia (FAO and WFP 2012). To reverse the situation, the Ethiopian government has design Growth and Transformation Plan (GTP-I) in the 5 years (2011–2015). According to the plan, smallholder farmers are among the major targeted groups where increased agricultural productivity is believed to be achieved (David et al. 2011). One of the basic strategies of the Ethiopian government in improving agricultural productivity is to adopt new technologies and use of modern inputs (Asfaw and Bekele 2010). However, where there is inefficiency in utilization of agricultural inputs, trying to introduce new technology may not bring the expected result. The existence of inefficiency in production comes from inefficient use of scarce resources. The measurement of efficiency in agricultural production is important issue for agricultural development, and it gives useful and powerful information for making relevant decision in the use of these scare resources and for reformulating agricultural policies. There is an introduction of new technologies for the production of pepper, but no one gives emphasis on the efficient utilization of these technologies.

Pepper has originated in Mexico and Central America regions and subsequently spread into Africa and Asia continents. It is the world's most important type of spice which provides nutritional value to consumers particularly vitamin A and E, flavoring and coloring food (Boseland and Votava 2000). The largest pepper producer countries in the world were Vietnam which produces (100,000 metric tonnes) followed by India (48,000 metric tonnes), Indonesia (37,000 metric tonnes), Brazil (35,000 metric tonnes), Malaysia (25,672 metric tonnes), Republic of China (23,300 metric tonnes) (Rosli et al. 2013). Likewise, Fig. 1 indicates the top five largest pepper producer countries in Africa were Madagascar which produces 6981 metric tonnes followed by Ethiopia (4511 metric tonnes), Ghana (3767 metric tonnes), Rwanda (2535 metric tonnes), and Uganda (2063 metric tonnes) (FAOSTAT 2016).

Ethiopia is a homeland for many spices and grows more than 14 types of spices, such as pepper (green, red and black), paprika, turmeric, fenugreek, garlic, korarima, coriander, ginger, cardamom, black cumin, white cumin, and basil (Girma et al. 2008). The past history of pepper in Ethiopia is possibly the most earliest than any other vegetable product. Ethiopians have strong attachment to red pepper, which has high value principally for its high pungency. The fine powdered pungent product is an indispensable flavoring and coloring ingredient in the common traditional sauce "Wot," whereas the green pod

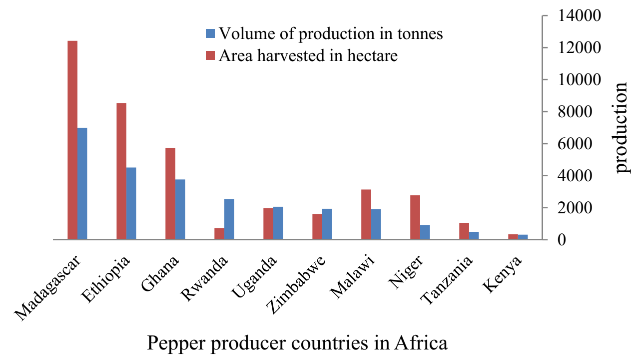

Fig. 1 Top 10 pepper producer countries in Africa *Source*: FAOSTAT (2016)

is consumed as a vegetable with other food items. There is a general belief among Ethiopians that a person who frequently consumes hot pepper has resistance to various diseases. The average daily consumption of hot pepper by Ethiopian adult is estimated 15 g, which is higher than tomatoes and most other vegetables (EEPA 2014).

Red pepper is widely cultivated in different agro-ecologies of Ethiopia. The Ethiopian Export Promotion Agency (2014) has carried out a spice potential market study in Amhara, Oromia and SNNPRS, and it identified the land coverage for pepper in the three regions. The total production of pepper in the country for the year 2008/09 Ethiopian main cropping season was estimated to be 1,834,026 quintals. In addition in Amhara region, the total production was 530.466 quintal for the same year. Therefore, the contribution of the Amhara region for the country production was 29%. The total area cultivated by red pepper small holder farmers for the meher season 2015/2016 in North Gondar zone was 7103.07 hectares. The estimated average productivity of red pepper in North Gondar zone was 15.25 quintals per hectare, which is low compared to Amhara Region an average of 16.75 quintals per hectare in 2015/16 (CSA 2016). The production of pepper in the region is dominantly by smallholder farmers using rain by traditional farming practice. Very small amount of pepper is being produced using irrigation and modern inputs such as fertilizer and improved seeds (Alemnew 2010).

The production of red pepper increases year to year. According to Alemayehu et al. (2012), there has been substantial growth in crops, in terms of area cultivated, yields and production since 2000, but a yield is low by international standards and overall production is highly susceptible to weather shocks, particularly draught. This shows that smallholder farmers are technically inefficient since they are producing below potential output using the existing technology. The author argued that future crop production growth need to come increasingly from yield improvements as there is little suitable land available for the expansion of crop cultivation in the country, especially in the highlands.

Now a day, in Ethiopia there has been increasing focus by policy makers on adoption of modern technologies rather than efforts targeted at improving the efficiency of inefficient farmers. Theoretically, introducing modern technologies can increase agricultural productivity and production. However, in areas where there is inefficiency in which the existing inputs and technologies are not efficiently utilized trying to introduce new technologies may not have the expected results. Obviously, the level of farmers' technical efficiency has paramount implications for country's choice of development strategy (Zenebe et al. 2004). According to Asefa (2012), if existing inputs and technologies are not efficiently utilized, trying to introduce new technologies will not be cost-effective. As a result, the use of the existing technologies is more cost-effective than applying new technologies. Thus, a technical efficiency analysis is crucial to find out if farmers are efficient in the use of the existing resources and to decide when to introduce new technologies.

Measuring efficiency level of farmers benefit economies by determining the extent to which it is possible to raise productivity by improving the neglected source of growth (efficiency) with the existing resource base and available technology. There have been various empirical studies conducted to measure technical efficiency in Ethiopia (for example: Hassen 2016; Shumet 2011; Musa et al. 2014; Berhan 2015; Getachew and Bamlak 2014). Nonetheless, findings of these studies might not be applicable to the case of pepper production in North Gondar zone due to the diverse agro-ecological zone, differences in the know-how of the farmers, differences in the output produced, and differences in technology and means of production. To the best of the authors' knowledge, not much studies undertaken on technical efficiency of red pepper producing farmers in the study area. Moreover, it is imperative to update the information based on the current productivity of farmers. However, the productivity of agricultural system in the study area is very low. The poor production and productivity of crop resulted in food insecurity. Therefore, this study was measured the technical efficiency and identifies factors affecting technical efficiency of smallholder farmers on red pepper production.

2 Research methodology

2.1 Description of the study area

The study was conducted in North Gondar zone, Amhara regional state, Ethiopia. It is located in the northwestern part of Ethiopia between 11 and 13 north latitude and 35 and 35 east longitudes, and it is 783 km far from Addis Ababa. The zonal capital city is Gondar, and geographically Gondar is located at 12°35′60.00″N latitude and 37°28′0.01″E longitudes with average elevation of 2133 meters above sea level. The zone is dominated by the agricultural sector, which employs about 90% of the working force. The zone is divided into 23 districts, and its boundaries are adjoin with Tigray region in the North, Awi zone and West Gojam zone in the South, Waghimra zone in the East, South Gondar zone in the Southeast and Sudan in the West. The total area of the zone is 50,970 Square Km. The low lands contain some of the largest tracts of semiarid and natural forest in Northwester Ethiopia. The zone also has a total population of 3,036,961 (83.39% rural and 16.61% urban) of which 50.69% are men (BoFED 2009). The study was conducted in two districts (namely Takusa and Dembia), which are the main potential red pepper producers districts (Fig. 2).

2.2 Sampling technique and sample size

A multistage sampling technique was used to select sample producers. In the first stage, Takusa and Dembia districts were selected purposively due to high potentials of red pepper production. In the second stage, eight largest kebeles namely, Mekonta, Chemera, Banbaro, Deber-zuria, Guramba-Michael, Arabia, Achera, and Gebaba-salge, were purposively selected in consultation with District Agriculture office experts due to the high production potential and best smallholder farming experience. In the third stage, using the population

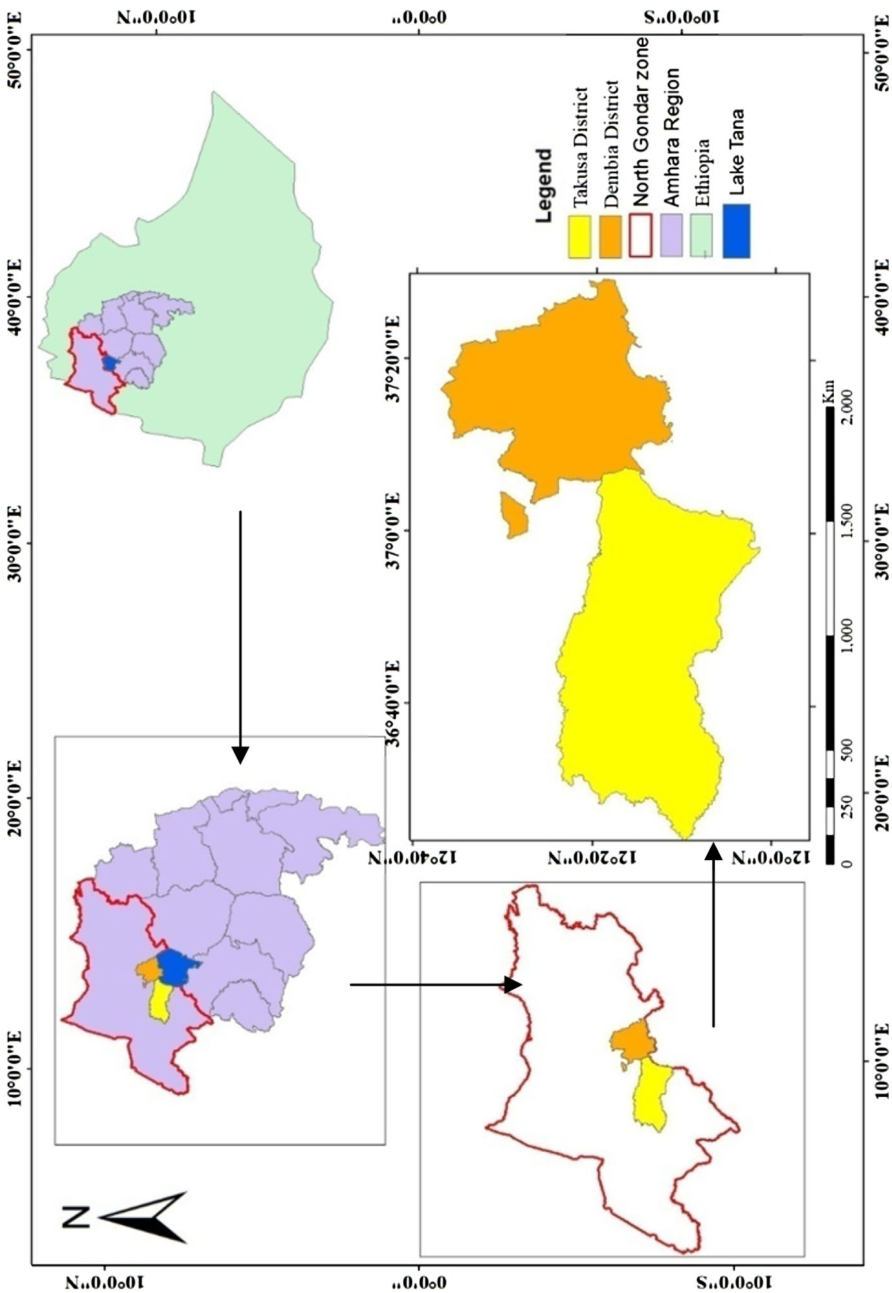

Fig. 2 Map of study area *Source*: Own developing using satellite data (2018)

list of red pepper producer from sample kebeles, the intended sample size was determined proportionally to population size of red pepper producer. Moreover, using systematic random sampling technique, 385 red pepper producers were selected using a formula developed by Cochran (1977)

$$n = \left[\frac{Z^2pq}{e^2}\right] = \frac{1.96^2(0.5 * 0.5)}{0.05^2} = 385 \quad (1)$$

where n = sample size; Z = confidence level (Z = 1.96); p = 0.5, q = 1 − p and e = 0.05 (error term).

2.3 Data source and data collection method

Both primary and secondary data were gathered to meet the objectives of the study. Primary data were collected through the administration of semi-structured and personal interview by a team of five trained enumerators to 385 small-scale red pepper farmers. Furthermore, key informants interview were used for data collection. Secondary data were collected from past reports and studies conducted by institutions and researchers.

2.4 Method of data analysis

Stochastic frontier approach was applied to estimate the level of technical efficiency of farmers, because for its ability to distinguish inefficiency from deviations that are caused from factors beyond the control of farmers. Crop production is likely to be affected by random shocks such as weather, pest infestation and drought. In addition, measurement errors are likely to be high. In such a condition where random shocks and measurement errors are high, a model that accounts for the effect of noise is more appropriate to choose. Thus, the stochastic efficiency decomposition methodology was more appropriate for this study. The stochastic frontier production function can be written as:

$$Y_i = F(X_i\beta)\exp(v_i - u_i) \quad i = 1, 2, 3, \ldots 385 \quad (2)$$

Using a linear representation, the empirical production function to be estimated is written as:

$$\ln Y_i = \beta_0 + \beta_1 \ln \text{lab} + \beta_2 \ln \text{land} + \beta_3 \ln \text{seed} + \beta_4 \ln \text{oxen} + \beta_5 \ln \text{chemical} + \beta_6 \ln \text{fert} + v_i - u_i \quad (3)$$

where Y_i is the production of the i th farmer, X_i is a vector of inputs used by the ith farmer, β is a vector of unknown parameters, v_i is a random variable which is assumed to be $N(0, \sigma_{v_i}^2)$ and independent of the u_i which is nonnegative random variable assumed to account for technical inefficiency in production.

Though a study done by Kopp and Smith (1980; cited in Musa et al. 2014) who suggests that functional specification has only a small impact on measurement of efficiency, but stochastic frontier method requires a prior specification of the functional form. Hence for this study, Cobb–Douglas production function was selected.

A single-stage estimation procedure was followed to analyze determinates of TE from a stochastic frontier production function. In single-stage estimation, inefficiency effects are defined as an explicit function of certain factors specific to the firm, and all the parameters are estimated in one-step using the maximum likelihood procedure. The major drawback with the two-step approach resides in the fact that, in the first step, inefficiency effects are assumed to be independently and identically distributed in order to use the Jondrow et al. (1982; cited in Musa et al. 2014) approach to predict the values of technical efficiency indicators. In the second step, however, the technical efficiency indicators thus obtained are assumed to be depend on a certain number of factors specific to the firm, which implies that the *TE* are not identically distributed unless all the coefficients of the factors considered happen to be simultaneously null.

Technical inefficiency of smallholder red pepper producers depends on various demographic, socioeconomic, farm attributes, institutional and marketing factors. These factors include age, education status, family size, land size, tropical livestock unit, land fragmentation, soil fertility, slope, distance to development center, extension service, credit access, market information, membership to cooperatives and off/non-farm income activity. The log likelihood ratio test indicated that technical inefficiency of smallholder red pepper producers was affected by various demographic, socioeconomic, farm attributes, institutional and marketing factors (Table 1). The expected influences of each of the hypothesized variables that affect technical inefficiency are discussed below.

Age of household head The age of household was expected to have a negative influence on technical inefficiency of red pepper production. This means that older farmers are expected to have greater access to labor, land and relevant tacit knowledge on productivity enhancing technology than younger farmers.

Education status It is a dummy variable considering farmers' education from illiterate up to the higher level of education. It takes 0 for illiterate and 1 for literate household. The educational background of the sample household heads is believed to be an important feature that determines the readiness of household head to accept new ideas and innovations. More educated farmers are expected to adopt new technologies to increase their land and labor productivities. A study conducted by Aye and Mungatana (2010) who found that education level has a positive influence on technical efficiency of maize production. Hence, education was expected to influence technical inefficiency negatively.

Family size (adult equivalent) The number of members of household head affects efficiency of red pepper producer farmers positively through its direct influence on availability of labor supply to undertake farm operation on time. A study done by Shumet (2011) found that family size was negatively affecting technical inefficiency of maize production. Hence, a household with large family size was hypothesized to be less technical inefficient than household with less family size.

Table 1 Summary of tests of the assumption of stochastic frontier approach *Source*: Model output (2018)

Null hypothesis	Degree of freedom	LR	x^2 value	Decision
$H_0 : \gamma = 0$	1	53.94	3.84	Not accepted
$H_0 : \beta_7 = \cdots = \beta_{27} = 0$	21	30.60	32.67	Accepted
$H_0 : \delta_0 = \cdots = \delta_{14}$	14	53.94	23.69	Not accepted

Land size Land is one of the most important and scarce resources in agricultural production. The size of land holding hypothesized to have positive impact on the technical inefficiencies of red pepper production. Small land size is expected to be more efficient than large farm because of its simplicity in management and transaction costs. A study conducted by Sisay (2016) found that land size was negatively affecting technical efficiency of maize production. Hence, a household with large land size was hypothesized to be more technical inefficient than household with less land size.

Tropical livestock unit (TLU) It refers to the number of livestock owned by household and measured by Tropical Livestock Unit (TLU). Livestock ownership is perceived as the accumulation of wealth status, use for draft power, manure, income from sale of butter and sale of livestock in times of risk to buy improved agricultural technologies such as seed, pesticides, etc. Households having large size of livestock can have better chance to earn more income from livestock. It is a continuous variable and therefore the more livestock owned by the farm; household will be the more possibility of purchasing improved agricultural inputs and/or the more investment in the off-farm activity. The farmer also has the chance to get oxen for draught power (Wondimu 2014; Bekele 2013 and Getahun 2014). Hence, those farmers owning more livestock were expected to be less technically inefficient than those who own less livestock.

Land fragmentation This refers to the number of farm plots that a farmer cultivates red pepper. This variable is continuous, and it was expected to influence technical inefficiency in a negative way.

Soil fertility Farmers were asked to rate the relative fertility status of their plots; hence, this variable is a dummy with 1 for fertile and zero otherwise. Therefore, those farmers who allocate fertile plot for red pepper production were expected to be less technically inefficient.

Slope of the farm land This is measured as discrete variable. Slope of the land may affect level of production. For instance, steep plots are usually subject to water erosion. As a result, they are likely to be of lower productivity. Since steep plots are vulnerable to erosion damage and they are likely infertile compared to plain plots, slopes of plot were found to be related negatively to technical efficiency (Alemayehu 2010). To take the effect of efficiency of different topography of the plot, an index was constructed based on the respondents' judgments. The index for the slope of the land is constructed based on the respondents response on whether the slope of their plot that takes a value of 1 if slope of plot is steep and zero otherwise. Hence, it was hypothesized that households who owns steeper farm land expected to be technically inefficient.

Distance to development center Distance to development center is used as proxy for assessing the accessibility of extension services to farmer in red pepper production. Proximity to development center has advantage of obtaining technical supports form extension workers related to the utilization of technologies in red pepper production. Hence, distance from the development center is likely to have a positive effect on technical inefficiency of red pepper production.

Extension service Farmers who have better extension service are expected to be more efficient than others. The more contact the farmer has with extension service, the more will be the information/knowledge she/he has and the better will be the use of agricultural inputs. Therefore, it is assumed that farmers who have better extension service are more likely to demand agricultural inputs due to the increased awareness (Dawit 2012). Hence, it was expected to affect the technical inefficiency negatively.

Access to credit This is a dummy variable indicating 1 if a farmer received and used credit in red pepper production and zero otherwise. It was used to capture the effect of credit on the production efficiency level of farmers. The availability of credit will be loosen the constraints of production, therefore facilitating the acquisition of inputs on a timely basis, and hence it is supposed to increase the level of efficiency of the farmers. Farmers who receive credit were assumed to overcome liquidity constraints, purchase more production inputs or a new technological package such as high-yielding seeds since this can be regarded as access to funds (Daniel 2009; Bekele 2013). Therefore, it was hypothesized that households who have used credit expected to be less technical inefficient than others.

Access to market information This is a dummy variable taking value of 1 if the producer had access to market information and zero otherwise. The better information farmers have the more efficient utilization of inputs which in turn increases the technical efficiency of red pepper production. The general idea is that maintaining a competitive advantage requires a sound business plan which means producing optimum red pepper. Hence, it was hypothesized that households who have access to better information expected to be less technical inefficient than others.

Cooperative membership Cooperative membership is used as proxy for assessing the role of association in efficiency of red pepper production. Farmer cooperative facilitates information provision related to price, profitability, availabilities of new technology and the provision of credit services to its members. A farmer who is member of farmer cooperative is more likely to adopt improved agricultural technologies and hence efficient in red pepper production than others. Therefore, a negative relationship was hypothesized between the variable cooperative membership and technical inefficiency of red pepper production.

Off/non-farm activities is a dummy variable and measured as 1 if the household was involved in off/non-farm activities and zero otherwise. Being involved in off/non-farm activities may have a systematic effect on the production efficiency of farmers. This is because farmers may allocate more of their time to off/non-farm activities and thus may lag in agricultural activities. The effect on the production of farmer being involved in off/non-farm activities may be of twofold. First, if farmer spends more time on off/non-farm activities relative to farm activities, this may negatively affect agricultural activities. Second, income generated from off/non-farm activities may be used to acquire purchased inputs and hence positively complement farm activities and may be used as extra cash to buy agricultural inputs and also be a supplement for home use (Teklemariam 2014; Getahun 2014). Therefore, it was hypothesized that a farmer engaged in off/non-farm activities to be less technical inefficient than his counterpart.

For the investigation of socioeconomic and institutional factors affecting technical efficiency levels, the following model was estimated:

$$
\begin{aligned}
\mathrm{TE}_i = \delta_0 &+ \delta_{1i}\left(\mathrm{Age}_i\right) + \delta_{2i}(\mathrm{Educ}_i) + \delta_{3i}(\mathrm{Famsize}_i) + \delta_{4i}(\mathrm{Landsize}_i) + \delta_{5i}(\mathrm{TLU}_i) \\
&+ \delta_{6i}\left(\mathrm{LFrag}_i\right) + \delta_{7i}(\mathrm{Soilf}_i) + \delta_{8i}\left(\mathrm{Slope}_i\right) + \delta_{9i}(\mathrm{DisDC}_i) + \delta_{10i}(\mathrm{Excs}_i) \\
&+ \delta_{11i}(\mathrm{Credit}_i) + \delta_{12i}(\mathrm{MktInfo}_I) + \delta_{13i}\left(\mathrm{Coop}_i\right) + \delta_{14i}(\mathrm{OFFNON}_i)
\end{aligned}
$$

3 Result and discussions

3.1 Estimation of production function

The stochastic production frontier was applied using the maximum likelihood estimation procedure using Frontier 4.1 computer program. Before proceeding to model estimation, tests were made for all assumption of stochastic frontier approach. First, a test was made for multicolinearity among the continuous and categorical explanatory variables using the variance inflation factor (VIF) and contingency coefficient (CC), respectively, and the values of VIF and CC for all variables entered into the model were below 10 and 0.75, respectively, which indicate that there is no sever problem of multicolinearity among the explanatory variables.

Second, it is necessary to detect the presence of inefficiency in the production function for the sample households. This is made in order to decide whether the traditional average production function (OLS) best fits the data set as compared to the stochastic frontier model (SFM). The test was carried out by estimating the stochastic frontier production function and conducting a likelihood ratio test assuming the null hypothesis of no technical inefficiency ($H_0 : \gamma = 0$). The likelihood ratio test statistics is calculated to be $\mathrm{LR} = -2(\mathrm{LH}_0 - \mathrm{LH}_1) = -2(-316.22 - (-289.25)) = 53.94$. This value exceeds the critical $x^2(5\%, 1)$ value of 3.84 at 5% level of significance (Table 1). Thus, the null hypothesis was not accepted indicating that there is statistically significant inefficiency in the data. Hence, stochastic frontier production function was an adequate representation of the data.

Third, test for the selection of the appropriate functional form for the data based on calculated log likelihood ratio (Cobb–Douglas versus Translog production function) were estimated. The calculated log likelihood ratio (LR) is equal to 30.90, and the critical value of χ^2 (x^2) at 21° of freedom and 5% significance level is 32.67 (Table 1). Thus, the null hypothesis that all coefficients of the interaction terms in Translog specification are equal to zero was accepted. This implies that the Cobb–Douglas functional form adequately represents the data under consideration. Hence, the Cobb–Douglas functional form was used to estimate the technical efficiency of the sample households in the study area.

Fourth, the test for farm-level technical inefficiencies is not affected by the socioeconomic variables included in the inefficiency model ($H_0 : \delta_0 = \delta_1 = \cdots = \delta_{14} = 0$) was performed. The calculated LR value of 53.94 was greater than the critical value of 23.69 at 14 degree of freedom. This shows that the null hypothesis (H_0) of explanatory variables are simultaneously equal to zero was not accepted at 5% significance level. Hence, the result revealed that all these variables included in the model were simultaneously explaining the sources of efficiency differences among the sample households.

The result of stochastic frontier model showed that five of the input variables in the production function, such as land, seed, chemical, oxen and labor, had a positive and significant effect on the level of red pepper production. Hence, an increase in these

Table 2 Ordinary least squares (OLS) estimates of the average production function and maximum likelihood (ML) estimate of stochastic production frontier for red pepper farmers *Source*: Model output (2018)

Variables	Parameters	Ordinary least square estimates		Maximum likelihood estimates	
		Coefficient	SE	Coefficient	SE
Constant	β_0	6.700***	0.208	7.056***	0.191
LnLand	β_1	0.630***	0.076	0.511***	0.075
Lnseed	β_2	0.297***	0.053	0.209***	0.056
Lnfertilizer	β_3	0.033**	0.018	0.009	0.018
LnChemical	β_4	0.021	0.033	0.067**	0.035
LnOxen	β_5	0.100**	0.052	0.135***	0.052
LnLabour	β_6	0.072**	0.029	0.052**	0.027
(σ^2)				0.4299***	0.0498
(γ)				0.4955***	00.663
Log likelihood function		− 316.22		− 289.25	
Total sample size		385		385	

***, **Show significance at 1% and 5%, respectively

Table 3 Red pepper yield gap due to technical inefficiency *Source*: Own survey result (2018)

Variable	Mean	SD	Min	Max
Actual yield (kg)	972.338	827.518	100	8000
TE	0.788	0.144	0.160	0.949
Potential yield (kg)	1163.789	860.223	115.108	8473.917
Yield gap (kg)	191.452	104.349	15.108	851.072

inputs would increase production of red pepper significantly as expected. As one percent increase in the size of land, amount of seed, amount of chemical, number of oxen and number of labor would increase red pepper production by 0.511%, 0.209%, 0.067%, 0.135% and 0.052%, respectively (Table 2).

The value of sigma-squared (σ^2) for frontier of red pepper output was 0.4299 implying that significantly different from zero and significant at 1% level of significance. The significant value indicates the goodness of fit of the specified assumption of the composite error terms distribution (Kifle et al. 2017; Musa et al. 2014). The estimated value of gamma was 0.4955. This indicates that 49.55% of total variation in red pepper farm output is due to technical inefficiency. The returns to scale analysis coefficients were calculated to be 0.983% indicating decreasing returns to scale. As a percent increase in all inputs proportionally would increase the total production by less than 1%. This study is in line with Bamlaku et al. (2007) who estimated the return to scale to be 0.962% in the study of TE of farming systems across agro-ecological zones in Ethiopia.

3.2 Efficiency scores and yield gap due to inefficiency

The model output presented in (Table 3) indicates that farmers in the study area were relatively good in TE. The mean TE was found to be 78.80%. This implies that in the

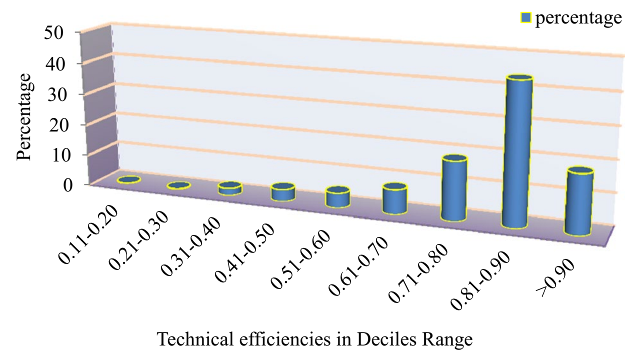

Fig. 3 Frequency distribution of technical efficiency *Source*: Own survey result (2018)

short run there are opportunities for reducing red pepper production inputs by 21.2% and performing the practice of technically efficient farmer in the locality. Or the mean of TE indicates that if sample households operated at full efficiency level, they would increase their output by 21.2% using the existing resources and level of technology. In other words, on average the sample households decrease their inputs by 21.2% to get the output they are currently getting.

The frequency distribution of TE at which sample households operate is presented in Fig. 3. They vary from one farmer to another in a range from 0.14 to 0.95. Most of households had a higher technical efficiency levels. That means the distribution of the TE scores is skewed to the right. Majority (83.33%) of the sample farmers have TE score greater than or equal to 50%. Moreover, 62.34% of sampled farmers have a TE score above 81%, implying that there is a room to enhance production by 19%. On the other hand, there are also groups of sample farmers with very low (less than 50%) level of efficiency. The frequency distribution of efficiency indexes indicates there is a high technical efficiency variation among producers. Therefore, the presence of technical inefficiencies could be eliminated by implementing the practice of technical efficient red pepper farmers in the study area.

Knowing the individual farmers technical efficiency and actual output in red pepper production enables to determine the potential level of red pepper output farmers produce through efficient use of existing inputs and technology. The potential red pepper output was estimated for sample red pepper producer farmers by dividing the actual individual level of red pepper output by the predicted technical efficiency scores from stochastic frontier model. After calculating potential red pepper output, the yield gap of red pepper was estimated. Yield gap is estimated by the difference between technically full efficient yield and observed yield.

It was observed that mean technical inefficiency was 21.2% which caused 191.452 kg yield gap of red pepper on average with mean value of the actual output and the potential output of 972.338 kg and 1163.789 kg, respectively. This shows that sample households in study area were producing on average 191.452 kg lower red pepper output than their potential yield. In other words, the result indicated that in the short run there is a potential to increase red pepper output on average by 191.452 kg at the existing input use and technology through improving technical efficiency of farmers. Figure 4 illustrates that

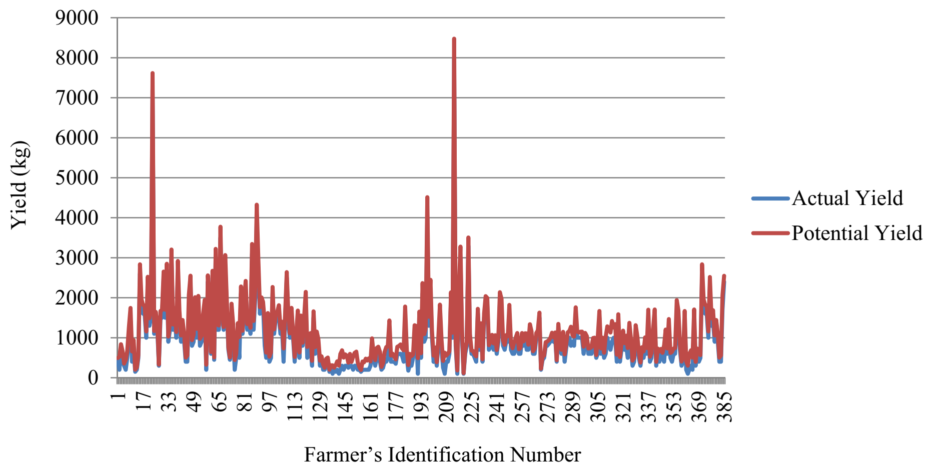

Fig. 4 Comparison of the actual and the potential level of yield *Source*: Own survey result (2018)

Table 4 Maximum likelihood estimates of factors affecting technical inefficiency *Source*: Model output (2018)

Variables	Coefficient	SE
Constant	1.280***	0.388
Age	− 0.025***	0.008
Education status	− 0.600***	0.192
Family size (AE)	− 0.025	0.039
Land size	0.298***	0.100
Tropical livestock unit	0.001	0.001
Land fragment	− 0.993***	0.373
Soil fertility	− 0.194	0.128
Slope	− 0.023	0.148
Distance to development center	− 0.12	0.019
Extension service	0.525**	0.238
Credit access	0.393**	0.171
Market information	0.347**	0.138
Membership to cooperatives	0.015	0.116
Off/non-farm income activity	− 0.175	0.128
Log likelihood function	− 289.253	

***, **Show significance at 1% and 5%, respectively

under the existing practices there is a room to increase red pepper yield following the best-practiced farms in the study area. This study is in line with Tigabu (2016).

3.3 Determinants of technical inefficiency of red pepper producers

After measuring the level of technical efficiency and having information about the existence of technical inefficiency, it is essential to identify sources of technical inefficiency. The maximum likelihood estimates of stochastic frontier model showed that among 14 variables used in the analysis age, education status, land size, land fragmentation, extension service, credit access and market information were found to be statistically and significantly affect the level of TE of red pepper farmers (Table 4).

Age of household head (which is a proxy variable for experience) had statistically significant and positive relationship with technical efficiency of red pepper production at 1% of level of significance. The result revealed that as the age of farmer's increases, their level of technical efficiency increases. This may be because farmers become more expert in different agronomic practices as they become experienced in red pepper production. This study is in line with Mesay et al. (2013), Solomon (2014) and Zinabu (2016).

Education status of household head (which is a proxy variable for managerial ability of the farmer) had statistically significant and positive relationship with technical efficiency of red pepper production at 1% level of significance. The result indicated that literate farmers had higher technical efficiency in red pepper production than those illiterate farmers. This is due to the fact that education increases the farmers' ability to utilize existing technologies and attain higher efficiency level. This result is in line with the findings of Amadou (2007), Bamlaku et al. (2007), Solomon (2014), Wondimu (2014) and Zinabu (2016).

Land holding of household head cultivated for red pepper production had statistically significant and negative relationship with technical efficiency of red pepper production at 1% level of significance. The result indicated that the size of land cultivated by red pepper farmers increases; technical efficiency level of red pepper production decreases. This can be explained by the fact that increased farm size diminishes the appropriateness (timeliness) of input use leading to decline in technical efficiency. Or as the farm size increases the managing ability of the farmer decreases given the level of technology which adversely affects technical efficiency. In other words, it might be due to the fact that farmers have limited supply of labor especially during the peak time of red pepper transplantation and moreover red pepper is labor-intensive crop (this lead to poor management with increase in farm size). Availability of large amount of timely financial resources at large farms could be another constraint; therefore, big farm size is finally resulting in higher technical inefficiency. This result is in line with the findings of Getachew and Bamlak (2014), Abedullah and Khalid (2007) and Aye and Mungatana (2010). On the other hand, Endrias et al. (2010) found a negative and statistically significant relationship between large land holding size and efficiency of crop production because large land holding farmers are more likely to employ modern agricultural practices and hence could be more efficient due to its advantage of the economic scale and scope associated with large farm size. Thus, this study contributes to the ongoing debate on the relationship between land size and efficiency by providing more results showing land holding size has a negative and significant effect on the efficiencies of red pepper production.

Land fragmentation represents the number of plots of land on which the farmer has grown red pepper during the production season in which this study was carried out. Fragmentation had statistically significant and positive relationship with technical efficiency of red pepper production at 1% level of significance. The result indicated that a farmer with more number of red pepper plots is more technical efficient than a farmer with less number of red pepper plots. The reason is perhaps as the number of plots operated by the farmer increases, the farmer will be able to distribute labor resources for different activities. Moreover, it might be used as one of the risk minimization strategies of farmers. Farmers may be benefited from fragmented red pepper plots in that different plots may represent the reduced risk that different plots provide if the plots are located sufficiently distributed, such that farmers face different degrees of weather-induced variations such as floods and mineral content on the different plots. This result is in line with the findings of Getachew and Bamlak (2014).

Extension service had statistically significant and negative relationship with technical efficiency of red pepper production at 1% level of significance. The result showed that farmers who got extension service was less technical efficient than those who did not have. The possible reason for this might be the first; the quality of extension service was poor. Particularly extension agents are actively involved in other political activities, besides their duty. The second reason might be because of problem of selection bias. Those farmers who need more extension support might be those who are inefficient in production of red pepper. The third reason may be because farmers not properly applied the service that they got or the service farmers got is not related to red pepper production. In other words, the extension service that farmers got may not fit the agro-ecological settings. Moreover, extension services in the study area have not been effective. This calls for the need for more effective policy support for extension services. Additional efforts need to be devoted to upgrade the skills and knowledge of the extension agents as well as ensuring timely dissemination of modern technological inputs and practices. The result of this study is similar with the findings of Jema (2007), Aye and Mungatana (2010) and Solomon (2014) they argued that unexpected result of extension contact was due to biasedness in extension program.

Credit access had a negative and statistically significant effect on technical efficiency of red pepper production at 1% level of significance. The result indicated that farmers who had access to credit are less technical efficient than those who did not have. This is may be due to the reason that farmers spend the accessed credit for consumption expenditure rather than purchasing inputs for red pepper production. In other words, farmers may use the loan for unintended purposes such as consumption smoothing rather than purchasing agricultural inputs for red pepper production.

Access to market information had statistically significant and negative relationship with technical efficiency at 1% level of significance. The result showed that farmers who had access to market information had less technical efficiency than who had not access to market information. This is may be because the information distribution for farmers was not timely available.

4 Conclusions and recommendations

There are a number of studies that have done with technical efficiency of farmers in developing countries. However, to the best of the authors' knowledge, not much studies were undertaken on technical efficiency of red pepper producing farmers in the study area. Therefore, this study was conducted to estimate technical efficiency and identify factors affecting technical efficiency among red pepper producer farmers in North Gondar zone, Amhara regional state, Ethiopia.

From the stochastic frontier analysis, results of this study confirmed that there is a room to enhance production and productivity by improving the technical efficiency of red pepper production, given same level of input and current technology. The maximum likelihood estimates of stochastic frontier model indicate that land, seed, chemical, oxen and labor had a positive and significant effect on the level of red pepper production. Hence, the increase in these inputs would increase production of red pepper. On the top of these, the maximum likelihood estimates of stochastic frontier model showed age, education status and land fragmentation were found to significantly and positively affect the level of TE of red pepper producer farmers while land size extension service credit access and market information were found to significantly and negatively affect the level of TE of red pepper producer farmers. Investment on education should be considered as a central ingredient in development strategy to achieve improved agricultural productivity. Besides to this, future endeavors may need to look into mechanisms by which farmers can get access to better ways of farming through extension services and improve market information. In a nutshell, this study indicates that improving farm household technical efficiency brings substantial productivity. Therefore, the existing level of inefficiency in red pepper production is high and this calls for better attention of policy makers and researchers in tackling the sources of these inefficiencies to improve the welfare of red pepper producing farmers.

Abbreviations

ADLI: agricultural development-led industrialization; BoFED: Bureau of Finance and Economic Development; CC: contingency coefficient; CSA: central statics agency; EEPA: ethiopian export promotion agency; FAO: food and agriculture organization; GDP: gross domestic product; GTP-I: growth and transformation plan-I; LH0: log likelihood ratio of null hypothesis; LH1: log likelihood ratio of alternative hypothesis; LR: log likelihood ratio; ML: maximum likelihood; OLS: ordinary least square; SFM: stochastic frontier model; SNNPRS: south nation nationality and people regional state; SPF: stochastic production frontier; TE: technical efficiency; UNDP: United Nation Development Program; VIF: variance inflation factor; WFP: World Food Programme.

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Authors' contributions

TMA, ABD and TMM were carried out "Technical Efficiency of Smallholder Farmers in Red Pepper Production in North Gondar Zone Amhara Regional State, Ethiopia" study, participated in proposal development, data collection and drafted manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

The authors want to declare that they can submit the data at any time based on publisher's request. The datasets used and/or analyzed during the current study were available from the authors on reasonable request.

Ethical approval and consent to participate

Ethical clearance letters were collected from University of Gondar research and community service directorate and Dera District of face to care for both the study participants and the researchers. During survey, official letters were written for each kebele/villages, informed verbal consent was obtained from each client, and confidentiality was maintained by giving codes for each respondent rather than recording their name. Study participants were informed that clients have a full right to discontinue or refuse to participate in the study. Hence, all participants throughout the research, including survey households, enumerators, the supervisors and key informants were fully informed of the objectives of the study. They were approached friendly in free moods until they do this research.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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