World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(Research Article)

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Analysis of the efficiency of production factors in shallot farming using True Seed of Shallot (TSS) in Adipala District, Cilacap Regency

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World Journal of Advanced Research and Reviews, 2025, 26(02), 3819-3834

Publication history: Received on 20 April 2025; revised on 25 May 2025; accepted on 27 May 2025

Article DOI: https://doi.org/10.30574/wjarr.2025.26.2.2077

Abstract

Red onion is one of the horticultural commodities with significant economic value. Cilacap Regency is a major red onion-producing area in Central Java, one of which is Adipala District. In 2023, the red onion production in Cilacap Regency reached 951.12 tons with a productivity of 8.38 tons/ha. The productivity of Cilacap Regency is still low compared to Central Java Province, which is 10.23 tons/ha. The productivity of red onions in Adipala Subdistrict is 9.16 tons/ha. This study was conducted using the census method. Primary data collection was carried out through interviews with red onion farmers as respondents using a questionnaire. The study was conducted in Adipala District with 65 red onion farmers as respondents. The primary data collected included: respondent characteristics, land area, seeds, labor, NPK fertilizer, organic fertilizer, dolomite, pesticides, age, education level, experience, extension services, and land status. Secondary data were obtained from the Ministry of Agriculture, the Central Statistics Agency, and the Provincial/District Agriculture Office. Data were analyzed using the Frontier 4.1 application, followed by allocative and economic efficiency analysis using the Cobb-Douglas production function dual cost equation. The results showed that land, seeds, labor, NPK fertilizer, and dolomite had a positive effect on production, meaning they increased production, while organic fertilizer and pesticides did not have a significant effect. The analysis indicates that the average technical and allocative efficiency of red onion farmers in TSS is sufficient, but economic efficiency is still lacking. The average technical, allocative, and economic efficiencies are 0.86, 0.70, and 0.60, respectively. Efforts to reduce inefficiency include optimizing extension services. To obtain more diverse data, further comprehensive research is needed on the efficiency of red onion farming during the same planting season.

Keywords: Horticulture; Onion; Production; Allocative Efficiency; Cobb-Douglas

1. Introduction

Shallots are a high economic value horticultural commodity in Indonesia. Regulation of the Minister of Agriculture Number 46 of 2019 establishes shallots as a national strategic commodity with the consideration that the commodity can affect the value of inflation, is needed in large quantities, cannot be substituted with other horticultural commodities and its production involves many farmers with a large development area.

Domestic shallot production over the past three decades has shown positive growth, in line with exports experiencing quite high growth, as well as significant growth in imports. Based on FAO (*Food and Agriculture Organization*) data, in 2017-2021 Indonesia in the ASEAN scope became the fourth-ranked exporting country exporting shallots with an average of 6.53 million USD as well as the second-ranked importing country importing shallots with an average of 51.76 million USD (Center for Agricultural Data and Information Systems, 2023).

The national shallot production centers in 2018-2022 are spread across ten provinces. The three provinces with contributions above 10% to national production are Central Java, East Java, and West Nusa Tenggara, each with

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contributions of 29.93% (average production of 531.88 thousand tons), 24.86% (average production of 441.78 thousand tons), and 11.41% (average production of 202.73 thousand tons). Central Java is the highest production center province in Indonesia. Two districts contribute 78.12% to shallot production in Central Java, namely Brebes with a contribution of 68.94% (production of 383.68 thousand tons) and Demak with a contribution of 9.18% (production of 51.08 thousand tons). While other districts contributed a total of 21.88%. (Center for Agricultural Data and Information System, 2023).

Cilacap Regency is one of the potential shallot development areas in Central Java Province. In 2023 Cilacap Regency had a planting area of 120.58 hectares, a harvest area of 113.53 hectares, a production of 951.12 tons and an average productivity of 8.38 tons/hectare (Central Bureau of Statistics, 2023). The potential for shallot development in Cilacap Regency is supported by agro-climatic conditions, namely climate, temperature and irradiation that are suitable for shallot cultivation. Shallot cultivation in Cilacap District develops on lowland/coastal land with sandy soil texture, among others in Adipala Sub-district, Nusawungu Sub-district and surrounding areas. Sandy soil is quite potential for farming because it has a crumbly soil structure, medium texture, and good drainage and aeration that support shallot cultivation, In addition, sandy land is relatively safer from disease (Iriani, 2013).

Adipala Sub-district is one of the shallot production centers in Cilacap Regency. Initially, shallot farmers in Adipala sub-district practiced bulb-based shallot farming. Starting in 2021, *shallot* farmers in Adipala Sub-district have been introduced to shallot farming from seed (*True Seed of Shallot/TSS*). The government continues to promote the use of TSS as an alternative seed to replace bulb seeds whose prices fluctuate as well as an effort to increase production and farmers' income.

Previous research (Monica *et al*, 2021) which conducted research in 2020 stated that shallot bulb farming in Adipala District was not technically efficient. Onion farming in Adipala District can still be increased in productivity through the efficient use of production factors, as stated by Nurjati et. Al. (2018) which states that the strategy that can be applied to increase competitiveness through optimizing *shallot* production inputs is through the use of botanical seed technology/true *seed of shallot*. Kusnadi *et al*. (2011) also mentioned that increasing productivity through the application of technical efficiency is important because it can be used as an effort to increase production in addition to agricultural extensification, considering the availability of agricultural land is decreasing along with the conversion of agricultural land and various other causes. In addition to increasing efficiency in terms of inputs, it should be noted that the social conditions of farmers such as age, education level, experience in farming and frequency in seeding create variations in allocating factors of production between one farmer and another.

Various studies on shallot production efficiency have been conducted. Among them is the research of Nurjati *et al*. (2018) which revealed that shallot farmers in Pati Regency are technically efficient, but not economically and allocatively efficient. Similar findings were also revealed by Mustiarasari *et al*. (2019) who stated that the average shallot farmer in Majalengka Regency is technically efficient. This is in line with Ismiasih *et al*. (2024) who analyzed farm businesses based on 11,206 shallot farmers collected by BPS in the 2013 Agricultural Census stated that the technical efficiency level of shallot farming in Indonesia was quite efficient. In contrast to previous studies, this study analyzes the production efficiency of TSS shallot farming in Adipala Subdistrict, which is one of the prospective areas for shallot development in Cilacap Regency.

2. Material and methods

The research was conducted in October-November 2024. The timing of the study considered when farmers finished harvesting shallots in the third planting season from June to August 2024. The research location was taken *purposively*, namely in Adipala Sub-district, Cilacap Regency. The reason for choosing the location is because Cilacap Regency is one of the districts in Central Java that is prospective for the development of shallot farming and Adipala Sub-district is the center of shallot production in Cilacap Regency where many farmers have begun to apply TSS shallot cultivation. The number of research samples was 65 farmers. Because the number of research samples was less than 100, the census method was used. Census research involves collecting data from all respondents to provide a comprehensive picture of the condition of an area. This type of research is quantitative descriptive research. Quantitative method is a method whose research data is in the form of numbers and analysis using statistics.

The data collected in this study were analyzed using Frontier 4.1 software and the results of the analysis were presented descriptively quantitatively. *The Stochastic Frontier method* is one of the methods used in estimating the production frontier and also measuring the level of production efficiency. According to Gujarati (2009), the Cobb-Douglas production function is one example of a log linear multiple regression model, a multiple linear regression model is a linear regression model with more than one explanatory variable. The formula is as follows:

$Y = aX_{(1)}{}^{(b1)}, X_{(2)}{}^{(b2)}, X_{(3)}{}^{(b3)}, X_{(4)}{}^{(b4)}, X_{(5)}{}^{(b5)}, X_{(6)}{}^{(b6)}, X_{(7)}{}^{(b7)}$ ……………….(3.)1

In the production function, the factors that are thought to affect production are land, seeds, NPK fertilizer, organic fertilizer, soil conditioner, pesticides and labor. To determine the efficiency of the use of production factors on the production of TSS system farms, *frontier* analysis is used, or the *stochastic production frontier* method. The stochastic frontier production function model for TSS shallot farming is as follows:

$Ln\ Y = \alpha o + \beta_1 ln\ X_1 + \beta_2 ln\ X_2 + \beta_3 ln\ X_{(3)} + \beta_4 ln\ X_4 + \beta_5 ln\ X_{(5)} + \beta_6 ln\ X_{(6)} + \beta_7 ln\ X_{(7)} + (vi-ui)$ ……………..(3.)2

Description:

- Y = TSS shallot production per growing season (kg)
- α = intercept
- β = regression coefficient (estimated parameter coefficient) (i=1 to 7)
- X_1= land area used for farming (ha)
- X_2= seed (stem)
- X_3= labor (HOK)
- X_4= NPK fertilizer (kg)
- X_5= organic fertilizer (kg)
- X_6= dolomite (kg)
- X_7= pesticide (ml)
- vi - ui = (vi) confounding error, (ui) technical inefficiency effect in the model.

Completion of the stochastic frontier production function using frontier 4.1 software with the *Maximum Likelihood Estimation* (MLE) method. The expected value of the regression coefficient is β1 - β7 > 0, which means that the estimation of the stochastic frontier production function gives a positive value of the estimated parameter. A positive coefficient means that an increase in input use is expected to increase TSS shallot production.

The coefficient value of each *independent* variable can be tested for its significant value using the t-count (t-ratio) value with the t-table value. If the t-count value is greater than the t-table, it can be said that it is significant to the *dependent* variable and vice versa if the t-count value is smaller than the t-table, it can be said that it is not significant to the dependent variable.

At this stage, a *classical assumptions* test is conducted to measure the regression function model to be used whether there are no violations of classical assumptions related to errors or independent variables. In addition, this method also serves to see whether the function model used is consistent and fulfills the assumptions of the *Cobb-Douglas* production function.

Analysis of the efficiency of the use of production factors is used to determine the extent to which the efficiency of the use of production factors (inputs) that can affect production (output). The analysis of the efficiency of the use of production factors in this study uses a stochastic frontier production function in the form of the Cobb-Douglas production function. Estimation of the production function is done in two ways, namely estimation using the Ordinary Least Squares (OLS) method and estimation using the Maximum Likelihood (MLE) method.

The MLE method is useful for estimating the overall production factor parameters, intercepts, and variances of both error components vi and ui. The variation of output from the frontier due to technical inefficiency can be represented by the gamma parameter (γ) as follows (Battese and Coelli 2005). The Maximum Likelihood Method (MLE), describes the relationship between the maximum production that can be achieved at the level of use of factors of production and existing technology. This analysis will determine the technical efficiency of the sample farmers, as well as the factors that influence technical inefficiency.

Technical efficiency analysis was calculated using the following formula (Coelli *et al*. 1998):

$$TE_i = \frac{Y_i}{Y_i^*} = \frac{E(Y_i|\mu_i, X_i)}{E(Y_i|\mu_i = 0, X_i)} = E[\exp(-U_i|\varepsilon_i)]$$

……………..(3.)3

Where TE is the technical efficiency of the i-th farmer, exp(-E[ui|εi]) is the expected value (*mean*) of $u_i$conditional on εi, so 0 ≤ TEi ≤ 1. The value of technical efficiency is inversely related to the value of the technical inefficiency effect and is only used for functions that have a certain number of outputs and inputs (*cross section* data).

Determination of the extent of the efficiency level is made by referring to Ojo's research, (2006) by dividing the distribution of efficiency levels as follows; highly efficient if TE ≥ 0.90, moderately efficient if 0.70 ≤TE ≤ 0.90 and not yet efficient if TE < 0.70.

In measuring allocative and economic efficiency, the dual cost function of the homogeneous Cobb-Douglas production function is first derived (Debertin 1986). The assumption used is the form of Cobb-Douglas production function using two inputs as follows:

$$Y = \beta_{(0)} x_{(1)}{}^{(\beta)(1)} x_{(2)}{}^{(\beta)(2)} \quad \text{......................}(3.)4$$

And the input cost function is

$$C = P_{(1)} x_{(1)} + P_{(2)} x_{(2)} \quad \text{................}(3.)5$$

The form of the dual cost function can be derived by using the assumption of cost minimization with output constraints Y = Y0. To obtain the dual cost function, the *expansion path* value must be obtained, which can be obtained through the *Langrange* function as follows:

$$L = P_{(1)} x_{(1)} + P_{(2)} x_2 + \lambda \left(Y - \beta_{(0)} x_{(1)}{}^{(\beta)(1)} x_{(2)}{}^{(\beta)(2)}\right) \quad \text{........}(3.)6$$

To obtain the values of x1 and x2 expansion path the *Langrange* function is derived in the *first-order condition* as follows:

$$\frac{dL}{dX_2} = P_1 - \lambda\beta_0\beta_1 X_1{}^{\beta_1 - 1} X_2{}^{\beta_2} = 0 \quad \text{.......}(3.)7$$

$$\frac{dL}{dL_2} = P_1 - \lambda\beta_0\beta_2 X_1{}^{\beta_1} X_2{}^{\beta_2 - 1} = 0 \quad \text{........}(3.)8$$

$$\frac{dL}{d\lambda} = Y - \beta_0 X_1{}^{\beta_1} X_2{}^{\beta_2} = 0 \quad \text{........}(3.)9$$

From equations (3.8) and (3.9) we obtain

X1 and X2 *expansion path* values are :

$$X_1 = \left(\frac{P_2}{P_1}\right)\left(\frac{\beta_1}{2}\right) X_2 \quad \text{............}(3.)10$$

$$X_2 = \left(\frac{P_1}{P_2}\right)\left(\frac{\beta_2}{\beta_1}\right) X_1 \quad \text{.....................}(3.)11$$

After that, equation (3.10) is substituted into equation (3.11) to become :

$$Y = \beta_0 X_1{}^{\beta_1} \left[\frac{P_1}{P_2}\frac{\beta_1}{\beta_2} X_1\right]^{\beta_2} \quad \text{.........}(3.)12$$

$$Y = \beta_0 P_1{}^{\beta_2} P_2{}^{-\beta_2} \beta_2{}^{\beta_2} \beta_1{}^{\beta_2} \quad \text{...........}(3.)13$$

$$X_1{}^{\beta_1 + \beta_2} = \frac{Y}{\beta_0 P_1{}^{\beta_2} P_2{}^{-\beta_2} \beta_2{}^{\beta_2} \beta_1{}^{\beta_2}}. \quad \text{........}(3.)14$$

From equation (3.12), the input demand function for X1 and X2 can be summarized as follows

is determined to be :

$$X_1 = \left[\frac{Y}{\beta_0 P_1{}^{\beta_2} P_2{}^{-\beta_2} \beta_2{}^{\beta_2} \beta_1{}^{-\beta_2}}\right]^{\frac{1}{\beta_1 + \beta_2}} \quad \text{.........}(3.)15$$

$$X_2 = \left[\frac{Y}{\beta_0 P_1{}^{\beta_2} P_2{}^{-\beta_2} \beta_2{}^{\beta_2} \beta_1{}^{-\beta_2}}\right]^{\frac{1}{\beta_1+\beta_2}} \quad ....(3.)16$$

To obtain the dual frontier cost function, the equations $X_1$and $X_2$are used.

is substituted into the cost equation (3.4) i.e. :

$$C^* = P_1 \left[\frac{Y}{\beta_0 P_1{}^{\beta_2} P_2{}^{-\beta_2} \beta_2{}^{\beta_2} \beta_1{}^{-\beta_2}}\right]^{\frac{1}{\beta_1+\beta_2}} + P_2 \left[\frac{Y}{\beta_0 P_2{}^{\beta_1} P_1{}^{-\beta_1} \beta_1{}^{\beta_1} \beta_2{}^{-\beta_1}}\right]^{\frac{1}{\beta_1+\beta_2}} \quad ....(3.)17$$

According to Jondrow *et al.* (1982), economic efficiency (EE) is defined as the ratio between the minimum observed total cost of production (C*) and the actual total cost (C) as shown in the following equation:

$$EE = \frac{C^*}{C} = \frac{E(Ci|ui=0,Yi,P}{E(Ci|ui,Yi,Pi)} = E[\exp.(Ui/\varepsilon)] \quad ....(3.)18$$

Economic efficiency (EE) is a combination of technical efficiency and allocative efficiency so that allocative

efficiency (AE) can be obtained by equation :

$$AE = \frac{EE}{TE} \quad ....(3.)19$$

where EA is 0≤ EA ≤1 and EE is 0≤ EE ≤1.

The value of technical efficiency is inversely related to the value of technical inefficiency effect. The inefficiency effect model used in this study refers to the technical inefficiency effect model developed by Battese and Coelli (2005). The use of software Frontier 4.1 in addition to producing regression analysis also produces an analysis of the effects of technical inefficiency in the form of the alleged value of the parameter u_i. The variable u_i, which is used to measure the effect of technical inefficiency, is assumed to be independent and normally truncated distribution with $N(u_{(i,)}\ _{(\sigma)}\ (^{2)}\ )$. According to Elly (2014), to determine the value of the distribution parameter (μi) of the technical inefficiency effect can use the following formula:

$$Ui = \delta o + \delta_1 z_1 + \delta_{(2)} z_2 + \delta_{(3)} z_3 + \delta_{(4)} z_4 + \omega_{(1)} d_1 \quad .... (3.)20$$

Where:

- Ui = technical inefficiency effect
- z_1= farmer age (years)
- z_2= farmer's formal education level (years)
- z_3= shallot farming experience (years)
- z_4= frequency of attending counseling (times/month)
- d_1= land ownership dummy (d1=0 if owned, d1=1 if rented)
- δ = regression coefficient (estimated parameter coefficient) (i=1 to 4)

The expected coefficient of the inefficiency estimation parameter (δ) is δ1 - δ4, ω1<0, which means that the estimation of the stochastic frontier production function gives a negative value of the estimated parameter.

In order to be consistent, the estimation of production function parameters and inefficiency function (equations 3.2 and 3.4) was done simultaneously with the *FRONTIER 4.1* program (*Coelli, 1996*). Testing the stochastic frontier parameters and technical inefficiency effects was done in two stages. The first stage is the estimation of parameter β1 using the OLS method. The second stage is the estimation of all parameters β0, β1, the variation of Ui and vi using the maximum likelihood method (MLE). The confidence level δ is 5% and 10%, while the test criterion used is the one-way generalized ratio test, with the following test equation:

$$\left[LR = -2\left\{Ln\left[\frac{L(H_0)}{L(H_i)}\right]\right\} = -2\left\{Ln\left[L(H_0)\right] - Ln\left[L(H_1)\right]\right\}\right]$$ ....(3.)21

Where L (H0) and L (H1) are the likelihood function values of the null hypothesis and alternative hypothesis, respectively.

Test criteria:

LR of one-sided error > x2 ($_{\text{(restriction)}}$ (Kodde Palm table) then reject H0

LR one-sided error < x2$_{\text{(restriction)}}$ (Kodde Palm table) then accept H0

If H_0: $\gamma = \delta_0 = \delta_{(1)}$............... δ_5= 0 states that the technical inefficiency effect does not exist in the production function model. If this hypothesis is accepted, then the production function model on average adequately represents the empirical data.

Processing results of the FRONTIER 4.1 program. according to Aigner *et al*., (1977), Jondrow *et al*. (1982) or Greene (2011), will provide an estimated value of variance in the form of parameterization as follows:

$$\sigma^2 = \sigma_v{}^2 + {}^{(2})$$ ....(3.22)

$$\gamma = \frac{\sigma_v^2}{\sigma_u^2}$$ .... (3.23)

The parameters of this variance can find a value , hence the value 0: γ:1. The value of the parameter γ is the contribution of technical efficiency in the total residuals.

3. Results and discussion

3.1. Overview of TSS Shallot Farming

Based on information from respondent farmers and the results of field observations, the general description of TSS shallot farming in the third planting season from June to August 2024 is shown through the results of descriptive analysis displayed in Table 1

Table 1 Descriptive Analysis of TSS Shallot Farming Respondents in Adipala Subdistrict, Cilacap Regency

Variables	**Minimum**	**Median**	**Average**	**Maximum**
Production (kg)	350	1.100	1.834	16.000
Productivity (tons/ha)	*8,00*	*14,28*	*13,44*	*18,85*
Cultivated area (ha)	0,04	0,07	0,13	1
Seedling Quantity (btg)	10.000	22.000	36.237	320.000
Seedling Usage (btg/ha)	*142.857*		*266.733*	*320.000*
Labor (HOK)	7	19	31	270
TK utilization (HOK/ha)	*142*		*232*	*328*
Amount of NPK Fertilizer (kg)	25	40	81	800
NPK Fertilizer Dose (kg/ha)	*357*		*563*	*875*
Amount of Organic Fertilizer (kg)	500	1.000	1.791	16.000
Dose of Organic Fertilizer (ton/ha)	*8,6*		*13,1*	*20,0*
Dolomite (kg)	15	50	87	1.000

Dolomite dosage (kg/ha)	*214*		*608*	*1.429*
Pesticide (ml)	200	1.800	1.656	3.500
Pesticide Dosage (ml/ha)	*214*		*608*	*1.429*

Source: Primary Data Analysis 2025

3.1.1. Production and Productivity

The production of shallots in the research area during the third planting season from June to August 2024 was 350 kg to 16,000 kg, depending on the area of land cultivated. Thus, the productivity ranges from 8–18 tons per hectare, with an average of 13.44 tons/ha. This result is higher compared to the average productivity of Central Java Province, which was 10.23 tons/ha, and Cilacap Regency, which was 8.38 tons/ha in 2023 (BPS, 2024).

3.1.2. Land Area

Mubyarto (1989) states that land is one of the production factors that serves as the "factory" for agricultural products, contributing significantly to agricultural activities. The scale of agricultural production is influenced by the size of the land used. However, Soekartawi (1993) notes that a larger agricultural land area does not necessarily mean higher land efficiency. On the contrary, with relatively narrow land, supervision of the use of production factors is better, the use of labor is sufficient, and the capital required is not too large. The land area cultivated by the respondents for TSS shallot cultivation ranged from 0.04 to 1.00 ha with an average of 0.13 ha.

3.1.3. Seedling

Seed quality determines the superiority of a commodity. The use of high-quality seeds can produce products with good quality. Red onion farmers in Adipala Subdistrict began implementing red onion farming using seed-based seedlings (*True Seed of Shallot*/TSS) in 2021. The red onion seed varieties (TSS) used in the study area include Maserari, Sanren, and Lokananta. These varieties are certified high-quality seeds released by the Ministry of Agriculture. The seeds must be sown first for 30–45 days before planting. Sowing is done using trays in a nursery. The seed requirement for TSS is 4–5 kg per hectare. If the plant population is 200,000 plants per hectare (planting distance 18 cm × 18 cm, reduced by 30% for drainage ditches), then 1,000 trays are needed for germination, assuming the use of trays with 200 holes per tray. To improve seedling efficiency, some farmers use trays with 220 holes and fill each hole with 2–3 seeds, resulting in more seedlings per tray. Based on interviews with the farmers, the number of seeds used by the farmers ranged from 10,000 to 320,000 stems depending on the land area, with an average of 266,733 stems per hectare per planting season.

3.1.4. Labor

Labor is an important production factor that must be considered in the production process in sufficient quantities, not only in terms of availability but also quality and type of labor (Soekartawi, 2003). Labor can be measured in man-days (MD), including land preparation, seedling production, planting, maintenance, fertilization, pest and disease control, and harvesting. The number of laborers used by the surveyed farmers ranged from 7 to 270, depending on the land area, with an average of 232 MD per hectare per growing season.

3.1.5. Fertilization

Applying fertilizer with the right composition can produce high-quality products. The most widely used fertilizer is NPK fertilizer, both subsidized and non-subsidized. Other fertilizers are adjusted to the needs of the land and farmers' habits, such as MAP, KNO3, KCl, and others. The first fertilization is carried out when the plants are 10–15 days old after planting. The second application is carried out when the plants are 1 month old after planting. The amount of NPK fertilizer applied by the respondents ranges from 25–800 kg, depending on the land area, with an average of 563 kg per hectare per growing season. The doses of other fertilizers were not studied in this research.

Organic fertilizers (such as compost, manure, or green manure) play an important role as base fertilizers in red onion cultivation. Their purpose is to improve soil fertility, provide macro and micro nutrients, enhance soil microorganism activity, and improve soil physical and chemical properties. The organic fertilizers used include cattle manure at a recommended rate of 10–20 tons per hectare or chicken manure at a rate of 5–6 tons per hectare. The organic fertilizers applied by the surveyed farmers ranged from 500 to 16,000 kg, depending on the land area, with an average of 13.1 tons per hectare per growing season.

The application of dolomite during soil preparation in red onion cultivation aims to neutralize soil acidity and improve soil structure to support plant growth. Dolomite contains calcium (Ca) and magnesium (Mg), which are important for strengthening plant tissues and enhancing nutrient absorption. Dolomite is typically applied at a rate of 1–2 tons per hectare, spread evenly over the field, and mixed into the soil during initial soil preparation before planting. With optimal soil pH (around 6.0–6.8), red onion growth becomes healthier, bulb yield increases, and the risk of root disease can be reduced. Dolomite applied by farmers in the study area ranged from 15 to 1,000 kg, depending on the land area, with an average of 600 kg per hectare per growing season.

3.1.6. Pest and Disease Control

Pest and disease control is carried out to keep plants healthy and produce optimal bulbs. Pesticides are used selectively according to the type of pest or disease attacking, such as insecticides for caterpillar or thrips pests, and fungicides for fusarium wilt or leaf spot diseases. Pesticide application should be based on the pest or disease threshold, with doses and intervals following recommendations to ensure effectiveness and prevent resistance. Excessive use of insecticides can cause losses for farmers, as the chemical compounds in insecticides can lead to environmental contamination and reduced crop yields. Pesticide application rates on red onion crops vary depending on the type of pesticide, target pest or disease, and the active ingredient used. The pesticides applied by the respondents in MT III were generally insecticides with a usage amount of 200–3,500 ml depending on the land area, with an average usage of 1,656 kg per planting season.

3.1.7. Harvesting and Post-Harvest

Farmers in the study area harvested red onions when the plants were 60–70 days after planting (DAP), characterized by yellowing leaves, wilting, dark red bulbs emerging from the soil surface, and the characteristic aroma of red onions.

Harvested red onions are tied to their stems for easier handling. The bulbs are then sun-dried until sufficiently dry (1–2 weeks) under direct sunlight, followed by grading according to bulb size.

3.2. Cobb Douglas Production Function Estimation Results

The stochastic frontier production function model used in this analysis is a Cobb-Douglas production function consisting of seven explanatory variables, namely land area, seeds, labor, NPK fertilizer, organic fertilizer, dolomite and pesticides. Based on Table 2 and Table 3, it is known that the MLE Log-likelihood value of 65.78 is much higher than OLS of 50.98, so the Likelihood-Ratio test rejects H_0 (OLS). This proves that the MLE method captures the real inefficiency structure. The log likelihood difference of 14.8 shows that the MLE model provides a much better fit to the data than OLS. MLE with its flexibility to use a more suitable distribution, captures the data pattern better, resulting in a higher log likelihood.

Table 2 Estimation of Frontier Production Function with OLS method on TSS Shallot Farming in Adipala District, Cilacap Regency

Variables	Parameters	Coefficient	Standard error	t-count	
Constant	α0	1.33699	0.80576	1.65930	ns
Planting area (X1)	β1	0.07418	0.10764	0.68916	ns
Seedlings (X2)	β2	0.13164	0.10361	1.27048	ns
Labor (X3)	β3	0.31865	0.07713	4.13154	***
NPK fertilizer (X4)	β4	-0.02991	0.11647	-0.25683	ns
Organic Fertilizer (X5)	β5	0.48720	0.13187	3.69456	***
Dolomite/Lime (X6)	β6	0.06151	0.06126	1.00405	ns
Pesticides (X7)	β7	0.00930	0.02054	0.45252	ns
sigma-square		0.01391			
gamma		0.62000			
OLS log likelihood		50.98			

Notes: *** significant at α 0.01 level (2.67), ** significant at α 0.05 level (2.01), ; * Significant at α level 0.10 (1.67)

Based on Table 3, it is known that the LR Test value in the MLE method is 29.60. This value is greater than 13.40 (Kodde palm table df = 7, α = 0.05) then $H_0$is rejected and $H_1$is accepted so it is concluded that there is a case of inefficiency in TSS shallot farming in Adipala District. The estimation results with the MLE method obtained a gamma value of 0.99 and a real effect at the level of α = 0.10. This result shows that 99 percent of the variation in TSS shallot production of respondent farmers is caused by technical efficiency. While the remaining 1 percent is influenced by external influences / stochastic effects that cannot be controlled by farmers such as pests, diseases, land fertility, temperature, climate and so on as well as the influence of random error (vi) or error in modeling.

Table 3 Estimation of Frontier Production Function with the MLE method on TSS Shallot Farming in Adipala Subdistrict, Cilacap Regency

Variables	**Parameters**	**Coefficient**	**Standard error**	**t-count**	
Constant	α0	3.45008	0.24734	13.94870	***
Planting area (X1)	β1	0.30147	0.05664	5.32272	***
Seedlings (X2)	β2	0.28895	0.09280	3.11380	***
Labor (X3)	β3	0.08965	0.04923	1.82094	*
NPK fertilizer (X4)	β4	1.03458	0.06001	1.72390	*
Organic Fertilizer (X5)	β5	0.09958	1.13496	0.87738	ns
Dolomite/Lime (X6)	β6	0.05754	0.02633	2.18550	**
Pesticides (X7)	β7	0.00123	0.01044	0.11808	ns
sigma-square		0.03978		5.65618	***
gamma		0.99883		173.189	***
LR-test:		29.60			
Log likelihood MLE		65.78			

Notes: *** significant at α 0.01 level (2.67), ** significant at α 0.05 level (2.01), ; * significant at α level 0.10 (1.67)

The significant value of γ = 0.99 (α = 0.10) confirms that the frontier model is very appropriate in capturing the technical inefficiency of TSSb shallot farming in the study location. Several studies on shallot farming in Indonesia report very high γ (gamma) values, ranging from 0.648 to 0.999, indicating that almost all deviations from the production frontier are due to technical inefficiency. Ismiasih & Jamhari (2024) at the national level (2013 Agricultural Census) found γ = 0.98 in the SFA MLE model, significant at 1% α. Bachtiar & Tamami (2024) in Pacet sub-district of Mojokerto district reported γ = 0.999, indicating the technical inefficiency component almost absolutely dominates the error variance. Mutiarasari *et al.* (2019) in Majalengka district recorded γ = 0.648 (α 5%), indicating technical inefficiency is still the main driver of output deviation.

To determine the effect of each variable on output, a significance test was conducted. Partial testing (t-test) of the production function, shows that the production factors Land area ($X_{1)}$, Seed ($X_{2)}$, Labor ($X_{3)}$, NPK Fertilizer (X_4) , Dolomite ($X_{6)}$, Pesticide ($X_{7)}$, affect the production of TSS shallots. Table 4.10 shows that all parameter signs in the TSS shallot production function with the MLE method are positive as expected. The parameter estimation value on the *stochastic frontier* production function can show the elasticity value of the inputs used. The input variables that significantly affect the production of TSS shallots are land area, seeds, labor, NPK fertilizer and dolomite. Meanwhile, the variables of organic fertilizer and pesticide have no significant effect.

Estimation of the Land Area variable ($X_{1)}$**.** The coefficient or elasticity value of the land variable has a real effect on TSS shallot production at the α = 0.01 level with a value of 0.301. This figure shows that the addition of land area can still increase the production of TSS shallots where other inputs remain. A 1% increase in land area increases shallot production by 0.301%, significant at 1%. The results of this finding are in accordance with the research of Muhaimin (2017), Aziza *et al.* (2022) Aziza *et al.* (2021); which states that land area has a positive and real effect on shallot production. The land area variable is quite responsive to shallot production, so that TSS shallot cultivation land extensification/expansion activities can be carried out as an effort to increase shallot production in Cilacap Regency. Local governments can support with policies that optimize land use including increased land access, better land management, and mitigation of natural disaster risks that can affect the available land area.

Estimation of Seed variable (X_2). The coefficient or elasticity of the seed variable was found to have a significant effect on TSS shallot production with a value of 0.289. This variable has a real effect at the α = 0.01 level. This indicates that an increase in the amount of seed use by 1 percent with other inputs remaining can increase TSS shallot production by 0.289 percent. This is consistent with the importance of TSS seeds in increasing yields. This result is in accordance with research conducted by Aziza *et al*. (2022) and Laili (2022); stating that seeds have a positive and significant effect on shallot production in bulbs. Based on the findings at the research location, the most widely used shallot seed in TSS shallot farming in Adipala Subdistrict is the maserati variety which is one of the shallot varieties that has been registered with the Ministry of Agriculture No. 037/Kpts/SR.120/D.2.7/4/2018. The average seed use by respondent farmers is equivalent to 266,733 seedlings per ha or 1,333 trays using 200-hole trays. The implication of this finding is that the Government needs to support the development of TSS (*True Shallot Seed*) seeds to ensure long-term seed availability through cultivation research and development activities. The use of seeds from shallot botanical seeds (*True Seed of Shallot-TSS*) is an innovation that can be a breakthrough in seed technology to overcome the problem of limited seeds as well as an alternative technology to obtain quality shallot seeds. Some of the advantages of TSS compared to seeds in the form of bulbs are relatively longer shelf life and no dormancy period. This makes seeds available throughout the year, saves production costs, produces healthier plants because they are free from seed-borne pathogens, larger bulbs and higher production, the need for lower seed volume, does not require a large storage area, and the price of TSS seeds is relatively stable because it is not influenced by market prices.

Estimation of Labor variable (X_3). The coefficient or elasticity of the labor variable was found to have a real effect on the production of TSS shallots with a value of 0.090 at the α = 0.1 level. This shows that an increase in the amount of labor by 1 percent with other inputs remaining, can increase the production of TSS shallots by 0.090 percent. This is in accordance with research conducted by Muzazin (2022) which states that labor has a positive and real effect on shallot production in Bendo Village, Kediri Regency. Based on the findings at the research location, the average amount of labor used in TSS shallot farming in Adipala Subdistrict is 233 HOK starting from making nursery, land processing, planting, fertilizing, maintenance to harvesting. The implication of government policy that can be taken to increase production in Cilacap Regency is to improve labor skills or labor allocation efficiency through training, *workshops* or *capacity building*.

Estimation of NPK fertilizer variable (X_4). The NPK fertilizer variable has a real effect at the α = 0.10 level with a coefficient or elasticity value of 1.035. This means that every additional NPK fertilizer of 1 percent will increase TSS shallot production by 1.035 percent. These results are consistent with the research of Nurjati (2018), Simatupang *et al* (2021) and Aziza *et al* (2022) which state that NPK fertilizer has a significant effect on increasing shallot production. The NPK fertilizer variable is the most responsive compared to other variables because it has the largest coefficient. Based on the findings at the research location, the average use of NPK fertilizer is 563 kg/ha. This dose is relatively higher than the recommended dose of the government allegedly because the soil type in Adipala Subdistrict is sandy soil that is prone to nutrient leaching so it requires more fertilizer. NPK fertilizers (Nitrogen, Phosphorus, Potassium) are known to be important for increasing shallot growth and yield. Research by Abuga (2014) and Arsadiarta (2024) showed that the right dose of NPK fertilizer can increase wet weight, dry weight, and production of shallot bulbs. The element nitrogen (N) can increase vegetative growth and bulb size, phosphorus (P) helps root development and early growth and potassium (K) supports plant health and disease resistance. The government needs to develop NPK fertilizer recommendations based on varieties and soil conditions. Farmers need to apply the optimal NPK fertilizer dosage based on government recommendations. To increase fertilizer efficiency, the government needs to recommend the addition of organic materials to improve the physical and chemical properties of sandy soil in Adipala sub-district.

Estimation of organic fertilizer variable (X_5). The organic fertilizer variable has no effect on TSS shallot production in Adipala Subdistrict, but the elasticity of frontier production is positive at 0.100. This is in line with the research of Aziza *et al*,. (2022 and Hindarti & Kiromah (2020) which states that organic fertilizer partially has no effect on shallot production. Some possible causes of organic fertilizer application are not significant in increasing shallot production both in terms of technical and management, including improper dosage, time and method of application. Organic fertilizers usually work slower than chemical fertilizers because it takes time to decompose so that the effect has not been seen significantly when viewed in one growing season. Quality also affects the effectiveness of organic fertilizers. Many organic fertilizers/composts are found that are not standard, especially locally made or non-commercial organic fertilizers. Another reason is that the soil in Adipala Sub-district is already quite fertile or has been given high amounts of chemical fertilizers (NPK fertilizers) so that additional organic fertilizers do not have much significant effect. Two years of field research showed that the use of organic fertilizers, including fully decomposed manure, was only able to produce about 24.3% to 48.8% of the yield obtained through NPK fertilization. This finding indicates that the addition of organic matter does not provide a significant yield increase (Brdar-Jokanović *et al*., 2011). Similarly, in another study, the different types of organic fertilizers tested were not able to consistently surpass the yields of conventional fertilization methods, with the organic system producing yields about 43% lower than the conventional system (Júnior *et al*., 2013). Based on the findings at the research site, the average use of organic fertilizer was 13 tonnes/ha. This dose is in accordance with government recommendations of 10-20 tons per ha (equivalent to 1-2 kg/m^2). The implication of this finding is that the government needs to provide training to farmers on the proper application of organic fertilizers (dose, time, and method of application), training on making good organic fertilizers, facilitating soil tests to determine fertilizer recommendations, and monitoring the quality of organic fertilizers circulating in the market.

Estimation of dolomite variable (X_6). The dolomite/agricultural lime variable has a real effect at the $\alpha = 0.05$ level with a coefficient or elasticity value of 0.058. This means that every addition of dolomite by 1 percent will increase TSS shallot production by 1.035 percent. This result is consistent with Muchlisin (2020) and Jayanti (2021) research which states that dolomite application has a significant effect on increasing shallot production. Ilham's research (2019) stated that dolomite application was proven to have a significant effect on shallot production through increasing soil pH, availability of essential nutrients, and improving soil physical and chemical properties. Based on the findings at the research location, the average use of dolomite was 563 kg/ha. The optimal dose varies depending on soil conditions and cultivation methods, but generally ranges from 1.5 tons/ha to 2 tons/ha. The implication of this finding is that the government needs to provide dolomite assistance to improve soil pH, encourage regular soil tests to determine the need for dolomite on farmers' land and training to farmers on the proper dolomite application method (dose, time, and application method).

Pesticide variable estimation (X_7). The pesticide variable has no effect on TSS shallot production in Adipala Subdistrict, but the frontier production elasticity is positive at 0.001. Some studies show that the use of pesticides does not always have a significant effect on shallot production. Research by Sarlan (2020), Nugraha (2022) and Mutiarasari (2019) found that pesticide variables were not significant in influencing shallot production. Based on the studies above, the use of pesticides does not always have a significant effect on shallot production. This can be caused by various factors, such as improper use, inappropriate dosage, or environmental conditions that do not support the effectiveness of pesticides. Based on the findings at the research location, the average use of pesticides in this case insecticides is equivalent to 18 liters/ha. The dose is very excessive and above the recommended dose. The recommended dose of pesticides for shallot crops is highly dependent on the type of pest being targeted (e.g. Thrips, armyworms, leafminers), the active ingredient of the insecticide, product formulation and concentration as well as environmental conditions and crop age. The implication of this finding is that the government needs to provide training to farmers on how to apply the right pesticide (dose, time, and method of application), supervise the distribution and use of pesticides circulating in the market, monitor pest resistance to pesticides regularly, use vegetable / biological pesticides and implement IPM (*Integrated Pest Management*).

3.2.1. Analysis of Technical, Allocative and Economic Efficiency of TSS Shallot Farming

Technical efficiency was analyzed using the stochastic frontier production function model with the Maximum Likelihood Estimate (MLE) estimation method with the frontier 4.1 program while the level of allocative and economic efficiency was analyzed using the dual *cost frontier*. The results of the analysis of technical, allocative and economic efficiency can be seen in Table 4.

The results showed that the average value of technical efficiency of TSS shallot farming in Adipala District was 0.86 with the lowest value of 0.527 and the highest value of 0.996, which means that TSS shallot farming in the research location is technically efficient. Of the 65 farmers, 60 farmers (92%) have reached an efficiency level above 0.700 or 70%. Only a small number of farmers are still at the level of technical efficiency below 70% or still experiencing technical inefficiency in their farms. The average value of technical efficiency in this study is greater than the average technical efficiency of shallot farming in Indonesia based on the findings of Ismiasih and Jamhari (2024) of 0.82, Komariyati (2017) Dringu District in Probolinggo Regency of 0.75, and Febriyanto *et al* (2021) in Demak Regency of 0.84. However, the technical efficiency of TSS shallot cultivation in Adipala Subdistrict is still lower than the research findings of Minarsih *et al* (2019) in Madiun District of 0.903 and Ikrima (2018) in Ngadiboyo Village, Rejoso Subdistrict, Nganjuk District of 0.899.

Table 4 Frequency Distribution of Technical, Allocative and Economic Efficiency of TSS Shallot Farming in Adipala Subdistrict, Cilacap Regency

criteria efficiency level	category	Technical Efficiency		Efficiency Allocative		Efficiency Economy	
		amount	%	amount	%	amount	%
≥ 0,9	Highly Efficient	33	50.8	3	4.6	0	0.0
0,70 ≤ 0,9	Moderately Efficient	27	41.5	30	46.2	2	3.1

< 0,70	Not yet Efficient	5	7.7	32	49.2	63	96.9
average		0,861		0.708		0.601	
minimum value		0,527		0.553		0.521	
maximum value		0,996		0.988		0.751	

The average value of technical efficiency in the research location of 0.861 can be interpreted that Farmers have been able to produce 86.1% of the maximum potential output with the inputs owned and respondent farmers still have the opportunity to obtain higher potential yields to achieve maximum yields as obtained by the most technically efficient farmers. It also shows that overall farmers can increase technical efficiency at the existing level of technology and inputs by 13.9 percent without increasing inputs. Some farmers with low efficiency show great potential for improvement. Farmers in Adipala can improve efficiency only by adopting practices from more efficient regions, such as input optimization (e.g. by reducing excess fertilizer) and by improving the way in which inputs are used such as planting method, dosage and timing of fertilization, optimizing the use of seeds and labour. The influence of other factors (vi) that cannot be controlled by TSS shallot farmers such as pests, diseases, land fertility, temperature, and climate is quite small at only 0.1% due to the large gamma value (99.9 percent).

The allocative and economic efficiency in this study was obtained through analysis of the production input side using the input and output prices of the farmers. Based on the interview results, the following results were obtained: the average price of land rent is 2,015,385 (Rp/ha/season), the average price of seeds is 125 (Rp/stick), the average price of labor is 96,923 (RpHOK), the average price of NPK fertilizer is 9,680 (Rp/kg), the average price of organic fertilizer is 502 (Rp/kg), the average price of dolomite is 876 (Rp/kg) and the average price of pesticides is 3,617 (Rp/ml).

The average value of allocative efficiency of TSS shallot farming in Adipala Subdistrict, Cilacap Regency is 0.70 with the lowest efficiency value of 0.55 and the highest value of 0.98 mostly in the range of 0.60 to 0.80 and there are only five farmers who are above 0.80. This means that respondent farmers have only allocated inputs in a cost-outcome manner of 70.8% of the optimal conditions. There are still inefficiencies in selecting or combining inputs in terms of price, for example, farmers may use too many expensive fertilizers/pesticides, or use seeds/labor that are not proportional to the yield. The average value of allocative efficiency of 0.70 means that if the average respondent farmers can achieve the highest level of allocative efficiency, then they can save costs by 28.34 percent (1 - 0.70/0.98), while the least efficient farmers, they will be able to save costs by 44.02 percent (1- 0.55/0.98).

The average value of economic efficiency in TSS shallot farming in Adipala Subdistrict, Cilacap Regency is 0.60 with the lowest efficiency value of 0.52 and the highest value of 0.75 mostly in the range of <0.70 and there are only four farmers who are in the range of 0.70 ≤ 0.9. This shows that overall, respondent farmers' farms are only 60.1% economically efficient. There is still an opportunity for 39.9% economic efficiency, by improving cultivation techniques and input cost planning. The average value of allocative efficiency of 0.60 means that if the average respondent farmer can achieve the highest level of economic efficiency, then they can save costs by 20.00 percent (1 - 0.60/0.75), while the least efficient farmers, they will be able to save costs by 30.67 percent (1- 0.52/0.75).

Based on the technical, allocative and economic efficiency values of 0.86, 0.70 and 0.60 respectively, it shows that TSS shallot farming in Adipala Subdistrict, Cilacap Regency is technically and allocatively efficient but not economically efficient. The value of technical efficiency is greater than the value of allocative and economic efficiency (ET>EA>EE) so this shows a case that is quite common in traditional or semi-modern agricultural cultivation practices where farmers can farm well technically but still not optimal economically and cost allocation. High technical efficiency of 0.86 means that farmers are able to use inputs well to physically produce outputs. For example, they can cultivate the land, set planting patterns, and utilize labor/fertilizers productively enough to produce an optimal amount of shallots. Allocative efficiency measures how optimally inputs are used in relation to input prices. If EA is lower than ET, then farmers have not fully chosen the cheapest or most cost-beneficial combination of inputs. Farmers are good at farming, but they are still not careful in choosing how much fertilizer or labour is appropriate for the price and its contribution to yield. Farmers use inputs that are expensive or not cost-efficient. For example, using excessive amounts of expensive fertilizers that are not necessary. using expensive fertilizers because they are "used to it", when there are cheaper & more effective ones. It could also be too much labor, or overdosing on fertilizers/pesticides. Economic efficiency combines technical and allocative efficiency. If the EE is the lowest, it means that overall, farmers have not been able to optimize their profits or production costs. Although the farmer can produce a lot, the costs incurred are still too high compared to the minimum potential costs for the yield. From the discussion above, it can be concluded that TSS shallots in Adipala Subdistrict can technically plant and harvest well, but are not yet cost efficient because they are not optimal in choosing a combination of inputs based on prices (allocative) and finally not maximized in reducing total costs to achieve profits (economic).

3.2.2. Technical Inefficiency of TSS Shallot Farming in Adipala Subdistrict, Cilacap Regency

Inefficiency in farming basically arises because of the assumption that farmers behave to maximize profits in running their farms (Adiyoga, 1999). The results of the calculation of the technical efficiency of TSS shallot farming in Adipala Subdistrict show that the average respondent farmer in the research area is technically efficient. However, if farmers want to improve the technical efficiency of their farms, it can be done by increasing the use of production inputs that have a real effect on production and paying attention to the factors that cause inefficiency. A negative sign on the inefficiency parameter indicates that the variable decreases technical inefficiency or in this case increases technical efficiency. Conversely, a positive sign indicates that an increase in the variable will increase technical inefficiency or decrease technical efficiency. Differences in efficiency can be caused by various factors that differ among farmers, among others: socioeconomic, infrastructure and environmental factors.

Analysis of the sources of technical inefficiency of TSS shallot farming was estimated using the *stochastic frontier* production model. The gamma value of 0.99 indicates that the error term only comes from the inefficiency effect and not from noise, so it is important to analyze the factors that affect technical efficiency. The inefficiency effect is the error term of the modeled production function. The estimation results using the inefficiency effect model of the stochastic frontier production function can be seen in Table 5. The value of technical efficiency is inversely related to the effect of technical inefficiency and is only used for functions that have a certain number of outputs and inputs (cross section data). The inefficiency effect model used refers to the inefficiency model developed by Battese and Coelli (2005).

Table 5 Parameter Estimation Results of the Technical Inefficiency Effect Model of the Stochastic Frontier Production Function of TSS Shallot Farming in Adipala District, Cilacap Regency

variable	parameters	coefficient	standard error	t-count	
Constant	δ0	-3,.8025	1.07387	-3.52022	***
Age (Z1)	δ1	0.78508	0.2112	3.71726	***
Education (Z2)	δ2	0.37046	0.13686	2.70686	***
Experience (Z3)	δ3	0.09463	0.07844	1.20631	ns
Counseling (Z4)	δ4	-0.89119	0.15685	-5.68188	***
Land status (Z5)	δ5	0.28697	0.14118	2.03271	***

Notes: *** significant at α 0.01 level (1%), ** significant at α 0.05 level (5%), ; * significant at α level 0.10 (10%)

Unlike the production function, which is determined by the use of production inputs, the inefficiency function is determined by factors other than inputs related to the managerial aspects of farmers. The estimation of the inefficiency function is a simultaneous result that is processed together with the production function using the Cobb-Douglas model with the MLE method. The factors that allegedly affect technical inefficiency are age (Z_1), education (Z_2), length of farming experience (Z_3), following extension (Z_4) and land status (Z_5).

Variables that significantly affect the technical inefficiency of TSS shallot cultivation in Adipala Subdistrict, Cilacap Regency are age, education, counseling, land status. While the variable experience in shallot farming is statistically insignificant.

Farmer age (Z_1). Farmer age variable has a positive and real effect at the α = 0.01 level on technical inefficiency with a coefficient value of 0.78. The age variable shows a real effect on the level of inefficiency of shallot farming TSS at the α level of 1 percent. The age variable is positive, meaning that the older the age of the farmer, the more inefficiency will increase (the more inefficient) in conducting TSS shallot farming. Based on interviews, the average age of respondent farmers is dominantly 36-45 years old and 96.6% are still in productive age (<66 years old). Some studies show that the older the age of farmers, the technical efficiency tends to decrease as in the research of Ismiasih & Jamhari (2024) in a national study with the 2013 Agricultural Census data using a stochastic frontier found that the coefficient of the farmer age variable on the technical inefficiency function is positive and significant (t-ratio 7.19) meaning that high age increases the technical inefficiency of shallot farming throughout Indonesia. Research by Cordanis *et al* (2022) in Reok - East Nusa Tenggara also shows that the age factor has a positive effect on technical inefficiency, the older the farmer, the lower the technical efficiency at the α level of 5 percent. This is thought to be because older farmers tend to be less responsive to new technologies and practices, making it difficult to reach the efficiency frontier (Brown, 2019), and field work on shallots requires intensive labor where advanced age reduces the physical ability to optimize input use (Ismiasih & Jamhari, 2024).

Education (Z_2). Education is measured based on the amount of time (years) taken by farmers in carrying out their formal education period (elementary school, junior high school, middle school, college). The statistical results showed that the farmer education variable had a positive and real effect at the level of α = 0.01 on technical inefficiency with a coefficient value of 0.37. The education variable shows that education has a real effect on the level of inefficiency of TSS shallot farming at the α level of 1 percent. The education variable is positive, meaning that the higher the education of farmers, the more inefficiency will increase (the more inefficient) in conducting TSS shallot farming. Based on the results of the interview, it is known that the average respondent farmer has a low education (dominated by junior high school to below), several previous studies have found that higher formal education correlates with increased technical inefficiency (or decreased efficiency) in shallot farming. This is evident in various regions, such as in the research of Wijaya (2023) who found that every additional year of formal education of farmers increases the technical inefficiency of shallot farming in Gebang District, Cirebon Regency. In a study in Bantul, Lisa *et al*. (2017) found that education is among the socioeconomic factors that affect technical inefficiency at the 15 percent significance level. It is suspected that highly educated farmers often treat farming as a side job, not a main job (Muhaimin & Abdul, 2020). This is consistent with other findings, such as the study by Saptana *et al*. (2001), that farmers with higher education tend to have other jobs, such as village government employees, teachers, or traders, so they do not fully focus on agricultural businesses. Another suspicion is that formal education generally does not include technical material on agricultural cultivation, so graduates do not automatically acquire input application and crop management skills.

Farming experience (Z_3). Farmer experience variable does not significantly affect technical inefficiency with a positive coefficient value of 0.37. The phenomenon of experience not having a real effect is also confirmed by a number of other studies in Indonesia, both on shallots and rice commodities, which confirm that the length of farming experience does not always increase efficiency. Research by Monica *et al*. (2021) in Adipala District, Cilacap Regency, found the t-count of farming experience = -0.017 < t-table, meaning that experience has no significant effect on the technical inefficiency of shallot farming. Research by Andriyani *et al*. (2023) in another region also mentioned similar results, that farmers without long experience can still achieve technical efficiency thanks to a gradual learning process in the field. Mulyana *et al*. (2020) and Cordanis *et al*. (2022) also reported that farming experience has little effect on the production activities of horticultural commodities, including shallots. Based on the results of the interview, it is known that the experience of respondent farmers in shallot cultivation is less than 1 year by 83 percent and only 17 percent are more than 4 years where almost all farmers live in one agroecosystem with uniform cultivation practices, so the difference in experience does not produce a big advantage. Information on shallot cultivation techniques is generally structured enough to be delivered by extension workers, so that even new farmers can achieve technical efficiency by following the standards/guidelines provided.

Extension (Z_4) . Extension allows farmers to access knowledge, skills, and technology. Farmer extension variable has a significant effect at the level α = 0.01 on technical inefficiency with a coefficient value of -0.89. The extension variable has a negative sign, meaning that the more often farmers follow the extension, the less inefficiency (more efficient) in conducting TSS shallot farming. Based on the interview results, it is known that the average respondent farmer gets 1-2 times of counseling per month. Various studies have shown that farmers' participation in extension activities reduces the level of technical inefficiency in shallot farming. The study of Moekani *et al*. (2023) on shallot millennial farmers in Bantul regency found that the dummy of extension participation has a negative coefficient and significantly affects technical inefficiency at the 5% significance level. This is consistent with Satrio's (2017) findings that the role of extension workers and the activeness of farmer groups increase technology adoption, thereby reducing input wastage and technical inefficiency. Taking into account the empirical evidence above, agricultural extension is one of the effective strategies to improve technical efficiency and reduce inefficiency in shallot farming.

Land status (Z_5). *Dummy* variable land status has a significant effect at the level of α = 0.01 on technical inefficiency with a coefficient value of -0.28. Based on the results of the interview known 45 farmers respondents (69.23%) farmers cultivate their own land the remaining 20 farmers respondents (30.76%) farmers rent. Variable land status is positive, meaning that the status of rental land can increase technical inefficiency in other words reduce technical efficiency. This is in line with the research of Ersa Monica *et al*. (2021) in Adipala District (58 respondents) showed that the land ownership dummy has a positive and significant coefficient at α 5% on the technical inefficiency function, meaning that rental land status contributes to increasing the inefficiency of shallot farming. Indrayana's (2017) study on shallots found that rental land status inhibits investment in balanced fertilization, so technical inefficiency increases on land that is not owned. In general, the high inefficiency of farming on land with a rental system is suspected that farmers are reluctant to make soil improvements through the application of organic fertilizers due to short-term contracts (one planting season), so that soil fertility decreases and inputs are not optimally utilized. Research by Gultom *et al*. (2014) showed that farmers who farm on their own land will exploit their land with optimal inputs to produce maximum production. In addition, rental fees are billed every planting season, increasing the burden of fixed costs so that the allocation of variable costs is not optimal and causes inefficiency.

4. Conclusion

- The variables that significantly influence the production frontier in TSS red onion farming in Adipala District, Cilacap Regency are land area, number of seedlings, number of workers, NPK fertilizer, and organic fertilizer. The most responsive variable is land area. Meanwhile, organic fertilizer and pesticides do not affect TSS red onion production.
- The average TSS red onion farmers in Adipala Subdistrict, Cilacap Regency, are technically and allocatively efficient but not economically efficient, with average technical, allocative, and economic efficiency of 0.86, 0.70, and 0.60, respectively.
- External factors that significantly reduce technical inefficiency include the frequency of extension services, while age, education, and land tenure status influence increases in technical inefficiency. Farming experience does not influence increases in technical inefficiency.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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