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EDITED BY
Denise Adelaide Gomes Elejalde,
Universidade Tecnológica Federal do Paraná
Pato Branco, Brazil

REVIEWED BY
Navjot Rana,
Lovely Professional University, India
Paulo André De Oliveira,
São Paulo State Technological College, Brazil

*CORRESPONDENCE
Kindye Ayen
ayenkindye19@gmail.com

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Technical and cost efficiency analysis of irrigated onion production insight from smallholders irrigated onion farmers in north East Amhara National Regional State, Ethiopia

Kindye Ayen[1]*, Tariku Kidane[2] and Adane Wubet[2]

[1]Adet Agricultural Research Center, BahirDar, Ethiopia, [2]Sekota Dry-Land Agricultural Research Center, Sekota, Ethiopia

Introduction: Onions are an imperative root crop that can be grown both under irrigation and rain-fed conditions. It is considered a complementary product to tomatoes and is a globally commercial crop. Onions are a popular crop in Ethiopia for human consumption and export.

Methods: For this study, 150 smallholder producers were surveyed to collect cross-sectional data. A single-step Cobb–Douglas stochastic frontier model was used to estimate both the technical and cost efficiency of irrigated onion production.

Results: The results from the maximum likelihood stochastic frontier model result indicated that the technical efficiency in onions was influenced by the age of the household head, slope of the land, number of extension contacts with development agents, distance from the sampled respondent's residence to the office of the kebele agriculture office, and the number of oxen owned by the sampled households. Cost efficiency, on the other hand, was determined by the age and educational status of the household head, family size in man equivalent, and the size of irrigated land owned by the onion farmer. The study found that the average technical efficiency score for irrigated onions in the study area was 87%, while the average cost efficiency score was 84%.

Discussion: This indicates that, on average, onion farmers in the study area could potentially increase their technical efficiency by 13% and their cost efficiency by 16% with existing inputs, technologies, and current environmental conditions. Thus, the study suggests institutional interventions such as providing extension services to farmers who are far from agriculture offices, advising on fertility reclamation measures, facilitating young farmers in onion production, and assisting in asset building, particularly in acquiring oxen, to maximize technical and cost efficiency in the study area.

KEYWORDS

onion production, Cobb-Douglass production function, technical efficiency, cost efficiency, stochastic frontier, Ethiopia

1 Introduction

Participation in irrigation agriculture was found to bring additional income of 20 to 300% for farm households, attributed to engagement in high-value crops, intensified production, and reduced production losses. Irrigation also plays a significant role in improving household nutrition security, increasing saving habits and accumulation of assets, and enhancing overall production and income levels. It is also an important adaptation strategy to cope with climate change by reducing vulnerability to water shortages (Sable et al., 2021; Rajesh et al., 2024). Global onion production data show that China, India, the USA, Egypt, Turkey, Iran, Afghanistan, Brazil, and South Korea are among the countries that mainly produce onions for local and international markets (FAO, 2021).

Onions (*Allium cepa*), an important root crop that can be grown both under irrigation and rain-fed conditions, are considered a complementary product to tomatoes and hold global commercial importance (Przygocka et al., 2020). It is becoming increasingly popular in Ethiopia (Habtamu, 2017), with the country having a huge potential for both domestic consumption and export, producing approximately 3,460,481 quintals of onions on 38,952.58 hectares of land, with an average yield of 88.83 quintals per hectare (CSA, 2021). Onions can be harvested twice per year under both irrigation and rain-fed conditions in different parts of the country (Belay et al., 2015).

In Amhara National Regional State, onions are one of the most widely produced and commercialized root crops, mainly grown under irrigation conditions. The region produced 1,729,111.90 quintals of onion on 14,078 hectares of land, with an average productivity of 122 quintals per hectare, involving 221,721 households (CSA, 2021).

While increasing the productivity of irrigated onion through expanding the cultivated land area is challenging, there is potential to enhance onion production by optimizing existing production technologies. Farmers' inefficiencies may stem from factors such as lack of experience, illiteracy, and various socioeconomic, environmental, biophysical, and institutional factors. Addressing these inefficiencies could potentially maximize productivity using currently available technologies and prevailing conditions.

Despite the importance of irrigated onion production, various studies have shown inefficiencies in its production (Birhan, 2015; Gebremariam et al., 2019; Alula et al., 2023; Gebremariam et al., 2019). However, these studies have used a two-step production frontier estimation method, which may lead to biased estimations of efficiency levels.

The Wag-Lasta area, situated in the eastern part of the Amhara region of Ethiopia, is characterized by non-conducive agricultural environments, including steep topography, shallow soil depth, irregular rainfall, and limited farmers' awareness of improvement in production techniques. Additionally, the efficiency levels of farmers, particularly in irrigated production, have not been studied in this administrative zone of the Amhara region. Therefore, this study aims to fill this gap by analyzing the technical and cost efficiency of farmers in irrigated onion production and respective determinants of technical and cost efficiency, excluding allocative efficiency due to the Green problem, which makes it impossible to decompose allocative inefficiency components from the error term parts and the challenge of modeling allocative inefficiency without a clear relationship between actual cost shares and optimal shares. This issue arises when attempting to estimate a cost-sharing system without a direct link between allocative inefficiency in input demand equations and the error terms representing allocative inefficiency (Green, 1980a).

2 Materials and methods

2.1 Description of the study area

This study was conducted in Lasta and Sekota Woredas in the 2021/2022 irrigation season. Lasta Woreda is found in the North Wollo Zone which is the North Eastern part of Amhara National Regional State, Ethiopia. The district is situated in the northeastern part of Amhara National Regional State at 13°20′ N′ latitude and 38°58′ E′ longitude. The Woreda is bordered by the Wagehimera zone in the north (Tezera and Mengesha, 2017). The woreda has 24 rural administrative kebeles with a total population of 119,482. The altitude of the woreda ranges from 1,400 to 4,200 meters above sea level with four agro-climatic zones, of which 48.1% are Woina dega, 38% are kola, 15.4% are dega, and 0.2% are frost. The area receives an average annual rainfall of 533–880 millimeters and minimum and maximum temperatures of 16°C and 27°C, respectively. Lasta woreda is characterized by food insecurity and drought-prone areas of the Amhara region, Ethiopia. Among the total 28,071 ha of arable land, 3,105 hectares of land is cultivated through irrigation (Tezera and Mengesha, 2017). Whereas, Sekota Woreda is found in the Wagehimera administrative Zone which is located at 12°68′35″ N and 39.01′41″ E latitude and longitude with an altitude of 1976 meters above sea level. It has an average annual rainfall of 500 to 650 mm with minimum and maximum temperatures of 26.6 and 31.6°C, respectively (Sekota Woreda Office Agriculture, 2021).

2.2 Data and method of data collection

Primary data were collected through formal interviews with sampled irrigation onion farmers using a semi-structured questionnaire. The primary data were collected by well-trained enumerators under the supervision and coordination of the researcher. The content of the survey (questionnaire) focused on onion farmers' socioeconomic characteristics, access to government and non-governmental institutions, fertility status of farmland, inputs used, cost of production incurred, and output generated from irrigated onion production. Secondary data were also collected from secondary data sources by reviewing different published and unpublished articles, proceedings, and books.

2.3 Sampling method

To undertake this particular study, a multi-stage sampling technique was used to select a representative sampled of irrigated onion farmers for this study. In the first stage, two Woreda were selected based on the potential for irrigation: Lasta Lalibela Woreda from the North Wollo Zone and Sekota Woreda from the Wagehimera administrative Zone. In the second stage, two kebeles were selected in each Woredas, purposefully based on the existence of a large number of irrigated onion farmers in these kebeles among the potential irrigated onion producer farmers in each Woredas. Finally, using a simple random sampling technique, sampled households were selected from each kebele, proportional to the total number of irrigation users producing onions as indicated in Table 1.

2.4 Analytical techniques

The data collected from sampled households were analyzed using both descriptive statistics, such as mean, minimum, maximum, standard deviation, and percentages, and econometric tools; specifically, a single-stage maximum likelihood stochastic frontier model with Cobb–Douglas functional form was used to estimate technical and cost efficiency and respective determinant factors

TABLE 1 Distribution of sampled households.

Kebele	Total irrigated land in hectare	Irrigation producers	Sampled households
Woleh	142	261(18)	39
Fikereselam	110	434(42)	31
Shumsheha	121	557	40
Kechinabeba	125	420	40

among smallholder farmers, which was proposed by Aigner et al. (1977).

The rationale for choosing a single-stage approach was based on the argument in the literature that a two-step stochastic frontier procedure ignores producer-specific factors (demographic, socioeconomic, institutional, and farm-specific factors) that directly affect the efficiency of smallholder farmers. The efficiency levels estimated while excluding household characteristics, institutional factors, and biophysical variables result in wrong inefficiency score predictions. Regressing this efficiency level against determinant factors resulted in biased and inconsistent parameter estimates in the second-stage estimation of the stochastic frontier model. Many scholars recommend incorporating demographic, socioeconomic, plot characteristics, biophysical, and institutional variables into the estimation of the production and cost frontier models (Wang and Schmidt, 2002; Kumbhakar et al., 1991; Aigner et al., 1977).

Therefore, considering the aforementioned literature and addressing these concerns, a one-step maximum likelihood estimation of the stochastic frontier production function model using the Cobb–Douglas functional form was used. This approach allows for the simultaneous estimation of individual technical and cost efficiency levels and their respective determinant factors among smallholder farmers (Equations 1–3, 5) (Battese and Coelli, 1995). The cross-sectional stochastic frontier model is specified as:

$$Y_i = \alpha + x_i'\beta + \varepsilon_i, i = 1 \ldots, N \tag{1}$$

$$\varepsilon_i = v_i \pm u_i \tag{2}$$

$$v_i \sim N\left(0, \sigma^2{}_v\right) \tag{3}$$

$$u_i \sim F$$

where Y_i represents the logarithm of the output of irrigated onions (or total cost of irrigated onion production) of the i^{th} productive unit, xi is a vector of inputs (input prices and input quantities for cost and technical efficiencies, respectively), and other explanatory variables that affect the technical and cost efficiency of onion producers, and β is the vector of technology parameters. The composed error term εi is the sum or difference of a normally distributed disturbance for cost and technical efficiencies, respectively, v_i, representing measurement and specification error, and a one-sided disturbance, ui, representing inefficiency. Moreover, u_i and v_i are assumed to be independent of each other and independent and identically distributed across observations.

Prior to undertaking the stochastic frontier model, the selection between the most common production functional forms, i.e., Cobb–Douglas and the trans-log (transcendental) production functional forms that properly fit our data were investigated. Unless we perform an appropriate testing hypothesis (Cobb–Douglass versus trans-log functional forms), it is impossible to say which one functional form is deemed superior to the other. In this study, a test of the hypothesis was implemented to choose one functional form over the other and was investigated using the log-likelihood functional value of the Cobb–Douglas and trans-log production. Accordingly, the likelihood ratio test failed to reject the Cobb–Douglas in favor of the trans-log specification of irrigated onion production with a decision probability of $p = 0.174$, and the maximum likelihood stochastic Cobb–Douglass production function was specified as follows:

$$Yi = \beta 0 + \sum_{j=1}^{N} \beta j ln X \mathrm{ij} + vi \pm ui \tag{4}$$

where ln = natural logarithm, Y_i is onion output measured in kilogram, and X_{ij} = is the quantity of input j and price of input j used in the production process for technical and cost efficiency, respectively. The cost efficiency was estimated following Jondrow et al. (1982). After estimating inefficiency (ui) in Equation 4, the inefficiency model was specified as follows:

$$u_i = \beta 0 \pm \beta 1 i X i_i + \beta 2 i X i \tag{5}$$

where i indicates the i^{th} household in the sample, β's indicates the parameters to be estimated, and Xi indicates the inefficiency factors.

2.5 Variable definitions

Input–output factors and technical efficiency in relation to demographic and socioeconomic characteristics are both considered in technical efficiency analysis.

The dependent variables were the total output (yield) of onions for the irrigation production period measured in kilograms and the total cost of irrigated onion production measured in Ethiopian Birr, for technical and cost efficiency, respectively.

The independent variables for this study were different demographic, socioeconomic, institutional, and biophysical factors were considered determinant factors for both technical and cost efficiency, which is depicted in Tables 2, 4 respectively.

3 Results and discussion

3.1 Descriptive results

Descriptive results are shown in Table 2.

TABLE 2 Definition of variables for technical efficiency.

Model variables	Variable definitions and measurement units	Mean	Standard deviation
Output	Quantity of irrigated onion output a farm household produced in kilograms (kg)	1042.787	1128.431
Direct inputs			
Land	Size of land used for onion production in hectares (ha)	0.154	0.118
Seed	Quantity of seed used in kilograms (kg)	0.72	0.614
Oxen	Oxen power used for ploughing (oxen days)	1.438	1.034
Labor	Quantity of family and hired labor used for production (in person-days)	23.59	13.838
Inorganic fertilizer	Amount of inorganic fertilizer used for the production of onions in kilograms (indexed)	18.05	20.617
Inefficiency factors			
Slope of the irrigated farm in the median	Slope of the field as perceived by the farmer (1 = flat, 2 = medium, 3 = slightly steep)	1	
Age	Age of household head in years	42	11
Education level of household head	1. Illiterate, 2. read and write, and 3. formal education (median)	2	
Family size in men equivalent	Family size in men equivalent	3.79	1.51
Distance from the nearest market	Distance from the nearest market in walking minutes	81.77	51.597
Number of extension contact	Number of extension contacts by the development agent	4.98	8.134
Distance from the office of agriculture	Distance of farmer residence from kebele office of agriculture in walking minutes	31.626	19.611
Ownership of oxen	Number of oxen owned in number	1.313	0.752
Size of irrigated land allocated for onion	The total irrigated onion land owned by a household head in a hectare.	0.15	0.11
Distance of irrigated onion plot from the irrigation water source	Distance from the source of irrigation water to the irrigated onion plot in walking minutes	20.96	20.19

3.2 Production frontier and production efficiency estimate

3.2.1 Production frontier estimate

The diagnostic test for the inefficiency component showed that sigma squared (δ2) was statistically significant at the 1% level, suggesting a good fit and accuracy of the distributional assumption of the composite error term component. The results also revealed that the gamma (γ) value of 0.67 is statistically significant at the 1% level, indicating that most of the deviations were caused by inefficiency. This affirmed the presence of technical inefficiency effects in irrigated onion production in the study area, with 67% of the total variation in onion producers' output attributed to production inefficiencies, while random factors accounted for approximately 33% of the difference in irrigated onion output across producers.

The estimated stochastic production frontier, as shown in Table 3, showed that the estimated coefficient of output and quantity of direct inputs, except oxen power, had the expected positive and statistically significant effects, indicating that the amount of irrigated onion output increased as the number of inputs increased. The results further revealed that irrigated onion output was more responsive to changes in seed under production relative to other inputs. The coefficient of labor indicates that, on average, a 1% increase in labor will increase output by approximately 0.31%, keeping all other incorporated input variables constant. Similar interpretations can be made for other input variables. The negative effect associated with oxen power suggests overuse and frequent plowing, a common practice among Ethiopian farmers (Temesgen et al., 2009).

3.2.2 Technical efficiency factors estimate

Among the technical inefficiency factors, as shown in Table 3, the stochastic frontier model results showed that the age of the household head, slope of the land, number of extension contacts by development agents, distance of the sampled respondent's residence from the office of the kebele agriculture office, and number of oxen owned by sampled households were important determinants of technical efficiency in onion production, as estimated using a single-stage stochastic frontier model approach:

TABLE 3 Parameter estimates of stochastic production frontier and technical inefficiency models.

Direct inputs (Deterministic frontier component)	Coefficient	SE
constant	6.224***	0.483
Lnlabor	0.311**	0.078
Lnland	0.307***	0 0.078
Lnoxen	−0.227	0.165
Lnseed	0.386***	0.154
lnfertilizer	0 0.054*	0.028
Technical inefficiency effect component		
Age of household head	0.362*	0.172
Educational status of the household head		
Read and write	8.04	2675.63
Formal education	48.05	2218.23
Distance of farmers' residence from the nearest market in walking minutes	−0.059	0.036
Number of extension contacts by development agents	−1.552**	0.794
Slope of the irrigated land (steep slope as a base category)		
Flat slope	−12.224**	6.229
Medium slope	−8.759***	5.021
Distance of farmer residence from farmer training center	0.109*	0.067
Family size in men equivalent	0.118	1.042
Irrigated land allocated for onion	−1.09	3.424
Number of oxen-owned	−2.002**	1.198
Variance parameters		
Sigma_v	0.703	0.114
Sigma_u	1.004	0.240
Sigma^2	1.504	0.364
Lambda	1.428	0.340
Gamma, $\sigma u^2/(\sigma u^2 + \sigma v^2) - +$	0.65	
Ln (likelihood)	−185.41***	
Mean technical efficiency	87	

*, **, and, *** show significance at 10, 5, and 1% probability levels, respectively. A negative coefficient. Parameters estimate on the inefficiency component shows that the variable has a positive effect on efficiency.

3.2.2.1 Age of household head

The age of the household head had a positive and significant effect on technical inefficiency, indicating that older farmers were technically inefficient compared to younger ones. This result is consistent with previous studies (Birhan, 2015; Oumer et al., 2022; Alula et al., 2023; Mohammad and Jamiya, 2014). The possible explanation for this might be that older farmers might be reluctant to adopt new technologies on their plots of land.

3.2.2.2 Slope of the land

The slope of the land had a negative effect on technical inefficiency, taking the steep slope of the plot as a reference category for the flat and medium slopes of the plot as perceived by respondents. The negative and significant effects of flat slope and medium slope plots suggest that sampled households with flat (good) slopes and medium slopes are more technically efficient than steep slopes. The explanation for the positive effect of flat slope- and medium-slope land on technical efficiency might be that steep irrigated farmlands are more susceptible to erosion, reducing the amount of output produced in a given plot of land. The result resembles the result studied by Oumer et al. (2022).

3.2.2.3 Number of extension contacts by development agents

A higher number of extension contacts by development agents had a negative and significant effect on technical inefficiency, indicating increased technical efficiency. Frequent extension visits help farmers gain awareness of the optimal use of necessary inputs and increase production efficiency. This result is consistent with the results of literature done on efficiency (Alula et al., 2023; Birhan, 2015; Oumer et al., 2022).

TABLE 4 Costs and factors used for onions in the 2021 irrigation production season.

Cost items	Variable definition	Mean	Std. Dev.
Total cost	Total cost of irrigated onion production in ETB	3842.823	2212.32
Price of seed	Seed price per kg in ETB	1328.2	881.034
Price of oxen power	Rental price for a pair of oxen power per oxen-day in ETB	317.26	35.15
Price of fertilizer (indexed)	Fertilizer price of NPS and urea per kilogram in ETB	12.447	3.764
Price of labor	Wage for labor price per person per day in ETB	85.326	52.436
Slope of the irrigated farm	Slope of the onion irrigated farm as perceived by a farmer (1 = flat, 2 = medium, and 3 = slightly steep slope)	1.413	0 0.687
Age	Age of the household head in the year	42.76	11.26
Education level of the household head	1. Illiterate, 2. read and write, and 3. formal education	2.033	0 0.937
Family size in men equivalent	Family size in men equivalent	3.79	1.51
Distance to the nearest market	Distance from the nearest market in walking minutes	81.773	51.597
Distance from the office of agriculture	Distance of farmer residence from kebele office of agriculture	31.626	19.611
Ownership of oxen	Number of oxen owned by respondents	1.313	0.752
Irrigated land allocated for onion	The total irrigated land owned by the household head is allocated for onions in hectare.	0.15	0.11
Distance of the irrigated onion plot from the irrigation water source.	Distance from the source of irrigation water to the irrigated onion plot in walking minutes.	20.96	20.19

3.2.2.4 Distance of sampled respondent's residence from kebele office agriculture

The distance of sampled respondents' residence from the office of the kebele agriculture office positively and significantly affects technical inefficiency. The positive sign suggests this factor reduces technical efficiency. This might be due to limited access to information on updating existing technologies, as farmers are far from the office of the Keble agriculture office. The reason might be that the extension service providers that are found in the study area might not reach those farmers who are far away from their respective offices of agriculture on frequent provision of extension services and awareness creation on the importance of the adoption of existing technologies.

3.2.2.5 Number of oxen owned by sampled households

The number of oxen possessed by sampled irrigated onion producers had a negative and statistically significant effect on technical inefficiency. The negative sign suggests that the number of oxen indicates more oxen (access to oxen) increases technical efficiency and reduces the output variability of irrigated onion, which enables producers to plough their farm at optimal levels as they like. The results of this study support the study conducted by Oumer et al. (2022).

3.2.3 Technical efficiency score analysis

As shown in the last row of Table 3. The mean technical efficiency of the sampled farmers is approximately 87% with a standard deviation of 11%. This result suggests that, on average, the sampled farmers could achieve only 87% of the maximal output from a given mix of inputs under prevailing technology. Thus, substantial productivity is lost due to inefficiency. Although the technical efficiency of onion production is high in the study area, production can be increased on average by 15% [((1–0.87)/0.87)*100], with efficiency improvements. This result is comparable to the results of Khan (2015).

3.2.4 Return to scale

The summation of the coefficients of parameters in the deterministic frontier component as shown in Table 3 is approximately 0.831, as the value is less than one. This suggests that onion producers are operating in the second stage of the production function, where output is increasing at a decreasing rate and resources are applied efficiently (Table 3).

3.3 Cost frontier and cost efficiency estimate

3.3.1 Definition of variables for cost efficiency

3.3.2 Estimation of cost frontier

The estimated stochastic cost frontier, as shown in Table 5, shows that the estimated coefficient of output and other input prices has the expected positive and statistically significant effects, except for the price of oxen power. This indicates that the cost incurred increases as output and other input prices increase. The coefficient of labor price indicates that, on average, a 1% increase in labor price will increase costs by approximately 0.65%, keeping all other incorporated variables constant. Similarly, the coefficient of fertilizer price indicates that a 1% increase in the price of inorganic fertilizer will increase the total cost of production of irrigated onions by approximately 0.75%, keeping all other incorporated variables constant. Other variables will be interpreted in the same approach, such as labor price.

TABLE 5 Parameter estimates of stochastic cost frontier and cost inefficiency models.

Total cost (Dependent variable)	Coefficient	SE
Constant	−0.754	0.95
output	0.188***	0.027
Labor price	0.649 ***	0.202
Seed price	0.275 ***	0 0.067
Oxen power price	0.139	0.145
Fertilizer price	0.752***	0.211
Cost inefficiency component		
Age of the household head	−0.062*	0.034
Educational status of household head		
Read and write	0.655	0.754
Formal education	−2.307*	1.25
Number of extension contact	0.006	0.039
Distance of farmers' residence from the nearest market in walking minutes	−0.011	0.021
Slope of the irrigated land covered by onion		
Flat slope	−0.452	0.843
Medium slope	−1.536	1.395
Distance of farmer residence from farmer training center	0.007	0.020
Family size in men equivalent	0.396**	0.236
Irrigated land owned by an onion farmer	−7.76**	4.043
Number of oxen-owned	0.0083	0.470
Distance of the onion plot from the irrigated water source in walking minutes.	0.0022	0.017
Variance parameters		
Sigma_v	0 0.306	0.054
Sigma_u	0.435	0.114
Sigma^2	0.18	0.021
Lambda	1.42	
Gamma, $\sigma u^2 /(\sigma u^2 + \sigma v^2)$	0.67	
Ln (likelihood)	−72.409	
Mean cost efficiency	84	

*, **, and *** show significance at 10, 5, and 1% probability levels, respectively.

3.3.3 Determinants of cost inefficiency

The output of the maximum likelihood stochastic frontier model, as illustrated in Table 5, revealed that among the cost inefficiency factors, age of the household head, educational status of household head, family size in man equivalent, and plot size of irrigated onion land owned by onion farmer are the determinant factors of cost inefficiency in onion production in the study area.

3.3.3.1 Age of the household head

The single-step stochastic cost frontier result showed that the age of the household head had a positive and significant effect on cost inefficiency, suggesting that older household heads are more cost inefficient compared to younger ones. This might be because older farmers are more reluctant to adopt new onion productiontechnologies. This result is consistent with studies by Alula et al. (2023), Birhan (2015), and Oumer et al. (2020).

3.3.3.2 Educational status of the household head

The educational status of farmers showed a negative relationship with cost inefficiency at a 10% significance level. This result indicates that more educated farmers are more cost-efficient in irrigated onion production compared to illiterate sampled households. The coefficient of education shows that formally educated sampled households are 2.307% more cost-efficient than illiterate sampled households. This result suggests that education enables onion producers to evaluate and apply new cost-effective irrigated onion technologies and tools more easily to farming operations. This finding is consistent with studies by Alula et al. (2023), Gebremariam et al. (2019), Oumer et al. (2020), Mezgebo et al. (2021).

3.3.3.3 Family size in men equivalent

The stochastic frontier inefficiency factors showed that family size in man equivalent had a significant positive effect on cost inefficiency levels. This suggests that cost efficiency decreases as household size increases. This might be due to the inadequate management skills of the family in using the available workforce. The number of household members engaged in irrigated onion farming and the effective time of family members engaged in irrigated onion production could also contribute to this inefficiency.

3.3.3.4 Size of irrigated land owned by an onion farmer

The amount of land owned by sampled households negatively affects cost efficiency. The justification for this negative and significant effect of the size of irrigated onion land on cost inefficiency (lower cost inefficiency) might be the benefit of economy of scale. This result coincides with other studies (Oumer et al., 2022).

3.3.4 Estimation of cost efficiency

As illustrated in Table 5, the estimated cost efficiency is 84%, with a minimum and maximum cost efficiency level of 29.24 and 99.81%, respectively. This result is comparable with many studies in Ethiopia on onions and other crops (Oumer et al., 2020).

4 Conclusion and recommendations

This study aimed to estimate the levels of technical and cost efficiency in irrigated onion production and identify the factors influencing these efficiencies using the maximum likelihood stochastic frontier with Cobb–Douglas functional form. Technical efficiency in onion production is influenced by the age of the household head, the slope of the land, the number of extension contacts with development agents, the distance of the sampled respondents' residence from the kebele office of agriculture, and the number of oxen owned by the households. Furthermore, cost inefficiency is affected by the age and educational status of the household head, family size in man equivalent, and the size of the irrigated land owned by the farmer. Therefore, the study recommends the following to enable, in efficiency, farmers to operate on the frontier.

The positive and significant effect of the educational status of the household head on cost efficiency highlights the need for efforts to improve human capital through easy access to formal and informal education, including short and long-term training, to reduce cost inefficiency and increase cost efficiency among irrigated onion producers. Extension services should be provided to farmers located far from the agriculture office to enhance their technical and cost efficiency levels. Further investment in recommended soil fertility reclamation measures should be made in steeper plots of irrigated land to improve technical efficiency, as households with steeper plots are less technically efficient than those with gentler slopes. Attention should be given to asset building among onion farmers, particularly in terms of draft oxen power, to maximize production efficiency, and awareness programs should be conducted to address skill gaps in fully managing available labor resources in an optimal way, coordinated by the respective agriculture office and other development practitioners engaged in the sector.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the participants was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

KA: Conceptualization, Data curation, Formal analysis, Methodology, Software, Supervision, Writing – original draft, Writing – review & editing. TK: Writing – review & editing, Investigation. AW: Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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