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Analysis of Technical Efficiency of Smallholder Irrigated Cotton Producers in Middle Awash Valley, Northeastern Ethiopia

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ABSTRACT

This study assesses the level of technical efficiency and its determinants of smallholder irrigated cotton farmers in the Middle Awash Valley of Northeastern Ethiopia. A multi stage purposive random sampling procedure was employed to select 74 irrigated cotton farmers from Amibara district of Afar region. A well-structured questionnaire and field observations were employed to collect relevant information from respondents. Data collected were analyzed using relevant econometric techniques. The results from stochastic frontier analysis indicated that elasticities of mean output for cotton area, labor cost, and irrigation frequency were positive while those of seed and pesticide costs were negative. The joint effects of socioeconomic and farm specific variables influenced technical efficiency but individual effects of some variables were not significant. Mean technical efficiency level of irrigated cotton farmers was estimated to be 71%; indicating that the possibility of increasing cotton production in the valley given the current state of technology and inputs level. Further, the empirical results from the inefficiency effect model revealed that cotton farming experience, extension service, credit access, tenancy status, salinity level, distance to main water canal and sowing time were found to be major determinants of farmers' technical efficiency in the study area. The study recommends that government efforts are of vital in increasing cotton yield through improvement in technical efficiency

by ensuring timely and adequate availability of the required inputs as well as adequate provision of credit facilities and promotion of research findings through extension services.

Keywords: Stochastic Frontier Analysis, Technical efficiency, **I**rrigated cotton farmers, Middle Awash Valley, Northeastern Ethiopia.

INTRODUCTION

Agriculture has consistently been the backbone and center to economic activities in Ethiopia. It contributes about 36% of the country's Gross Domestic Product (GDP), 73% of employment and 70% of export earnings (Getachew *et al*., 2018, NBE, 2018) as well as important providers of raw materials (inputs) for other production activities, especially the manufacturing sector. Moreover, the government development policies propose agriculture to be the main source of capital to be accumulated for the process of establishing future industrialized Ethiopia, which again shows the importance of the sector in bringing about sustainable economic development for the country in the years to come. Thus, the growth of all other sectors of the economy in the country is by and large depend on the growth and development of the agricultural sector. However, the challenge facing the sector is not only to feed the ever-increasing population but also commensurately to create employment opportunities as well as leading the process of structural transformation of the country's economy.

In this context, the Government of Ethiopia (GOE) has intended to make the textile and garment industry as one of the economic engines that will prop growth since it has the potential not only transforming Ethiopia's agrarian economy into an industrial one but also creating massive employment both at farm and off farm. Consequently, the cotton crop, which is the major supplier of raw materials, is becoming one of the strategic cash crops central to the development of textile and garment industries. In Ethiopia, cotton has gained much significance because it served the dual purpose of providing raw materials to the burgeoning apparel and textile industry as well as creating massive employment opportunities along the value chain of the crop, which encompasses cotton growing, ginning, spinning, yarn dyeing, weaving, and knitting, as well as confection and garment finishing. Besides, in the sector, there are ginneries, yarn producing companies, garment factories and cottage industries that involve large numbers of workers. Moreover, about 85% rural population meets a significant part of its textile needs from cotton.

Ethiopia has a long tradition of cultivating cotton and the crop is growing in many parts of the country. Almost all regions of the country except Harari region have favorable environmental conditions suitable for the cultivation of cotton both under rainfed and irrigation conditions. Different estimates have showed that Ethiopia has 2.6 to 3 million hectares of land suitable for cotton cultivation. Areas, such as Omo-Ghibe, Wabi Shebele, Awash, Baro-Akobo, Blue Nile, and Tekezze river basins lie within the optimal altitude range for growing cotton; between 300 meters and 1,400 meters above sea level.

Even though Ethiopia has ideal conditions for growing cotton and a significant amount of land potentially suitable for its production, the cotton sector and its related industry has failed to reach its potential, in terms of yields, marketing, processing and improvement of livelihoods involved in the cotton value chain. Cotton production in Ethiopia has consistently fallen below domestic demand from textile and apparel sector, thus resulting in a deficit, which is often catered for through importation. The current seed cotton production level of the country still explains neither the cotton sub-sector's potential nor the satisfying of domestic-industry's demand and yield obtained per hectare in Ethiopia is far less than the other countries.

Production and productivity of cotton vary considerably from farm to farm. Productivity of commercial varieties under research managed condition is about 3.5 to 4 tons per hectare. The same varieties yield 2-3 and 1-1.2 tons per hectare in irrigated and rain grown commercial farms, respectively. The yield under farmers' production systems is far below and approximates about 0.3-0.7 tons per hectare while the national average is 1.36 tons per hectare. Likewise, low productivity of 812 kg/ha, of seed cotton has been reported for the Metema District of Ethiopia. So, there is a wide gap between the attainable and actual yield of seed cotton among producers. This means that existing technologies possess the needed capability to increase the seed cotton yield. The gap between commercial farm yield and the national average yield represents the untapped yield reservoir existing at the current level of technology and the availability of appropriate technologies best suited to the production systems. The smallholder farmers, although participate in large number in cotton production, contribute 24 percent of the total cotton production.

To increase farmers' productivity, the focus is usually on whether farmers are using better and improved technologies. It is, however, necessary to investigate whether these farmers are even making maximum use of what is available to them in terms of inputs. Therefore, to increase cotton productivity, there is a need to understand the efficiency of production, since increasing productivity is directly related to production efficiency. Hence, it is necessary to raise the productivity of farmers by helping them to reduce their inefficiency.

Improving agricultural productivity among cotton farmers has a multiplier effect on the sector. It is likely to improve income of cotton farmers and subsequently help to reduce poverty. It can also improve the profitability of lint production among ginning companies and consequently improve revenue contribution to the national economy. Therefore, improving technical efficiency (TE) of cotton farmers is a key step if the objectives of the national cotton development strategy (NCDS, 2017) of making Ethiopia one of the world top producers of sustainable quality cotton by 2032. This can be achieved through increasing cotton production, on the one side, and through investing in the textile and apparel domains to transform Ethiopia's agrarian economy into an industrial one and to create employment opportunities, on the other side. Achieving these are critical in making the Ethiopian cotton sector competitive in the international market are realistic. Given the importance of cotton and the opportunities arising in the cotton industry, it is expected that cotton is likely to take center stage as strategic cash crop; it is thus vital that policy makers, researchers and other actors of the value chain understand the efficiency of cotton production.

The increase in population and expansion of industrialization are the main reasons for increase in demand for cotton fabric and this has pushed cotton producing countries including Ethiopia to meet the increased demand. To meet this ever-increasing demand for cotton, boosting production and productivity is of utmost important. Notwithstanding the indispensable role of the cotton sector in enhancing economic transformation and poverty reduction strategies, previously no study was conducted to estimate efficiency of cotton in Ethiopia. Majority of empirical efficiency studies were geared towards other food crops. Overtime, cotton-related researches have focused on the agronomic and/or breeding aspects, much to the exclusion of other important aspects of cotton production along the value chain such as resource use efficiency and enterprise profitability. This study is, therefore, undertaken in the Middle Awash Valley, representing the major irrigated cotton producing areas, of Ethiopia with the objectives of assessing the level of technical efficiency and identifying sources of inefficiency among smallholder irrigated cotton producers.

MATERIALS AND METHODS

The study area

The study was conducted at Amibara district of the Middle Awash Valley, which stretches between the towns of Awash and Gewane. Geographically located between 9°12'8" to 9°27'46" North latitude and 40°5'41" to 40°15'21" East longitude. The climate of the area is characterized as semi-arid bimodal (long and short rainy seasons) rainfall of about 533mm annually. The long rainy season occurs from July to September with 49% of the total rain. The short rainy season extends from February to April and accounts about 29% of the total rain. The mean minimum temperature of the area is 115.2°c in December and 23°c in June, while the mean maximum temperature is about 32.5°c in December and 38°c in June.

The study area represents one of the major irrigated cotton growing areas of the country. Cotton produced in this valley is of high quality given the suitable climatic condition and access of irrigation water (Awash River). Besides cotton, the study area is suitable for the cultivation of maize, wheat, onion, tomato and sugarcane.

Sampling technique and data sources

The sampling frame/the population/ of this study was all farmers who produced cotton under irrigation in Amibara district. Multi-stage sampling technique was used in selecting respondents for this study. The first stage involved the purposive selection of Amibara district based on the volume of cotton cultivation and the availability of well-established irrigation scheme to aid regular supply of water for crop production. At the second stage, four local *kebeles* were purposively sampled based on the intensity of cotton cultivation (*Badhamo*, *Bonta*, *Waydulalie* and *Bedulalie*). In the third stage, with the help of Agricultural Extension Agents, taking list of cotton farmers at each *kebele*, random sampling technique was used to select farmers from the *kebele*. A total of 74 cotton farmers were sampled.

The primary data for this study were collected using structured questionnaires administered through face-to-face interview with the sampled farmers. Observations and key informant interviews were also employed in collecting data.

Analysis techniques

Descriptive and econometric statistical analyses were employed to analyze the primary data collected from the field survey. Descriptive statistics such as frequency distribution, mean, percentage, and standard deviation were used describe the socio-economic and farm specific characteristics of the farmers obtained from field data. Moreover, the study adopted the parametric methodology (econometric model), stochastic frontier analysis (SFA) approach to estimate the production function, determine the sources of inefficiency and to estimate the level of technical efficiency. Moreover, maximum likelihood estimation (MLE) technique was employed as the estimation procedure. Though there exist different methods to estimate maximum likelihood estimation, this study used STATA version 14 for the maximum likelihood estimation.

The stochastic frontier analysis

In stochastic frontier analysis, the farm is constrained to produce at or below the deterministic production frontier. The approach is preferred for efficiency studies in agricultural production due to the inherent stochastic nature of the agricultural systems. The stochastic frontier production function was first independently proposed. A stochastic frontier production function comprises a production function of the usual regression type with a composed disturbance term equal to the sum of two error components. One error component represents the effects of statistical and random noise (example weather, measurement error, etc.) the other is attributed to technical inefficiency. The major advantage of the stochastic frontier production function model is the introduction of disturbance term representing noise, measurement error and exogenous factors beyond the control of the production unit, in addition to the inefficiency component.

Following the model proposed general stochastic frontier production function can be expressed as:

$$Y_i = f(X_i, \beta) + \varepsilon_i = \exp(X_i\beta + \varepsilon_i) \quad (1)$$

Where i= 1, 2..., n

Y_i = output level of the i^{th} sample farm

f (χ_i, β) = a suitable function such as Cobb-Douglas or transcendental (translog) production functions

χ_i = vector of inputs

β = vector of unknown parameter to be estimated

ε_i = the double component error term ($\varepsilon_i = V_i - U_i$), where v_i is assumed to account for random effects on production associated with factors such as measurement errors in production and other factors which the farmer does not have control over and u_i is a nonnegative error term associated with farm-specific factors, which leads to the i^{th} farm not attaining maximum efficiency of production. Thus, u_i measure$_s$ the technical inefficiency effects that falls within the control of the decision-making unit.

Stochastic frontier approach specifies technical efficiency of an individual farm as the ratio of the observed output to the corresponding frontier output given the level of inputs and technology used by the farm. The technical efficiency (TE) of the ith farm, defined relative to the estimated frontier output of an efficient farm using the same set of inputs, can be specified as

$$TE_i = \frac{Y_i}{Y_i^*} = \frac{f(X_i;\beta)\exp(V_{i-U_i})}{f(X_i;\beta)\,expV_i} = \exp(-U_i) = \exp(-Z_i\delta - w_i) \qquad (2)$$

Where Y_i is the actual (observed) yield obtained by a sampled farmed and Y^* is the maximum (unobserved) possible yield.

According to Battese and Coeli (1995), the error term V_i is assumed to be identically, independently and normally distributed with zero mean and a constant variance, $N(0,\sigma_v^2)$. The error term U_i is also assumed to be distributed as truncation of the normal distribution with mean U_i and variance $N(U_i,\sigma_u^2)$ such that inefficiency error term can be explained by exogenous variables as

$$U_i = Zi\delta + w_i \qquad (3)$$

Where Z_i is a vector of explanatory variables δ_i is a vector of unknown parameters to be estimated and W_i is unobservable random variable defined by the truncation of normal distribution with a mean of zero and a variance δ^2.

In this study, a single stage maximum likelihood approach was used to estimate technical efficiency level of irrigated cotton farmers and the determinants of technical inefficiency simultaneously. This simultaneous estimation approach ensures that the assumption of identical distribution of the error term U_i is not violated. The maximum likelihood estimates of the stochastic frontier model provide the estimates of β and the gamma (γ), where the gamma explains the variation of the total output from the frontier output. The gamma estimate is specified as;

$$\gamma = {\delta_u^2}/{\delta^2} \qquad (4)$$

where γ has a value between zero and one, δ_u^2 is variance of the error term associated with inefficiency and δ^2 is the overall variation in the model specified as the sum of variance associated with inefficiency and that associated with random noise factors. Thus;

$$\delta^2 = \delta_u^2 + \delta_v^2 \qquad (5)$$

The closer the value of the gamma (γ) to one, the more the deviation of the observed output from the deterministic output, which is as the result of inefficiency factors. However, if the value is closer to zero, then the deviations are as a result of random factors. And if the value lies between one and zero, then deviations are as a result of both inefficiency and random factors.

Empirical model

In stochastic frontier model, the two most important functional forms widely used are Cobb-Douglas and Translog production functions. Though both functional forms have their own strengths and short-comings, Cobb-Douglas production function was employed in this study for simplicity related to cotton production. The Cobb-Douglas has been widely used in efficiency studies on the agricultural sector of developed and developing countries, and especially on cotton (Chakraborty *et al*., 2002; Gebremedhin *et al*., 2009; Mal *et al*., 2011). The Cobb-Douglas stochastic frontier model is written as;

$$lnY_i = \beta_0 + \sum_{j=1}^{m} \beta_j \, lnX_{ji} + V_i - U_i \quad (6)$$

The model of technical inefficiency effects on the stochastic frontier equation (6), including socio-economic and farm specific factors, is given by:

$$U_i = \delta_0 + \sum_{j=1}^{n} \delta_j Z_{ji} + w_i \quad (7)$$

Descriptions of variables used in the model

The description of output, input and inefficiency variables used in the model and their priori expectation. In regression, all the independent variables for frontier model are in logarithm form along with dependent variable, whereas, variables in the TE model are in absolute values. The dependent variable, Y_i, is the seed-cotton production in Kg for the $_i$-th farm. The independent variables for frontier model are defined as X_{1i} to X_{7i} as follows: X_{1i} indicates the natural logarithm of irrigated cotton cultivated area in hectares, X_{2i} is the amount of cotton seed used (Kg) (Table 1).

Variables	**Coding system**	**Category**	**Expected sign**
lnX_{1i} = Cultivated cotton area	Hectares	Continuous	+
lmX_{2i} = Quantity of cotton seed	Kg	Continuous	+
lnX_{3i} = Quantity of fertilizer	Kg	Continuous	+
lnX_{4i} = Pesticide costs	Birr	Continuous	+
lnX_{5i} = Labor costs	Birr	Continuous	-
lnX_{6i} = Machinery cost	Birr	Continuous	-
lnX_{7i} = Irrigation frequency	Number of irrigations	Continuous	+/-
Z_{1i} = Age of household head	Number of years	Continuous	+/-
Z_{2i} = Education level	1= literate, 0= otherwise	Dummy	+

Z_{3i} = Cotton farming experience	Number of years	Continuous	+
Z_{4i} = Extension access	1= yes, 0= otherwise	Dummy	+
Z_{5i} = Access to credit	1= yes, 0= otherwise	Dummy	+
Z_{6i} = Off farm activities	1= yes, 0= otherwise	Dummy	+/-
Z_{7i} = Tenancy system of farmland	1= lessee/rented, 0= owner	Dummy	-
Z_{8i} = Salinity status of the farmland	1= saline, 0= otherwise	Dummy	-
Z_{9i} = Distance to water cannel	Kilometers	Continuous	-
Z_{10i} = Time of planting	1=Mid-April to Mid- May, 0= otherwise	Dummy	+

Table 1: Definition of variables used in the model.

X_{3i} and X_{4i} show monetary values of fertilizers and pesticides costs respectively. X_{5i} is the cost of hired labor, which is measured in terms of monetary value due to unavailability of person-days data because of hiring labor on contract basis. The labor cost used in this study is the aggregate costs of all manually operated activities in the cotton production process. X_{6i} represents machinery operated costs, it was also measured as monetary value of working hours for ploughing, leveling and ridging. X_{7i} shows the number of irrigations applied to cotton area of production.

The variables for the model of technical inefficiency effects are represented from Z_{1i} to Z_{10i}. Z_{1i} shows the age (in numbers) of household head. Z_{2i} is a dummy variable indicating the level of education of household head (if the farmer is literate, then it has the value of one, zero otherwise). Z_{3i} represents cotton farming experience in years. Z_{4i} represents a dummy variable for the contact of extension for cotton crop (it has taken a value one if the farmer has access to extension and zero otherwise). Z_{5i} and Z_{6i} are dummy variables indicating access of credit service and participation in off-farm activity respectively. The dummy variables, Z_{7i} and Z_{8i}, are introduced in the inefficiency effect mode to determine the impacts of tenancy and soil quality of the cotton farmland on technical efficiency respectively. Z_{9i} represents the variable for the distance (km) from the farmland to the main irrigation canal (the main water source), while, Z_{10i} represents a dummy variable for timely sowing.

RESULTS AND DISCUSSION

Descriptive Statistics

The general characteristics of household respondents of irrigated cotton farmers in the study area are presented in the subsequent tables. These results refer to the descriptive analysis of the demographic and socio-economic characteristics of sampled households shows the demographic characteristics of irrigated cotton farmers in the study area. The table comprises gender, age, level of education of the household heads and total number of family members in the household. The table revealed that in all the villages, cotton production is dominated by male farmers who compromised about 95% of the sampled respondents as against their female (5%) counterparts; this may be explained by socio-cultural factors, but not as the result of technical inefficiency. Most irrigated cotton farmers are (64%) below the age of 41 years with the mean age of 39 years. This implies that irrigated cotton farming is mainly practiced by younger farmers. The preponderance of young farmers in the cotton farming profession mean that their productivity is expected to be high as they are active and energetic. Education is thought to make the farmer more skilled and efficient. Therefore, literacy level was asked from the selected cotton farmers in the study area. The study shows that 30% of the respondents have had formal education ranging from primary to secondary and above, 46% of the respondents can at least read and write, whilst 24% of the cotton farmers were illiterate (Table 2).

Variable	Group	Frequency	Percentage
	Male	70	94.59
Gender	Female	4	5.41
	20-40	47	63.51
Age	41-60	25	33.78
	≥ 61	2	2.7
	Illiterate	18	24.32
Level of education	Informal	34	45.95
	Primary	10	13.51
	Secondary and above	12	16.22
	1-5	23	31.08
Household size	6-10	49	66.22
	≥ 11	2	2.7

Table 2: Demographic characteristics of respondents.

In terms of household size, 31% of the selected cotton growers had 1-5 family members, 62% had 6-10 family members. It was a minority (3%) of the households who had 11 family members or more. However, the mean family size was 6.82 members ranged from 1 to 13 members.

Table 3 describes some of the socio-economic and farm characteristics of cotton growers in the study area. In this study, experience comprises knowledge or skills gained through involvement in cotton farming only. The result in shows that 93% of the respondents belonged to more than 5 years of experience in producing irrigated cotton, while 7% of the respondents belonged to 1-5 years of cotton farming experience in the study area. In terms of the farmland size, the table showed that the majority (98.64%) of the cotton farmers have had less than 5 hectares of land, while only 1.36% owned a farmland of more than 5 hectares.

As of the constitutional law, the land within the Amibara Irrigation Scheme is owned by the state. However, after abolishing of the state farms, the land around the irrigation scheme was reallocated to farmers through their respective clans. The reapportioned plots become the permanent properties of the various clans and farm families. When the clan or farmer do not intent his plot for a particular year, he often leases it for a prospective user. Interaction with the farmers during the survey revealed that the status of land ownership in cotton production in the study area is of two types i.e., landowners and lessee/rent. Inferring from Table 3, it could be deduced that 55% of the cotton growers acquired land for irrigation farms through ownership while 45% of the cotton growers obtained land through rent. The table also revealed that 54% of the farmers who cultivate cotton have involved in other income generating activities to subsidies both cotton farming and their livelihoods (Table 3).

Variable	**Category**	**Frequency**	**Percentage**
Cotton farming experience	44317	5	6.76
	44475	46	62.16
	≥ 11	23	31.08
Farmland size	0.5-2.0	55	74.32
	2.1-5.0	18	24.32
	≥ 5.1	1	1.35
Off-farm activities	Yes	40	54.05
	No	34	45.95
Land tenure system	Owner	41	55.41
	Lessee/rent	33	44.59
Farmland quality	Saline	39	52.7
	Non-saline	35	47.3
Extension contacts	Yes	5	6.76
	No	69	93.24
Source of capital	Own	6	8.11
	Investors	50	67.57
	Relatives	18	24.32
Source of seed	Research center	10	13.51
	Ginnery	17	22.97
	Investors	47	63.51
Cotton varieties planted	DP-90	66	89.19
	Stam	4	5.41
	Unknown	4	5.41

Table 3: Farm characteristics of sample respondents.

Farmers were also asked about their farmland condition in terms of salinity status. Accordingly, 53% of the respondents had reported that their farmland is affected by any form of salinity.

The accessibility factors like extension services, credit facilities and sources of cotton seed varieties of the respondents are assumed to play vital roles in increasing production and productivity of cotton. Extension education has the potential to increase farmers managerial skills which will help them combine productive inputs appropriately and also ensure the execution of agronomic practices appropriately presents farmer’s access to extension services, credit facilities and availability of cotton seed sources in the study area. As of the results of the table (Table 3), only 7% of the respondents had received extension services regarding cotton production in the study area. This implies how the cotton crop is neglected by the public extension service. Similarly, only 8% of the growers have reported to cover all the operational costs by themselves. The majority (92%) of the producers have almost no access to farm credit. They can only borrow from their relatives or from investors at a very high interest rate. This, therefore, suggests that, most of smallholder cotton farmers might lack the proper managerial knowledge and skills as well as essential resources to efficiently carry out production activities to optimize yield.

The table (Table 3) also reveals the various sources of seed supply for planting. It is observed that 64% of respondents obtain their cotton seed from private investors, 14% got from research center while 23% got their seeds from the private ginnery found at their vicinity. As a smallholder producer, no one has reported the use of seeds from previous production. The result in Table 4 shown that the most popular commercial cotton variety grown by the farmers in the study area is DP-90 planted by 89% of the studied farms. The remaining 5% of the cotton land was covered by the variety called 'Stam' while 5% of the cotton farms were reported covered by unknown cotton varieties. The implication of the above results is that cotton farmers in the study area are using an old and obsolete cotton varieties.

The mean, standard deviation, minimum and maximum values of input, output and other variables involved in the stochastic frontier production function (SFP) as well as inefficiency effect model are presented in (Table 4).

Variables	**Mean**	**SD**	**Minimum**	**Maximum**
Output (Kg)	4455.41	3785.7	1100	200000
Cotton area (Ha)	1.89	1.29	0.5	7
Cotton seed (Kg)	56.35	35.87	15	225
Fertilizer (Kg)	26.68	35.68	0	150
Pesticides (Birr)	10775.49	8280.24	15500	49000
Manual labor (Birr)	22680.29	17367.27	5300	104730
Machinery operation (Birr)	10603.38	7493.53	2725	42700
Irrigation (Frequency)	8.2	1.2	7	12
Distance to water cannel (Km)	0.48	0.19	0.2	0.9

Table 4: Summary statistics of input, output and other variables.

Irrigated cotton farmers in the study area harvested, on average, about 4,455 kg of seed cotton yield with standard deviation of 3,786, indicating that there was high variability in the average productivity of irrigated cotton among farmers in the study area. The mean size of land used for the production of cotton was 1.89 hectare. The average seed quantity used by the sample farmers was 56.35 kilogram with a minimum of 15 kg and a maximum of 225 kg. In the production process, on average, 27 kilograms of urea fertilizer was used with high standard deviation of 36 showing the high variability of the variable. The average cost of pesticides was Birr 10,776 while for that of manual labor cost and machinery operation costs were Birr 22,680 and 10,603, respectively. The results of the descriptive statistics from the table also revealed that on average producers applied irrigation water 8 times from sowing to physiological maturity of the crop. Meanwhile, the irrigation water has traveled about 0.5 kilometer to reach to the cotton farmland.

Econometric Results

Choice of function form plays an important role in the empirical studies and could significantly affect results of the model. In spite of strong weakness, due to its easiness in estimation and interpretation Cobb Douglas type of production function has been employed in this study. Generalized likelihood ratio statistics has been carried out for possibility of existence of technical inefficiency. In the stochastic model, the sign of coefficient directly shows the direction of the effect. On the other hand, the sign and coefficients in the technical inefficiency model are interpreted in opposite way such that a negative sign decrease inefficiency and positive sign increase inefficiency.

Stochastic frontier production analysis

Table 5 presents the maximum likelihood estimates (MLE) of the stochastic production frontier model and inefficiency effects model. The results of MLE indicated that gamma (γ), which is the ratio of the variance of technical inefficiency effects (u_i) to the variance of random errors (v_i) has a coefficient of 0.83 and significantly different from zero, hence assuring the stochastic nature of the production function. These results indicate that about 83% of variation in cotton output is attributable to differences in technical efficiencies among smallholder irrigated cotton farmers, while the random effect was only 17% attributes to variation in cotton output among smallholder irrigated cotton farmers in the study area. The results further showed that 11 out of 17 parameters estimated in the model were found to be statistically significant.

The Cobb-Douglas production function parameters can be interpreted directly as output elasticities. The maximum likelihood estimates results showed that all the input parameters, except amount of fertilizer used and land preparation cost, were found statistically significant, which implies that these inputs are playing a major role in cotton production (Table 5). There exists positive relationship between input variables of cotton area (ha), labor cost (ETH Birr), and irrigation frequency (number) with output (seed-cotton yield in kg) variable. On the other hand, cotton seed (Kg) and crop protection costs (ETH Birr) have negative relationship with output variable.

The area under cotton cultivation had a coefficient estimated to be positive (0.090) that met the priori expectation and statistically significant (at 5% level) indicating that a 1% increase in area under cotton cultivation would lead to an increase (0.10%) in cotton output. These results appear to agree with the findings of Veronique and Renata (2014); Ahmad and Afzal (2012); Awal (2016) and Fok. (2008).

Given other factors, seed rate determines the plant population in a field of certain crop and thus, is an important factor in determining yield. The maximum likelihood estimates of stochastic frontier production model revealed that coefficient of seed rate (amount of seed used) had a negative sign with a value of -0.240 and was significantly significant at 5% level; showing that it is contributing negatively to cotton output. The implication is that farmers in the study area sow higher than the recommended rate for cotton. Negative coefficient of seed rate also implies that farmers use poor quality of seeds which have low germination percentage that ultimately results in low crop production.

Hence, there is a need to teach farmers to use the recommended amount of seed rate and pure seed sources. The results are in line with the studies of Ahmad and Afzal (2012) and Suleiman and Ibrahim (2014).

The production of conventional cotton requires excessive use of inputs in the form of pesticides, fertilizers and irrigation. In Middle Awash Valley, the study area, herbicide use is not common and fertilizers use is still below average. Likewise, no defoliants are used as the produce is picked manually. Hence, pesticide refers to insecticides only in this study. The coefficient for pesticide costs was negative and significant at 1% level with a value of -2.087. The incidence of pests on cotton crop is a growing problem in all cotton growing areas of Ethiopia and adoption of chemical control methods are increasingly becoming popular among the cotton growers and thus, the irrational use of insecticide is extremely high. This indicates that farmers are not applying insecticides efficiently in cotton production. The implication is that seed-cotton yield appears to decline in response to expenditures on plant protection measures (insecticide costs). Growers are spending too much and perhaps using too much insecticide each time they spray. The negative sign for elasticity of pesticide cost could be attributed to more use of different types of pesticides due to the fact that quality and efficacy of chemicals would not be fit for controlling pests in the study area (Table 5).

Variables	**Parameters**	**Coefficient**	**Std. Error**	**t-value**
Stochastic production frontier				
Constant	β_0	-19.491	4.154	-4.69
Ln Cultivated cotton area	β_1	0.09	0.045	1.98**
Ln Cotton seed quantity	β_2	-0.24	0.031	-7.82**
Ln Fertilizer quantity	β_3	0.004	0.01	0.39
Ln Pesticides cost	β_4	-2.087	0.492	-4.24***
Ln Manual labor cost	β_5	0.946	0.097	9.75***
Ln Machinery operation cost	β_6	0.266	0.22	1.21
Ln Irrigation frequency	β_7	0.024	0.014	1.74*

Inefficiency effect				
Constant	δ_0	-5.972	2.686	-2.22
Age of the farmer	δ_1	0.06	0.064	0.94
Educational level	δ_2	-0.049	0.066	-0.74
Cotton farming experience	δ_3	-0.025	0.009	-2.720***
Extension access	δ_4	0.295	0.121	2.430**
Access to credit	δ_5	-0.024	0.009	-2.620***
Off-farm activities	δ_6	-0.003	0.003	-0.98
Tenancy status	δ_7	0.161	0.081	2.000**
Salinity level	δ_8	0.255	0.054	4.750***
Distance to main water canal	δ_9	0.298	0.128	2.320**
Time of planting	δ_{10}	-0.097	0.067	-1.45
Variance parameters				
Sigma square	δ^2	0.2945	0.0917	3.24***
Gamma	γ	0.831	0.3938	2.11**
Log likelihood function		39.5092		
Likelihood ratio	LR= 18.58***			

Table 5: Maximum likelihood estimates of Stochastic Frontier Production model.

On the other hand, proliferation of substandard insecticides in the market, aggressive marketing by pesticide companies, and the limited knowledge of the farming households about pest control methods and practices as well as over reliance on chemicals and indiscriminate use of pesticides have led to inefficient use and high cost. Thus, ensuring pesticide quality at the grass root level and reduce the application of pesticides is advisable to achieve effective pest control. These results agree with the findings by Swamy et al., (2013); Sekumade and Toluwase (2014) and Yenihebit *et al*., (2020). On the other hand, other researchers such as Ahmad and Afzal (2012), have documented positive and significant effect of plant protection expenditures on cotton yield.

Labor plays a very important role in cotton production. Most activities in the farm require the use of labor e.g., land cleaning, sowing, weeding, hoeing, irrigating, spraying, picking, etc. In this study, labor costs are considered as costs incurred for all manually operated activities practiced in cotton production process. Form the analysis, the coefficient for cost of labor was positive and statistically significant at 1% level, with value of 0.946, indicating that the cotton yield (output) increases by 0.95% as labor cost increased by 1%. The higher elasticity of labor is also an indication that cotton farming is a labor-intensive venture. Similar findings have been reported in Abid *et al.*, (2011a, 2011b) and Muhammad *et al.,* (2012) for cotton productivity.

Irrigation combined with integrated nutrient and pest management can trigger higher productivity and significantly affects crop production in areas where cultivation is totally accompanied by irrigation. Number of irrigation (irrigation frequency) variable has got coefficient of 0.024, which was statistically significant at 10% level of significance. A relative increase of 1% in number of irrigations causes a relative increase of 0.024% in yield (output) of cotton. Similar results have been found by Elgilany, A. *et al*. (2011).

Determinants of technical inefficiency

From the technical inefficiency effects model presented in Table 5, a negative coefficient implies an increase in the variable concerned would increase technical efficiency and productivity and vice versa. Results of the inefficiency effects model are quite interesting and attractive from policy making view point. Accordingly, ten variables were incorporated to ascertain determinants of technical inefficiency of irrigated cotton farmers. Out of these variables, six variables were found to be significantly different from zero. The results revealed that variables such as cotton farming experience and access to credit were found to be negatively related with inefficiency and statistically significant. Whereas, extension service for cotton, tenancy status, distance to main water canal and salinity level of the farm land were positively related with inefficiency and statistically significant. Thus, increase in these variables, reduced the technical inefficiency of the sample farms. These findings imply that farming experience, credit access, tenancy status, salinity level and distance to main water canal contribute substantially to increase technical efficiency in cotton production.

The coefficient for cotton farming experience with technical inefficiency was negatively signed and statistically significant at 1% level. The implication was that experience cotton farmers were more technically efficient than inexperienced ones. This is because farmers with many years of cotton farming experience are more likely to be familiar with the required skills needed for cotton production and therefore are more likely to have higher outputs and consequently more technically efficient. This agreed with the findings of Awal (2016).

The state-run agricultural extension service is still the most important player in terms of input delivery and technical advices to smallholder farmers in Ethiopia. Interestingly, the estimated coefficient for extension services on cotton crop was found to be positive and statistically significant at 5% level. This implies networks in the world but does not use it for cotton paradoxically. This could be taken as the hallmark of poor linkage between the research system and the producers in the cotton sector of the country. The findings relate to Musa *et al*., (2014) who also reported negative relationship between extension contact and technical efficiency of maize producers.

The effect of the dummy for credit access on technical inefficiency for irrigated cotton farmers in the sample was negative and is expected. The variable was statistically significant at 1% level. The implication is that farmers with access to credit are more technically efficient than farmers without credit access. This is because farmers, particularly the smallholders, do not have adequate savings to purchase farm inputs. Thus, they apply sub-optimal quantities of inputs and, quite often, fail to apply them in time. Lower does coupled with delayed application result in low farm output. Credit availability can enhance farmers' capacity to purchase farm inputs well in-time and ensure timely application in optimal does. It is all the most important for cotton where input costs are very high. This is consistent with the findings of Mohammad (2009) who found a negative relationship between access in credit and inefficiency in the cotton-wheat and rice-wheat systems in Pakistan. Similarly, Assefa (2011) and Dessale (2019) reported that credit of smallholders in Ethiopia.

Tenancy status (owner operated farms dummy) variable had positive estimate with coefficient of 0.161 and was statistically significant at 5% level therefore, decrease technical efficiency. It means that owners are less technically efficient than their renter counterparts in cotton production in the study area. The plausible reason for these findings would be that the owners of the land in the study area are Afars (native to the area) who are hitherto pastoralists and have little knowledge of farming activities.

Salinization is an acute problem in semi-arid area where this study was carried out. In irrigated cotton production system, soil salinization occurs as a consequence of limited drainage combined with the application of saline or sodic water. The sign of variable relating to salinity level of the soil (saline soil dummy) was positive, according to expectation, and found to be statistically significant at 1% level. The findings revealed that farmers who have a farm land affected by salinity had high level of inefficiency. Thus, the malfunctioning of the existing drainage system and the poor quality of the irrigation water exacerbated the salinization process and hence inefficiency in the study area. The other reason for salinization in the study area is associated with the type of irrigation application. In the study area, surface irrigation particularly furrow type of application is the most dominant practice used for decades by producers.

Distance of the farmland to the main irrigation water canal, which is directly related to access of the crop to irrigation water on time, had positive sign as expected. The coefficient for the distance from source of irrigation to a farm was found to be 0.298, which was statistically significant at 5% level. A unit increase on this variable decrease efficiency of cotton farmers by 0.298 unit. Thus, the farther the farm land from the main water canal, the lower the probability of the crop to be irrigated on time, which results in shortage of water to the cotton crop and in turn leads to inefficiency of farmers. As a technical fact, increasing the distance from source of irrigation to the farm will increase irrigation water loses due to the water percolation and evaporation.

Technical efficiency level of irrigated cotton farmers

The frequency distributions of the technical efficiency scores of smallholders irrigated cotton farmers are presented in Table 6. The predicted technical efficiency level ranged from 40% and 99.99%; indicating that technical efficiencies vary greatly among the cotton farmers in the study area. The mean technical efficiency was estimated to be 71%, which implies that the average cotton farmers in the study area produces about 71% of the potential output given the current technology and inputs level. That is, cotton farmers in the study area produce at a level below 29% of the frontier output. The findings of the study indicated that irrigated cotton farmers are not making right combination of available inputs and technologies to obtain maximum yield. Thus, in the short run, there is enough room for cotton farmers to increase their production by 29% by exploiting the available resources fully (Table 6).

TE scores	**Frequency**	**Percentage**
TE ≤ 0.50	8	10.81
0.51 ≤ TE ≤ 0.60	9	12.16
0.61 ≤ TE ≤ 0.70	18	24.32
0.71 ≤ TE ≤ 0.80	17	22.97
0.81 ≤ TE ≤ 1.00	22	29.73
Total	74	100
Mean		71.09
Min.		40.09
Max.		99.99
Standard Deviation		14.99

Table 6: Distribution of technical efficiency of irrigated cotton farmers.

These results are comparable with other technical efficiency studies on cotton sector. Using stochastic frontier analysis, Veronique and Renata (2014) calculated the average technical efficiency score of 80% for West African cotton producers. Using a non-parametric approach based on the assumption of constant and variable returns to scale, Gul et al., (2009) calculated an average technical efficiency scores of 72% and 89% for Turkish cotton farmers. Similarly, an average technical efficiency scores of 85% and 66% were estimated for non-Bt cotton producers in North India and South Africa, respectively (Thirtle *et al*., 2003; Mal *et al*., 2011). Furthermore, Awal (2016) analyzed technical efficiency of smallholder cotton farmers using stochastic frontier model in Ghana and had technical efficiency ranging from 16% to 98% with mean technical efficiency of 85%.

CONCLUSION

The study identified the main determinants and levels of smallholder irrigated cotton farmers' technical efficiency in the Middle Awash Valley of Ethiopia. Results of the Cobb-Douglas stochastic frontier production function and technical inefficiency effect models indicated that all key production factors except for fertilizer quantity and machinery operation costs were found important inputs contributing substantially to cotton output. Quantity of seed and pesticide costs have negative signs implying that these variables were decreasing cotton yield. However, all other significant variables including cotton area, labor cost and irrigation frequency, have positive effect on cotton output.

We also investigated the factors affecting technical inefficiency of irrigated cotton farmers. Results showed that cotton farming experience, access to credit and sowing time were reducing inefficiency. Whereas, extension services to cotton, tenancy status, salinity level of the cotton farm and distance from the main water canal were increasing inefficiency. On the other hand, age of household head, level of education and off-farm activities were found to be insignificant. The mean technical efficiency level was estimated to be 71%. This indicates that there is a possibility of increasing cotton productivity in the valley, given the current state of technology and input level. This can be achieved in the short run by increasing the technical efficiency level of the farmers by 29% through proper combination of inputs.

The results revealed that cotton growers in the study area have not been successful in employing best practice production methods and achieving the maximum possible output from existing technologies. Thus, increase in productivity must come from improvement in technical efficiency. This requires continuous government efforts in ensuring timely and adequate supply of required inputs, adequate provision of credit facilities, extension services and research works with effective quality control. The quality of water to be used for irrigation need to be regulated and proper drainage system has to come in effect in order to mitigate the salinization effect. The efforts of concerned bodies involved in the distribution and quality control of vital inputs need to be accentuated further. In the long run, there should be a type of irrigation system other than the surface irrigation that need to be offered as an alternative means so as enable to reduce salinization and enhance cotton productivity.

Finally, the current study mainly used cross-sectional data. It did not use farm-level panel data, as it was not available. Cross-sectional data is fraught with challenges such as inability to trace the dynamics of efficiency of farmers over a period. Besides, the study focused only irrigated cotton whereas rainfed cotton production is booming in the country. Thus, it is suggested that future researches could undertake efficiency analysis using farm-level panel data both at irrigation and rainfed conditions in order to be able to track the dynamics of cotton farmers' efficiency over time.

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