Relative Efficiency of Potato Farming with Data Envelopment Analysis (DEA) Approach in Karangreja District, Purbalingga Regency

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Abstract. Potato farming has a contribution in improving the welfare of potato farmers in Karangreja District. However, a high amount of production does not guarantee farmers get high profits as well. The level of income obtained by farmers depends on the level of production achieved in managing their farm with the support of the application of farming technology and the price received in the sale of their production. This study aims are determining the level of technical efficiency of potato farming in Karangreja, Purbalingga and its determinant factors. Output oriented assumption measure efficiency score from each farms observed analyzed with Data Envelopment Analysis (DEA). The sampling method is purposive. The method of analysis uses data envelopment analysis. Based on DEA-CRS calculations, there are 45,71% potato farming which has been efficient, while the calculations of DEA-VRS shows there are 51,43% potato farming which has been efficient; The average technical efficiency with the constant return to scale (CRS) approach is 0.883 while the technical efficiency with the variable return to scale approach is 0.919; and Farms that have reached the condition of Constant Return to scale are 51.43%. This is that most of the Atlantic potato farmers in Karangreja District have been optimal in allocating their inputs.

Keywords: Relative Technical Efficiency · Data Envelopment Analysis · Potato · Atlantic

1 Introduction

Potato (*Solanum tuberosum L*) is one of the national superior vegetable commodities that get priority to be developed. According to the Central Statistics Agency (2020), 22.8% of national potato production comes from Central Java. Central Java ranks second as the center of potato production in Indonesia after East Java which contributes 23.77% to the national potato production.

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Table 1. Production, harvested area, and potato productivity in Karangreja District in 2016–2020.

Year	Production (ton)	Harvest Area (Ha)	Productivity (ton/Ha)
2016	1.796,41	114,00	15,76
2017	908,40	163,00	5,6
2018	3.782,00	175,00	19,15
2019	1.722,00	82,00	21
2020	7.363,00	370,00	19,9

Source: Badan Pusat Statistik Purbalingga, 2021

Potato is a commodity that is easily developed into various preparations including chips, potato chips, starch, flour, french fries, and other preparations that can increase farmers' income.

One of the potato-producing areas in Central Java is Karangreja District, Purbalingga Regency, which is located at the foot of Mount Slamet at an altitude of 790 meters above sea level, so that the natural conditions are suitable for growing potato plants. Good soil conditions for the growth of potato plants are soils that are crumbly, loose, contain lots of organic matter, fertile, easily bind water, and have a soil pH of 5.0–7.0. The optimal daily average temperature for potato growth is 18–21 °C with a humidity level of around 80%–90%. In addition, the appropriate rainfall for cultivating potatoes is 1,500 mm per year [1]. The development of production harvested area, and potato productivity in Karangreja District can be seen in Table 1.

According to the Purbalingga Central Statistics Agency 2021, one of the most widely produced food crops in Karangreja is potato, especially in Serang Village and Kutabawa Village. The types of potatoes that are widely grown in Karangreja District are granola potatoes and Atlantic potatoes. One of the factors supporting the high production of potatoes in Karangreja District is that farmers benefit from fertile land conditions making it suitable for potato farming activities. Potato farming activities are carried out from generation to generation by the community in Karangreja District because it is a source of community income in meeting their needs and maintaining their survival.

According to the Purbalingga Central Statistics Agency [2], potato is one of the most widely produced food crops in Karangreja District, especially in Serang and Kutabawa villages. The types of potatoes that are widely grown in Karangreja District are granola potatoes and Atlantic potatoes. One of the factors supporting the high production of potatoes in Karangreja District is that farmers benefit from fertile land conditions making it suitable for potato farming activities. Potato farming activities are carried out from generation to generation by the community in Karangreja District because it is a source of community income in meeting their needs and maintaining their survival.

High potato production in Karangreja District is often not accompanied by an increase in income received by farmers because the use of production factors in farming is not optimal. The use of seeds in farming will determine the quality of production. Superior seeds are more resistant to disease and produce high quality products so that prices can be competitive in the market. The seeds that are often used in potato farming in Karangreja District are Atlantic and granola varieties because they are considered suitable for planting on farmers' land. The current price of potatoes at the farm level is IDR 5,000/kg for small potatoes and IDR 9,000/kg for large potatoes. The size of the resulting potato depends on the seeds planted. The problem of seedling in Serang and Kutabawa villages is actually quite serious because some farmers are still having difficulty getting potato seeds. The high price of seeds is still an obstacle for farmers. The average price of seeds purchased by farmers is Rp. 20,000, - to Rp. 35,000, -/kg. The seeds used by farmers to produce consumption potatoes are generally from the fifth generation (G5). Furthermore, derivatives from the fifth generation are used for planting material for the next season, even though the longer the seeds are used, the resistance to disease will also decrease which in turn will have the potential to reduce production levels and productivity.

This study aims to determine the level of relative technical efficiency and efficiency scale in potato farming of Atlantic varieties in Purbalingga Regency.

2 Methods

The basic method used is descriptive analysis research [3]. This type of research is a survey with an explanatory analysis study method. The research was conducted in Purbalingga Regency with the determination of the research location carried out purposively, namely Karangreja District which is the center of potato farming of Atlantic varieties. Determination of the research sample using the Quota Sampling technique, namely the selection is not random or according to a predetermined quota and this method is proportional and non-proportional. In this study, non-proportional is used to determine the minimum number of sample units from a category. The number of samples taken in this study were 35 potato farmers with Atlantic varieties. Input output data is taken for the last 1 year, namely June 2021-July 2022. Data analysis uses technical efficiency data analysis using non-parametric methods, namely Data Envelopment Analysis (DEA Model used is DEA-CCR which uses Constant Return to Scale and Variable Return approaches to Scale with output orientation.

Technical efficiency is obtained based on the following linear programming model [4]:

Maximize θ, λ

$$\begin{aligned} &\textit{Subject to} \sum_{j=1}^{n} \lambda j \cdot yj - \theta i \cdot yi - s = 0 \\ &\sum_{j=1}^{n} \lambda_j X_{kj} + e_k = X_{ki} \\ &\lambda_j \geq 0;\ \ s \geq 0;\ \ e_k = 0 \end{aligned} \tag{1}$$

where is the probability of increasing the proportion of output for the i-th DMU (Decision Making Unit in this study is potato farmer), j is the vector Nx1 weight relative to the DMU efficiency, s is the slack output, and ek is the i-th variable input slack. [5] suggested adapting the DEA CRS model in order to re-explain the situation of the scale variables.

By adding the convexity constraint N1'λ= 1, the model can be modified to VRS DEA. A proportional increase in the possible output is achieved when the slack output, i.e. s becomes zero. The outcome of a DMU is efficient when the values of and i are equal to 1, and j = 0. On the other hand, a DMU is inefficient when > 1, i = 0; and j 0. Solving (1) we can obtain a TE measure that reflects the distance between the observed and the optimal production yield for a given amount of input:

$$TE = \frac{Y_i}{Y_i^*} = \frac{1}{\theta_i} \qquad 0 \le TE_i \le 1 \tag{2}$$

where Yi and Yi* are the maximum possible output (optimal) of each by comparing the TECRS and TEVRS scores. The difference between the two TE values indicates that there is a scale of inefficiency that limits the achievement of the optimal (constant) scale:

$$TE_i^{CRS} = TE_i^{VRS} * SE_i \tag{3}$$

Therefore, it can be calculated as follows [6]:

$$SE_i = \frac{TE^{CRS}}{TE^{VRS}} \qquad 0 \le SE_i \le 1 \tag{4}$$

where SEi = 1 indicates full scale efficiency and SEi < 1 indicates scale inefficiency. However, the weakness of the SE score is that it does not indicate whether a farm is operating under decreasing or increasing returns to scale. This is overcome by only non-increasing return to scale (NIRS) according to the conditions in the DEA model, namely changing the convexity of the constraint N1'λ = 1 from the DEA VRS model to N1'λ 1. If the TENIRS and TEVRS are not the same, then the farm operates under increasing returns to scale (IRS), if both are the same, it means that there are farms operating with decreasing returns to scale [7].

The relative efficiency score of each DMU is identified by calculating the DEA-CCR which uses a constant return to scale (CRS) approach with an output-oriented approach. In general, DMU considers it to be efficient if it produces a score of 1 and if the score is less than 1 the implication that it is inefficient. Analysis with output oriented model, the result is efficient farmer means able to combine input and output efficiently to achieve the specified output. Calculation of data using the DEA method in this study was not done manually but using DEAP Version 2.1 software to measure the efficiency of potato farming of Atlantic varieties.

3 Result and Discussion

The calculation of the relative technical efficiency analysis uses data envelopment analysis using 8 input variables and 1 output variable. The input variables used include land area (ha), number of seeds (kg), SP 36 fertilizer (kg), Phonska fertilizer (kg), drum fertilizer (kg), solid pesticide (kg), liquid pesticide (ml) and labor. work (HOK). While the output variable is potato production (kg)/planting season.

The results of the analysis show that the average technical efficiency with the constant return to scale (CRS) approach is 0.883 while the technical efficiency with the Variable return to scale approach is 0.919 (Table 2).

Table 2. Estimating the Technical Efficiency of Atlantic Potato Farming with Data Envelopment analysis

Technical Efficiency	TE ^{CRS}	TE^{VRS}	SE
Mean	0.883	0.919	0.961
Standar Deviation	0.132	0.116	0.074
Min	0.617	0.629	0.694
Max	1.000	1.000	1.000

Source: Results of primary data analysis 2022

Table 3. Number of efficient and inefficient DMUs

	CRS	%	VRS	%
Efficient DMU	16	45.57	17	48.57
InEfisien DMU	19	54.43	18	51.43
Total	36	100.00	35	100.00

Table 4. Efficiency scale and return to scale from DEA

Number of DMUs		Percentage (%)	Efficiency Scale
Total Sample	35	100,00	0.961
Decreasing Return to Scale	10	28.57	0.925
Constant Return to Scale	18	51.43	1.000
Increasing Return to Scale	7	20.00	0.913

Source: DEA Analysis Results, 2020

Based on the CRS approach, there are 16 efficient DMUs and 19 inefficient DMUs, while with the C=VRS approach there are 17 efficient DMUs and 18 inefficient DMUs. The lowest efficiency value of potato farming is 0.617 which is found in the 5th DMU. The inefficiency in the 5th DMU occurs due to the inefficient use of inputs of seeds, fertilizers and pesticides.

Inappropriate input allocation is the main cause of inefficiency in potato farming. If the input used is excessive, it causes inefficient farming. The right combination of inputs is very important in potato farming which has a high risk, when it reaches full efficiency, it will in turn provide maximum income for farmers [8, 9] (Tables 3 and 4).

Based on the results of the analysis, there are 28.57% of farms that are in decreasing returns to scale. This indicates that the allocation of input use is not appropriate so that it tends to reduce yields and make potato farming costs even greater (Fig. 1).

Meanwhile, there are 20.00% of farms in conditions of increasing return to scale, meaning that with adding a certain amount of input, potato farming is able to achieve full efficiency, because farmers are reluctant to take risks, the farmers tend to be careful

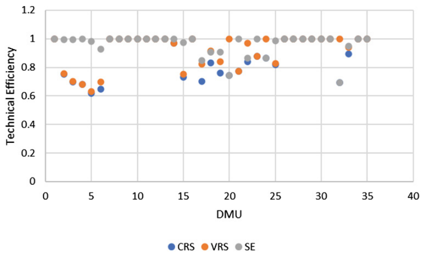

Fig. 1. Distribution of the Technical Efficiency of Potato Farming

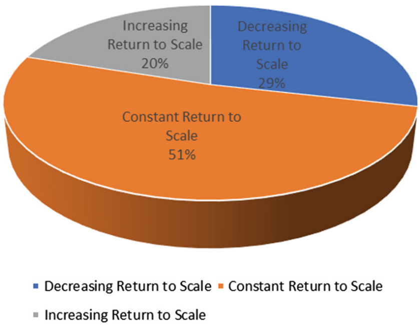

Fig. 2. Distribution of CRS, DRS, and IRS for Potato Farming

in the use of inputs, but the inputs allocated affect the level of efficiency of the farm. Farming that has reached the condition of Constant Return to scale reached 51.43%. This indicates that most of the Atlantic varieties of potato farmers in Karangreja District have been optimal in allocating their inputs (Fig. 2).

4 Conclusion

Analysis of the relative technical efficiency of the atlantic variety of potato cultivation in Karangreja sub-district can be concluded as follows:

1. The average efficiency that the average technical efficiency with the constant return to scale (CRS) approach is 0.883 while the technical efficiency with the Variable return to scale approach reaches 0.919
2. Farms that have reached the condition of Constant Return to scale are 51.43%. This indicates that most of the Atlantic varieties of potato farmers in Karangreja District have been optimal in allocating their inputs

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Authors' Contributions. *Dindy Darmawati Putri* designs models, analyzes data, and makes research reports

Irene Kartika Eka Wijayanti, Altri Mulyani and Ratna Satriani conducted data collection in the field and helped tabulate the data

Agus Sutanto, Djeimy Kusnaman and Suyono made scientific articles

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