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# The Effect of Conservation Use on Technical Efficiency of Carrot Farming in East Java, Indonesia

**Muhammad Diffa Imanullah[1♥], Rosihan Asmara[2], and Fahriyah[2]**

[1] Master of Agricultural Economics Study Program, Agriculture Faculty, Brawijaya University, Malang, Indonesia
[2] Department of Agricultural Socioeconomics, Agriculture Faculty, Brawijaya University, Malang, Indonesia
♥Corresponding author email: diffa1999@gmail.com

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**Abstract**. East Java Province, one of the carrot centers, experiences fluctuations in carrot production, which is thought to be due to inefficient production factors and land degradation due to low conservation use. The study investigates the level of conservation activities adopted by carrot farmers in East Java Province, focusing on technical efficiency and the impact of socio-economic factors on this efficiency. This study was conducted purposively in Sumberbrantas Village, Batu City, and Wonokerso Village, Probolinggo Regency, using a simple random sampling method with data collection through interviews. The analysis method used was the Likert scale scoring method for the level of conservation adoption by farmers, stochastic frontier analysis using the Cobb-Douglas function with maximum likelihood estimate (MLE), and tobit regression analysis to determine the effect of conservation on technical efficiency. Results show that conservation adoption is mostly low, with factors like land, chemical fertilizers, organic fertilizers, pesticides, and labor positively affecting production. The average level of technical efficiency is 0.4970, with location and education having a significant positive effect. Conservation variables do not have a significant effect.

**Keywords:** carrot farming; conservation agriculture; East Java; stochastic frontier analysis; technical efficiency

## INTRODUCTION

Population growth will increase the demand for food (Miladinov, 2023). Food is one of the important needs for humans. Providing sufficient food will create quality human resources in a region (Rumawas et al., 2021). The increase in demand for food in Indonesia is a serious challenge in food policy. According to Arifin et al. (2019), the increase in demand for food in Indonesia is 4.03% per year. If food production in Indonesia is unable to meet food demand, one solution that can be done is to import. However, several things need to be considered when importing.

One of the leading commodities in the agricultural sector and widely consumed by the Indonesian people is carrots. Carrots are one type of plant that farmers commonly plant because they have high value and low maintenance (Pariasa & Hardana, 2023). Carotenoids, phenolic chemicals, polyacetylenes, and vitamins are abundant in carrots, which may help lower the risk of some diseases (Varshney & Mishra, 2022). One of the centers of carrot production is in East Java Province. From 2021 to 2022, carrot consumption in Indonesia increased by 5.53%, but the supply of carrots in Indonesia decreased by 38.93% (Pusat Data dan Sistem Informasi Pertanian, 2022). In addition, carrot production in East Java fluctuated from 2019-2022 (BPS, 2023). Production in 2020 decreased by 11.66% even though the harvested land area increased by 5.39% from 2019. Meanwhile, in 2021, carrot production increased by 14.01%, but the harvested land area decreased by 45.35% compared to 2020.

This production fluctuation is thought to be due to carrot farmers in East Java not carrying out their carrot farming efficiently. Inefficient farming activities will cause farmers to lose the opportunity to increase their income (Chaira et al., 2024). Inefficiency occurs because the farmer does not use their production factors optimally. Technical efficiency is the ability of a farm to use minimum inputs to produce maximum output at a certain level of technology, and technical efficiency analysis is used to

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determine the extent to which a farm operation deviates from the production function at a certain technology (Ivanni et al., 2019). Previous research on technical efficiency was conducted by analyzing the influence of production factors, such as land area, seeds, chemical fertilizers, pesticides, and labor, on farmer farming production so that the level of technical efficiency of farmers was obtained which was then analyzed to find out what factors, such as age, number of family members, education, and special variables studied, affect farmer efficiency (Abunyuwah et al., 2019; Sari et al., 2019). The results of this study can then be considered to increase farmer production and efficiency, thereby increasing farmer income.

Carrot farming is carried out in highland areas. Farmers generally plant carrots on sloping land. The use of sloping land for farming activities will have a high risk of erosion (Senoaji et al., 2022). Erosion will cause land degradation. Land degradation, which can be caused by nature and humans, is a decrease in land productivity that can be temporary or permanent (Mahata & Sharma, 2021). Land degradation can be the cause of fluctuations in carrot production in East Java, especially because carrot farmers farm on sloping land. Prevention or improvement of land degradation is carried out through conservation agriculture. Conservation agriculture is a crop management technique that uses less tillage and keeps crop residues on the surface to protect soil, which focuses on conserving resources by enhancing biological and natural processes above and below ground (Adhikary et al., 2020). Previous research by Hanani et al. (2013) and Sholeh (2014) In one village in East Java, it was shown that the level of conservation use by farmers was still low, even though farmers were in areas with sloping land.

Many studies have been conducted on the effect of conservation on farmers' technical efficiency. Examples include research by Paz et al. (2024) on farmers in Bangladesh and Singh et al. (2024) on farmers in India, where the use of conservation can increase technical efficiency. However, research by Li et al. (2019) found that payments for conservation reduced farmers' technical efficiency. This study contributes to the literature on how conservation affects farmers' technical efficiency in Indonesia, especially in carrots. The objectives of this study were to determine the level of adoption of conservation activities that had been carried out by carrot farmers in East Java, analyze the level of technical efficiency of carrot farmers in East Java, and analyze the effect of the level of adoption of conservation activities and socio-economic factors of farmers on the technical efficiency of carrot farmers in East Java.

## METHODS

This study was conducted in Sumberbrantas Village, Batu City, and Wonokerso Village, Probolinggo Regency, which were selected purposively. The reason for choosing these two villages was that they are located in the highlands with carrot farming in the highlands and are agricultural center areas. This study was conducted from July to November 2023. The population selected from both villages was carrot farmers with a planting season between 2022 and 2023. The sample size was determined by the simple random sampling method and by the Slovin formula method; 79 sample farmers were determined. Data collection method through interviews in the form of questionnaires with respondents.

Determination of the level of use of conservation activities is carried out using the Likert scale scoring method based on research by Hanani et al. (2013) and Sholeh (2014). The initial step in measuring with this method is to provide a score that has a Likert scale, where each answer to the existing variables is given a certain score to make it easier to measure the level of each variable. In this study, the Likert scale scoring method has 7 indicators, namely the use of terraces, annual plants, terrace strengthening plants,

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infiltration channels, drainage channels, manure, and litter. Each indicator has a score of one to five, where 1 if there is no use, 2 if use is on 1-25% of carrot farming land, 3 if use is on 26-50% of carrot farming land, 4 if use is on 51-75% of carrot farming land, and 5 if use is on more than 75% of carrot farming land. The scores of each indicator are then added to obtain a total score to determine the high or low category of the level of conservation adoption by farmers, with a minimum total score of 7 and a maximum of 35. The interval between the high and low categories was determined using the Sturges formula, where the interval between categories was 14. The level of conservation adoption is considered low if farmers have a score between 7 and 20. While farmers are supposed to have a high level of conservation adoption if they have a score between 21-35

The production function used in this study is the Cobb-Douglas production function. The dependent variable is carrot production (Kg) in one planting season, while the independent variables are production factors used by farmers in one planting season in the form of land area (M2), carrot seeds (Kg), chemical fertilizers (Kg), organic fertilizers (Kg), liquid pesticides (Lt), solid pesticides (Kg), and labor (HOK). The stochastic frontier model of the Cobb-Douglas production function is on equation (*1.*

$$LnY = \beta_0+\beta_1 lnLA+\beta_2 lnCS+ \beta_3 lnCF+ \beta_4 lnOF+\beta_5 lnLP+ \beta_6 lnSP+\beta_7 lnLB+ v_i-u_i \quad (1)$$

Where:
Y = Carrot production output (Kg)
$\beta_0$ = Constant/intercept
$\beta_i$ = Parameter of input
LA = Land area ($M^2$)
CS = Carrot seeds (Kg)
CF = Chemical fertilizers (Kg)
OF = Organic fertilizer (Kg)
LP = Liquid pesticides (Lt)
SP = Solid pesticides (Kg)
= Labor (HOK)
$v_i$ = Disturbed random error
$u_i$ = One-sided error term

The Cobb-Douglas production function will then be analyzed using stochastic frontier analysis to estimate the technical efficiency level of sample farmers. The estimation of the technical efficiency level based on Coelli et al. (2005). The model (*2* is:

$$TE = Y_i/y_i = exp(-u_i) \quad (2)$$

Where:
TE = Technical Efficiency
$Y_i$ = The amount of production at i
$y_i$ = The amount of predicted production at observation i through the production function
$u_i$ = One-sided error term

The results of the technical efficiency analysis are between 0-1 or 0<TE<1. These results are then used in the tobit regression analysis to determine the effect of conservation on technical efficiency. In addition to the conservation use variable, other variables are also used in the tobit regression analysis, such as farmer age (years), number of family members (people), land type dummy (1=irrigated land, 0=dry land), and location dummy (1=Batu, 0=Probolinggo). The equation in the tobit regression analysis is on formula (*3* .

$$TE = \delta_0 + \delta_1 CON + \delta_2 AGE + \delta_3 FAM+ \delta_4 LOC + \delta_5 EDU.. \quad (3)$$

Where:
TE = Technical Efficiency
$\delta_0$ = Constant/intercept
$\delta_i$ = Coefficient
CON = Dummy Conservation (1=Conservation adoption high, 0=Conservation adoption low)
AGE = Age (years)
FAM = Number of family members (people)
LOC = Dummy location (1=Batu, 0=Probolinggo)
EDU = Education (years)

## RESULTS AND DISCUSSION

The use of conservation in sample farmers is assessed by giving scores on the

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use of terraces, planting of annual plants, planting of terrace-strengthening plants, use of infiltration channels, use of drainage channels, use of manure, and use of litter. Table 1 shows the distribution of the use of conservation in respondent farmers

**Table 1.** Distribution of the use of conservation

| Level | Farmers (People) | | | | | | |
|---|---|---|---|---|---|---|---|
| | terrace | annual plants | terrace-strengthening plants | infiltration channels | drainage channels | manure | litters |
| >75% | 13 | 8 | 11 | 16 | 18 | 42 | 21 |
| 51-75% | 5 | 8 | 9 | 12 | 12 | 19 | 9 |
| 26-50% | 3 | 8 | 6 | 6 | 7 | 4 | 1 |
| 1-25% | 5 | 26 | 23 | 33 | 36 | 1 | 10 |
| Nothing | 53 | 29 | 30 | 12 | 6 | 13 | 38 |
| Total | 79 | 79 | 79 | 79 | 79 | 79 | 79 |

The use of terraces, planting of perennial crops, and planting of terrace-strengthening plants are mostly not used. The reason farmers do not use terraces on carrot farming land is that it requires large costs and labor to make them. This is in accordance with research by Oladele et al. (2020), where one of the reasons farmers do not use conservation is because of inadequate costs and resources. Meanwhile, planting of perennial crops and terrace-strengthening plants is not carried out due to concerns about competition between plants on the land which will reduce production. According to Swieter et al. (2022), there is competition between plants for conservation and cultivated plants regarding space, nutrients, water, and light. This competition can be minimized by determining the planting distance between conservation plants and cultivated plants.

The use of infiltration channels and drainage channels is highest at 1-25% of carrot farming land. Even so, there are still farmers who do not use infiltration channels and drainage channels. Farmers are expected to use infiltration channels and drainage channels because they function to reduce excessive water discharge from damaging the plants, which can reduce productivity (Sholeh et al., 2020; Suhardi et al., 2024). In the use of manure, there are still some farmers who do not use it. The reason farmers do not use manure is that in the previous planting season, they have used manure, and there are concerns about the excessive use of manure. According to Hays et al. (2023), excessive use of manure will cause the loss (runoff) of N and P elements which can cause water pollution. The use of litter is highest in the none category. This is because farmers still do not understand the use of litter on their land.

The level of conservation adoption by carrot farmers is categorized into two, namely high and low. The level of conservation adoption is considered low if farmers have a score between 7 and 20. While farmers are considered to have a high level of conservation adoption if they have a score between 21-35.

**Table 2.** Distribution of conservation adoption level by category

| No | Category of Adoption Level | respondents | |
|---|---|---|---|
| | | People | % |
| 1 | Low | 44 | 55.70 |
| 2 | High | 35 | 44.30 |
| | Total | 79 | 100 |

According to Table 2, most carrot farmers are in the low conservation adoption category, which is 44 people or 55.70% of all respondent farmers. The remaining 44.30% are in the high adoption category. This low level of conservation adoption is caused by

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the use of conservation requiring large capital and labor and concerns about competition in plants on the land, which reduces production results.

The technical efficiency analysis was carried out using Stochastic Frontier Analysis (SFA) using Front 4.1 software with Maximum Likelihood Estimated (MLE) to analyze the effect of production factors on carrot production. The

Table ***3*** is the result of the production function estimation. The likelihood ratio-test (LR Test) value of 22.323 is greater than the Codde-Palm value of 8.273 at the 1% level. The LR Test value which is greater than the Codde-Palm value means that the model used in this study is good and there is an influence of inefficiency (Ahdiningtyas et al., 2022). This is also supported by the Sigma-squared value, which is 1.631, which is greater than 0 and significant at the 1% level, which means that the model used has an influence of technical inefficiency (Hayati et al., 2024). The gamma value is the ratio between production variations caused by inefficiency and uncontrollable variables (Widyantari et al., 2023). The gamma value of 0.999 which is significant at the 1% level means that 99% of the variation in carrot production is due to farmer inefficiency and the remaining 1% is due to uncontrollable variables (such as natural disasters, climate, pests, diseases, etc.).

**Table 3.** Estimation of the production function

| Variable | Parameter | Maximum Likelihood Estimation (MLE) | | | |
|---|---|---|---|---|---|
| | | Coef | Std. error | T-ratio | |
| Intercept | $\beta_0$ | 4.003 | 0.430 | 9.308 | |
| Land Area | $\beta_1$ | 0.532 | 0.058 | 9.227 | *** |
| Carrot Seeds | $\beta_2$ | 0.058 | 0.080 | 0.724 | |
| Chemical Fertilizers | $\beta_3$ | 0.062 | 0.034 | 1.858 | * |
| Organic Fertilizers | $\beta_4$ | 0.030 | 0.009 | 3.474 | *** |
| Liquid Pesticides | $\beta_5$ | 0.055 | 0.027 | 2.019 | ** |
| Solid Pesticides | $\beta_6$ | 0.029 | 0.016 | 1.862 | * |
| Labor | $\beta_7$ | 0.203 | 0.050 | 4.078 | *** |
| *Sigma-squarred* | σ | 1.631 | 0.322 | 5.060 | *** |
| *Gamma* | γ | 0.999 | 0.000 | 130583 | *** |
| LR Test | | | 22.323 | | *** |

Source: Primary Data (2023)
Notes: *** if significant at 1% level (> T-table = 2.647), ** if significant at 5% level (> T-table = 1.994), * if significant at 10% level (> T-table = 1.667)

The land variable has a positive and significant effect at the 1% level with a coefficient of 0.532, which means that an increase in the use of land area by 1% will increase carrot production by 0.532%. This result is in accordance with previous research (Ayeni et al., 2023). The average area of farmer's land is 5,610 m2. The chemical

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fertilizer variable has a positive and significant effect at the 10% level with a coefficient of 0.062, which means that an increase in the use of chemical fertilizers by 1% will increase carrot production by 0.062. This result is in accordance with research by Samarakoon et al. (2022). The organic fertilizer variable has a positive and significant effect at the 1% level with a coefficient of 0.030, which means that an increase in the use of organic fertilizers by 1% will increase carrot production by 0.030%. This result is in accordance with previous research (Nurfita & Tamami, 2023). The average use of chemical and organic fertilizers by farmers is 271.5 Kg and 2,515 Kg respectively. Although the use of organic fertilizers is greater than chemical fertilizers on average, some farmers use more chemical fertilizers than organic fertilizers. Farmers assume that the use of organic fertilizers from the planting season before carrots is sufficient for the land so that in the carrot planting season they only use a little organic fertilizer.

The liquid pesticide variable has a positive and significant effect at the 5% level with a coefficient of 0.055, which means that an additional 1% use of liquid pesticides will increase carrot production by 0.055%. These results are in accordance with previous research (Edison, 2021). The average use of liquid pesticides by farmers is 4.56 liters and the type of liquid pesticide widely used by farmers is insecticide. The solid pesticide variable has a positive and significant effect at the 10% level with a coefficient of 0.029, which means that an additional 1% use of solid pesticides will increase carrot production by 0.029%. This result is different from the research by Yusnina et al. (2024), where solid pesticides have a negative effect on production. This positive result means that the use of solid pesticides is still below the safe limit. The average use of solid pesticides by farmers is 6.43 kg and the type of solid pesticide widely used by farmers is fungicide. This means that the pests that often attack farmers are insects and fungi. The labor variable has a positive and significant effect at the 1% level with a coefficient of 0.203, which means that an additional 1% use of labor will increase carrot production by 0.203%. These results are in accordance with research by Waty et al. (2021). The average use of labor by farmers is 82.5 HOK.

The technical efficiency value is obtained through the results of stochastic frontier analysis with Front 4.1 software. The results are grouped in Table ***4***.

**Table 4.** Distribution of technical efficiency

| Technical Efficiency | Respondents (People) | Percentage (%) |
|---|---|---|
| <0.501 | 48 | 60.76 |
| 0.501-0.600 | 8 | 10.13 |
| 0.601-0.700 | 4 | 5.06 |
| 0.701-0.800 | 5 | 6.33 |
| 0.801-0.900 | 5 | 6.33 |
| >0.900 | 9 | 11.39 |
| Total | 79 | 100 |
| Average | 0.497 | |
| Maximum | 0.999 | |
| Minimum | 0.058 | |

Source: Primary Data (2023)

Table ***4*** indicates that carrot farming in Sumberbrantas and Wonokerso Villages is still not technically efficient (TE<1). The average level of technical efficiency of

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farmers is 0.497 and as many as 48 farmers have a technical efficiency value below 0.5. According to BPS (2015), a technical efficiency value below 0.5 is categorized as a low level of technical efficiency. This means that farmers are still not using production factors, such as land, fertilizer, and labor, efficiently, which causes low carrot production.

Table ***5*** is the result of tobit regression analysis. The pseudo r-square value of 0.6809 means that 68.09% of the variation of the dependent variable in the form of technical efficiency value can be explained by the independent variables in the form of conservation adoption level, age, number of family members, type of land, and location.

Tobit regression analysis was used to determine the factors that affect the technical efficiency of carrot farmers. Tobit regression analysis was performed using Stata software. The

The prob>chi2 value of 0.0312 means that the variables of conservation adoption level, age, number of family members, type of land, and location have a simultaneous effect on farmers' technical efficiency. While partially, only the location and education have a significant effect.

**Table 5.** Estimation of tobit regression

| Variable | Parameter | Coef | Probability | |
|---|---|---|---|---|
| Intercept | $\delta_0$ | 0.1305326 | 0.448 | |
| Conservation | $\delta_1$ | -0.0631706 | 0.561 | |
| Age | $\delta_2$ | 0.0018816 | 0.433 | |
| Number of Family Members | $\delta_3$ | 0.0188565 | 0.498 | |
| Location | $\delta_4$ | 0.1523877 | 0.013 | ** |
| Education | $\delta_5$ | 0.0167627 | 0.084 | * |
| Prob > chi2 | | 0.0312 | | |
| Pseudo R2 | | 0.6809 | | |

Source: Primary Data (2023)
Notes: ***) Significant at 1% level, **) Significant at 5% level, *) Significant at 10% level

The variable of conservation adoption level has a not significant and negative effect on the technical efficiency of carrot farmers. This result is contrary to several previous studies (Adhi et al., 2022; Teng et al., 2023). The negative effect of the use of conservation is thought to be due to the low level of conservation adoption by farmers so that its use is not optimal, causing farmers to be inefficient. According to Oduol et al. (2011), there are several things that cause the adoption of conservation activities to have a negative effect. The first is that the benefits of adopting conservation activities are in the long term so that the benefits cannot be felt in the short term, especially if its use is only new and less than optimal. Then in using conservation activities, it costs a lot of money and labor, thus eliminating the benefits of adopting conservation activities. And the last is that in implementing conservation activities, assistance from extension workers and experts is needed so that in its implementation it will benefit.

The location dummy variable has a significant and positive effect on farmers' technical efficiency at the 5% level. This means that farmers in Batu City are more technically efficient than farmers in Probolinggo Regency. The results of this tobit regression analysis are in accordance with research by Dagar et al. (2018). One of the reasons farmers in Batu City are more efficient than farmers in Probolinggo Regency is because the location of farmers in Sumberbrantas Village, Batu City, is at an altitude of 1,200 meters above sea level which is at the optimal altitude for carrot growth (Fajaryanto & Purnamaningsih, 2020). According to Košařová & Urbaníková (2024), differences in the level of technical efficiency between the two regions can occur

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due to several factors, such as access to resources, level of technology adoption, policies, and market conditions.

The education variable has a significant and positive effect on the technical efficiency of farmers at the 10% level. This means that the higher the education of farmers, the more efficient the farmer is compared to other farmers. This is in accordance with research by Ali et al. (2022). According to Arifin et al. (2021), farmers who have higher education have a faster and wider network of information access. From faster and wider access to information, farmers will find it easier to obtain information and knowledge about technology that can make their farming more efficient.

## CONCLUSION

The level of conservation adoption among carrot farmers is mostly at a low level, which is 44 farmers or 55.70% of respondent farmers. This low level of use occurs because of the high capital needed for the implementation of conservation and the concern about a decrease in carrot production when using conservation activities. In the stochastic frontier analysis, the variables that have a significant and positive effect on carrot production are land, chemical fertilizers, organic fertilizers, liquid pesticides, solid pesticides, and labor. The average level of technical efficiency of carrot farmers is 0.4970 which is included in the low level of technical efficiency of farmers. Tobit regression analysis found that the level of conservation adoption did not have a significant effect on the technical efficiency of farmers, while location and education had a significant and positive effect on technical efficiency.

Several things can be recommendations for policy makers and related agencies. The first is the provision of appropriate subsidies for fertilizers and pesticides for farmers. Then a comparative study can be conducted between farmers from Probolinggo Regency and farmers from Batu City so that there is an exchange of information that can increase the technical efficiency of farmers. And the last is to involve highly educated farmers as an example in the use of new technology that can increase the efficiency and income of farmers so that other farmers can follow in adopting the new technology to improve their welfare.underway.

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