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Levels And Factors Influencing The Technical Efficiency Of Carrot Farming in East Java, Indonesia

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Abstract. Carrots are a horticultural agricultural product with good prospects for development in East Java with a harvest area of 4,495 Ha and production of 8,9847 Tons. Apart from that, the increase in carrot consumption figures increased from 2021 by 1,354 kg.capita^{-1}.year^{-1} to 1,429 kg.capita^{-1}.year^{-1} in 2022. However, the productivity of carrot farming in East Java experiences fluctuations every year, which is influenced by production factors, so it cannot keep up with ever-increasing demand. This research aims to determine the level of technical efficiency of carrot farming and the factors that influence it. The methods used are Data Envelopment Analysis (DEA) and Tobit regression. The research was conducted in Sumberbrantas and Wonokerso villages for 3 months, from July 2023 to October 2023. Sampling using the simple random sampling method. The research results show that carrot farming in East Java has still not reached the full level of technical efficiency, with an average VRS of 0.826. The opportunity to increase technical efficiency is 0.174 by improving the input combination to suit already technically efficient farmers. Factors that significantly influence the technical efficiency of carrot farming in East Java are land area, experience, and dummy land ownership status. Meanwhile, age, education and number of family dependents do not significantly influence the level of technical efficiency.

Keywords: carrot farming; data envelopment analysis (DEA); horticulture; technical efficiency; tobit regression

INTRODUCTION

Agriculture is the use of biological resources by humans in an effort to produce food, industrial raw materials, or energy sources, as well as to manage the environment. Agriculture is the most important sector in Indonesia. In the agricultural sector, the types of plants grown in Indonesia are very diverse, from forestry, plantation, food and horticultural crops. Horticulture is a cultivation activity such as vegetables, fruit or ornamental plants carried out in gardens or yards. One of the vegetable horticultural crops that has very good business prospects is carrots.

Carrots are vegetables that contain vitamins that are useful for health and are usually processed into food and liked by people. Carrots are subtropical plants that require cool temperatures (15-21℃), humidity and sufficient sunlight and are usually found in areas with an altitude of between 1.200-1.500 m above sea level (Setyowati & Rahayu, 2020). According to Rukmana, (2005) in Setyowati & Rahayu, (2020), carrots are vegetables that are widely known to the public and are popular as a source of vitamin A, containing vitamins B, C, and other substances that are beneficial for human health. Carrots themselves are much sought after and consumed by Indonesian people in various kinds of preparations. This can be seen from data on per capita carrot consumption which is always increasing. In 2019, the level of carrot consumption reached 1,283 kg.capita-1.year-1, and then in 2020, it increased to 1,285 kg.capita^{-1}.year^{-1}. Furthermore, in 2021 and 2022 the figure for carrot consumption will increase to 1,354 kg.capita^{-1}.year^{-1} and 1,429 kg.capita^{-1}.year^{-1} (Kementerian Pertanian, 2022).

Carrots in Indonesia have good prospects for development. Carrot productivity in Indonesia will reach 18,880 kg.ha^{-1} in 2022 and will increase in 2023, reaching 19,300 kg.ha^{-1} (Kementerian Pertanian, 2024). This data experiences increases and decreases every time. Carrots have long been cultivated in various regions,

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one of which is East Java. The harvested area of carrot vegetables in East Java is very extensive as can be seen from data from the Central Statistics Agency (BPS), namely 5,281 Ha in 2021 and 4,495 Ha in 2022. Carrot productivity in East Java from 2019 to 2022 respectively namely 9,930 kg.ha^{-1}, 8,320 kg.ha^{-1}, 17,360 kg.ha^{-1}, and 19,990 kg.ha^{-1} (Badan Pusat Statistik Jawa Timur, 2024). This shows that carrot productivity fluctuates every year. Fluctuations in carrot production occur due to inappropriate use of inputs and input combinations.

The increase in carrot consumption per year is not balanced by the increase and decrease in carrot productivity levels. So consumer demand cannot be fully met. To meet consumer demand, it is necessary to increase carrot production. Increasing carrot production can be achieved through the technical efficiency of a farming business. A farming business can reach an efficient level if it can allocate production factors such as seeds, fertilizer, pesticides and other inputs optimally so that the resulting output is high. Therefore, this research was conducted to determine the level of technical efficiency of carrot farming in East Java and what factors can influence the level of technical efficiency of carrots in East Java.

METHODS

Location determination in this research was carried out using a multistage sampling method. Multistage sampling is the process of moving from a wide sample to a narrow sample using a step-by-step process (Firmansyah & Dede, 2022). This method is carried out by dividing the population into several groups for research and with more than 1 stage. The first stage was to determine the province and East Java Province was selected. In the second stage, 2 districts or cities were determined using purposive sampling. Purposive sampling is sampling based on certain considerations or criteria that have been formulated in advance by researchers (Ani et al., 2021). The criteria were cities/regencies in East Java, cities/regencies located in the highlands which are suitable for horticulture cultivation, and cities/regencies that carry out carrot farming activities, so Batu City and Probolinggo Regency were selected. The next stage is that the determination of sub-districts and villages is carried out randomly according to data and information from the relevant institutions, namely the Bumi Aji District Agricultural Extension Center, the Sumberbrantas Village Office, and the Sumber Agricultural Extension Service. So East Java Province was chosen with 2 villages, namely Sumberbrantas and Wonokerso. This research was conducted for 3 months starting in July 2023 to October 2023. The sample was determined using a simple random sampling method by taking it randomly without considering the strata that might exist in the population. Determination of sample size used the Slovin formula with a sample size of 374 farmers and a tolerance limit of 10% which resulted in 79 farmers as respondents. The data collection method was carried out by interviews using a questionnaire aimed at carrot farmers. There are 2 data used in this research, namely primary data obtained from interviews with carrot farmers and secondary data from the Bumiaji Agricultural Extension Center (BPP), Sumberbrantas Village Office, Sumber Agricultural Extension Officers, and the Central Statistics Agency (BPS).

The data analysis method in this research uses 2 methods, namely Data Envelopment Analysis (DEA) and Tobit Regression. Data Envelopment Analysis (DEA) is a non-parametric method used to calculate the technical efficiency of all units in production activities, productivity and decision making. DEAP 2.1 software is used to help complete the Data Envelopment Analysis method. According to (Abdullah et al., 2020), Data Envelopment Analysis (DEA) is carried out by comparing one Decision Making Unit (DMU) with another DMU by utilizing the same resources to produce the same output. Decision Making Unit (DMU) is the unit that will be analyzed

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in measuring efficiency (Irawan, 2020). The DMU in this study was 79 carrot farmers in East Java. DEA in this study uses the BCC (Bankers, Charnes, and Cooper) model with the VRS (Variable Return to Scale) assumption because it assumes that the ratio between additional input and output is not the same. The BBC model with the VRS assumption is a DEA model with the assumption that the ratio between additional input and output is not balanced (Amalia & Fitri, 2018). The production variables that will be processed in this research are production yield variables, seed variables, chemical fertilizer variables, manure variables, pesticide variables, land area variables, and labor variables used during carrot farming activities. VRS assumption equation with addition *convexity constraint*:

$$\begin{gathered} \text{Min}\theta\lambda\ \theta \\ \text{St} - qi + Q\lambda \geq 0, \\ \theta xi - x\lambda \geq 0, \\ I1'\lambda = 1 \\ \lambda \geq 0 \end{gathered} \quad 1)$$

Note: I1 = Vector lxl, θ = proportional reduction of input for the ith dmi, λ = Weight of the jth DMU

Apart from that, to find out the factors that influence the technical efficiency of carrot farming using the Tobit Regression method with Stata software. Tobit regression is an analysis used for dependent variables where some of the data has a discrete measurement scale and others have a continuous scale (Sembiring, 2019). The factors included in the tobit regression of this research include the age of carrot farmers, the education that carrot farmers have received, experience, family responsibilities, dummy land ownership status, and the area of land used in carrot farming in East Java. The Tobit regression equation in this research is:

$$TE = \beta 0 + \beta 1X1 + \beta 2X2 + \beta 3X3 + \beta 4X4 + \beta 5X5 + \beta 6X6 + \in \quad (2)$$

Where: X1 = Age
X2 = Education
X3 = Experience
X4 = Number of Family Dependents
X5 = Dummy Land Ownership Status
X6 = Land Area

RESULTS AND DISCUSSION

Analysis of Technical Efficiency of Carrot Farming

In this study, the factors that can influence carrot production include: carrot seeds (X1), chemical fertilizers (X2), manure (X3), pesticides (X4), land area (X5), and labor (X6). It is known that there are 2 carrot farmers who have the lowest efficiency value in the interval 0.137 – 0.244 with a percentage of 2.5%. Meanwhile, most of the technical efficiency of carrot farming in East Java is at a value of 0.893 – 1 with a percentage of 59.5%. This shows that the level of technical efficiency value of carrot farming in East Java varies and there are differences in the combination of inputs used by farmers in the carrot farming they run. Farmers who have a farming technical efficiency value of 1 indicate that the farmer can combine the inputs used well so that they are able to reach the maximum point. Data on the frequency distribution of technical efficiency and the level of technical efficiency of carrot farming in East Java based on VRS assumptions can be seen in Table 1.

Based on the results of the technical efficiency calculations in the table above, there are 43 carrot farmers in East Java who have reached the technically efficient value with a percentage of 54.43% and there are 36 farmers who have not reached the technically efficient value in carrot farming activities. A farm is said to have reached the level of efficiency if it has a VRS value of 1, whereas if it is less than 1 it is considered to have not reached the level of technical efficiency (Arifin et al., 2021). The average efficiency value of carrot farming assuming Variable Return of Scale (VRS) for 79 farmers is 0.826 or average production reaches 82.6% of potential carrot production

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and there is still 17.4% for the average farmer to increase their production. This result is still below the average value of technical efficiency for carrot farming in Bumiaji, Batu, carried out by Sholeh et al., (2013) which shows that the average respondent farmer has a fairly high level of technical efficiency, namely 0.87, which means that the average farmer has achieved 87% production, but has not yet reached the technical efficiency value. This means that carrot farming in East Java has not yet reached the full level of technical efficiency, so it is still possible to improve the technical efficiency of the farming.

Table 1. Frequency distribution and technical efficiency assuming VRS of carrot business in East Java

Efficiency Value	Many Farmers	Percentage
0.137 – 0.244	2	2.5%
0.245 – 0.352	2	2.5%
0.353 – 0.460	3	3.8%
0.461 – 0.568	6	7.6%
0.569 – 0.676	9	11.4%
0.677 – 0.784	7	8.9%
0.785 – 0.892	3	3.8%
0.893 – 1	47	59.5%
Total	**79**	**100%**
Total efficiency = 1	43	54.43%
total efficiency < 1	36	45.57%
Average	0.826	
Minimum	0.137	
Maximum	1	

(Source: Data Processing Results, 2024)

Increasing technical efficiency can be done by improving the use of input combinations and other factors in farming activities so that carrot farming activities can be efficient and achieve maximum output. Farmers who have not yet reached the level of technical efficiency can refer to farmers who are already efficient when making improvements to input combinations. A list of inefficient farmers and their references can be seen in Table 2.

For farmers who have not yet reached the efficiency value, they can use other farmers who are already efficient as a reference so that the output produced can achieve maximum technical efficiency results, and farmers who are technically efficient can maintain the combination of inputs used. For example, farmers or the 2nd DMU are not technically efficient with a value of 0.622. If you want to achieve technically efficient values, you can use farmers 34, 8, 43, 74 and 78 as references regarding using inputs in carrying out carrot farming activities.

Data Envelopment Analysis (DEA) in the results also shows the scale of production efficiency of carrot farmers in East Java when carrying out carrot production activities. Data on the efficiency scale of carrot farming production in East Java can be seen in Table 3.

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Table 2. Peer Group DMU

DMU	Peer Group	DMU	Peer Group
2	34 8 43 74 78	23	60 42 78 74 63 62
3	6 43 34 8	24	59 78 42 60
5	73 78 71	25	8 60 63 71
9	62 63	26	71 78 44 74
12	62 49 51	27	73 77 76 16
13	44 74 15	28	77 49 16
14	34 8 74 43 78	29	47 77 44 72
17	63	30	74 44 15
18	34 78 59 74 60	31	15 60 74 44
19	43 78 8 34	32	78 34 71 8
20	60 71 8 63	33	34 78 74 59
21	62 49 51	35	60 63 15 8 74
22	78 60 42 63 74	36	64 63
37	63 72 77 60	54	43 59 78 34
38	77 8 71 64 76	56	59 74 8 55 34 60
39	76 71 64 8	61	62 63
40	78 8 60 63 71	65	8 63
41	8 60 63 64 15	66	42 62 49 64
45	71 78 60 8 63	68	78 63 1 10 67
48	63 8 1 74 78 10	69	63 71 78 49
50	42 49 78 63 62	70	43 15 74 8 34
52	63	79	63
53	59 42 74 57		

(Source: Data Processing Results, 2024)

Table 3. Carrot farming production scale in East Java

Explanation	Observation	Percentage
Decreasing Return to Scale (drs)	4	5.06
Constant Return to Scale (crs)	27	34.18
Increasing Return to Scale (irs)	48	60.76
Total	**79**	**100**

(Source: Data Processing Results, 2024)

The results in Table 3 show that 4 farmers carry out their production on the Decreasing Return to Scale (DRS) scale or by adding production factors that exceed the proportion of production increase. 27 farmers carry out carrot farming activities with proportional additions of input and production results on the Constant Return to Scale (CRS) scale or 34.18%. Meanwhile, 60.76% of carrot farmers in East Java carry out production activities on the Increasing Return to Scale (IRS) scale, which means that the proportion of additional production factors will result in a greater increase in production. The condition of farmers' carrot production scale is not yet optimal and is experiencing technical inefficiencies because the majority of farmers are still in an Increasing Return To Scale condition and require appropriate input allocation in order to produce maximum output.

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Factors Affecting the Technical Efficiency of Carrot Farming

The aim of the next research is to find out what factors influence the technical efficiency of carrot farming in East Java. In this second objective analysis, a method is used, namely Tobit Regression. The Tobit regression method in this research uses an application or software called STATA. Factors thought to influence the technical efficiency of carrot farming in East Java include the age of the farmer, education (length of formal education completed), experience in carrot farming, number of dependents in the family of carrot farmers in East Java, dummy land ownership status used in the activity. farming, and land area used in carrot farming in East Java. The results of the Tobit regression analysis are listed in Table 4.

Table 4. Tobit regression calculation results

Variabel	Koefisien Regresi	Standar Error	P>|t|
Age	-0.009	0.030	0.777
Education	0.034	0.026	0.203
Experience	0.047	0.028	0.097**
Number of family dependents	-0.033	0.049	0.501
Land Ownership Status Dummy	0.214	0.127	0.096**
Land Area	-0.00004	0.000	0.005*
Constanta	0.964	0.233	0.000
Prob>chi2		0.027	
Sigma		0.380	
Pseudo R^2		0.141	

Note: (*) significant at α 5%, (**) significant at α 10%
(Source: Data Processing Results, 2024)

The table shows a Prob>chi2 result of 0.027, which means this research has an error rate of 2.7%. This model has an error rate value lower than 5%, so it is suitable for evaluating factors that influence technical efficiency. The Pseudo R2 value of 14.1% means that Tobit regression can explain the influence of the factors above by 14.1% and the rest can come from other factors. A variable is said to have a real effect if the value of P>|t| < Alpha (15%), whereas if it is more than 15%, it is considered not to have a significant effect (Artamevia et al., 2023).

Age does not significantly affect the technical efficiency of carrot farming in East Java because it has a value of P>|t| amounting to 0.777 greater than alpha (15%). The age coefficient shows a value of -0.009, which means that if age increases by 1 year, the technical efficiency of carrot farming in East Java can be reduced by 0.009. A person's involvement in carrot farming is not the same; some have been hereditary, starting as teenagers, and some have started as adults, so their abilities are also different and do not depend on the age of the farmer. This statement is in line with research by Ahmed et al. (2013), This research shows that age does not have a significant effect on smallholder household production in Girawa District, Ethiopia. Age does not have a significant effect on the technical efficiency of shallot farming in Torongrejo Village because farmers have their own cultivation systems and have carried it out from generation to generation, so it is not certain that young farmers will have higher production while older farmers who have weaker energy will produce lower products. , could be high due to higher experience and capital (Winarso et al., 2021).

Coefficients and P>|t| The education variable shows figures of 0.034 and 0.203

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respectively. This means that the education variable has no real effect on the technical efficiency of carrot farming in East Java. When someone undergoes formal education, the focus in learning is not only on agriculture but also on other general knowledge. Agricultural knowledge can be obtained from non-formal education. This statement is in line with research conducted by Adrian et al. (2024); this research suggests that farmers' formal education has no real effect on clove inefficiency because there is no difference between farmers who go to school and those who don't and farmers' education is almost uniform.

Farmer experience significantly and positively influences the technical efficiency of carrot farming in East Java. The level of technical efficiency will increase by 0.047 when experience increases by 1 year. The longer the experience, the more skills, knowledge and technological capabilities farmers have in carrying out carrot farming in East Java so that they can reduce the decline in carrot production. This statement is in accordance with research conducted by Artamevia et al., (2023) and Cahyaningsih et al., (2022) which states that experience can reduce inefficiency. Farmer experience has a significant influence on the technical efficiency of coconut production in Johor, Malaysia, because experienced farmers have good knowledge, resulting in higher productivity and technical efficiency (Omar & Fatah, 2021)

The number of family dependents does not significantly affect carrot farming in Java. The coefficient for the number of family dependents is -0.033, where if there is an additional 1 person, technical efficiency will be reduced by 3.3%. Even though there are many members in a farming family, their ignorance about managing a carrot farming business will not make a positive contribution. And the large number of family responsibilities means that expenses will increase so that farmers will save on costs allocated to farming which can cause production to decrease. This statement is also in line with research conducted by Sholeh et al. (2013), which states that even though there are many families, if they do not know how to manage a carrot farm, it will not help farmers in cultivating carrots.

Land Ownership Status is measured using a dummy with the provisions 0=rented land and 1=own land. Dummy land ownership status significantly affects the technical efficiency of carrot farming in East Java with a value of P>|t| of 0.096. Farmers whose land they own will have a 21.4% higher efficiency level and tend to be more technically efficient because farmers have an incentive to maintain the fertility of their land so that the quality of the crops in the following season does not decrease. And if farmers have their own land they don't need to pay land rental costs and can focus on allocating inputs. This statement is in line with research conducted by Sholeh et al., (2013), which states that ownership status has a real negative effect on the technical inefficiency of carrot farming, which means that farmers with their own land will be more efficient than farmers who borrow land and will continue to be careful in maintaining the fertility of their land so that their land remains in good condition and does not decline which can affect yields. carrot production.

The land area has a constant value and P>|t| respectively -0.00004 and 0.005, which means they significantly and negatively affect the technical efficiency of carrot farming in East Java. The technical efficiency of carrot farming in East Java will decrease by 0.00004 if 1 unit of land is added. If additional land is added, the area of land used for farming activities will increase, but this could reduce the technical efficiency of carrot production. This is because if the land area becomes larger, the production focus will be divided because there is a lot of land being managed, and there will be a reduction in input to be divided among each piece of land. So it can reduce production yields and technical efficiency of carrot farming in East Java.

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This statement is in line with Balogun & Akinyemi, (2017), who state that land area influences the technical efficiency of cassava farmers in Nigeria. Besides that, Abunyuwah et al., (2019) his research found that land area had a significant effect on inefficiency, meaning that increasing land area would increase the technical efficiency of carrot production in Asante-Mampong City, Ghana. However, the results of this research contradict the research conducted by Kabeakan et al., (2022) which states that land area does not have a significant effect on corn production and if the land area is increased by 1% it will increase production yields by 0.556 %.

CONCLUSION

Carrot farming in East Java with the VRS assumption has an average technical efficiency value of 0.826. This shows that carrot farming in East Java has not yet reached the full level of technical efficiency, so it is still possible to improve the technical efficiency of farming. Increasing technical efficiency can be done by improving the combination of inputs such as carrot seeds, chemical fertilizers, manure, pesticides, land area and labor. Increasing technical efficiency is carried out by using other farmers who have reached the full level of technical efficiency as a reference for making improvements. Based on the analysis that has been carried out, of the 6 variables, there are two variables that have a significant and positive influence on the technical efficiency of carrot farming in East Java, namely the Experience variable and the land ownership status dummy. The land area variable has a negative effect on the technical efficiency of carrot farming in East Java. Meanwhile, the variables Age, Education, and Number of family dependents do not significantly influence the technical efficiency of carrot farming in East Java.

For further research, experiments can be carried out on other variables that can influence the technical efficiency of carrot farming. Future researchers can also increase the number of respondents. Research can be carried out using other analytical tools.

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