Technical Efficiency Analysis of Potato Farming in Wonokerso Village, Probolinggo Regency, East Java Province Using DEA Based on Business Analytics in the Digital Era

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A R T I CLEINFO

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A B STR A K

This study analyzes the technical efficiency of potato farming in Wonokerso Village, Probolinggo Regency, using the Data Envelopment Analysis (DEA) method with a Business Analytics approach in the digital era. Data were obtained from 42 farmers through simple random sampling and analyzed using the DEA-VRS model. The results show an average technical efficiency of 93.9%, with 74% of farmers in a fully efficient state. The integration of DEA and business analytics enables the translation of analytical results into data-driven prescriptive strategies, supporting efficiency improvements and sustainable digital agricultural transformation.

INTRODUCTION

The horticulture subsector is a crucial component of national agricultural development, both as a provider of nutritious food and as a source of income for farmers. One of the leading horticultural commodities is the potato, widely cultivated in highland areas such as Wonokerso Village, Probolinggo Regency, East Java Province. This commodity has high economic value due to increasing market demand, both for household consumption and the processing industry. According to Statistics Indonesia (BPS, 2023), Probolinggo Regency is a potato production center in East Java Province, with a land area of 3,663 hectares and a production volume of 49,720 tons with a productivity of 13.6.

Despite its significant economic potential, potato farming productivity at the farmer level still faces serious challenges, particularly in terms of inefficient use of production inputs. Farmers often allocate land, seeds, labor, and fertilizer suboptimally, resulting in suboptimal yields. Research by (Sinaga et al., 2024) shows that the average technical efficiency of potato farmers in Wonokerso and Sumberberantas is only 0.840, indicating a potential for a 16% increase in efficiency. (Boakye et al., 2024) explain that

inefficiency is caused not only by poor input allocation but also by suboptimal production scale. This provides a theoretical basis for data-analytic policy interventions to be directed at improving both technical efficiency and scale efficiency in agriculture.

In addressing these challenges, the advancement of the digital era presents a significant opportunity for modern agriculture. (Nyoman Kutha Krisnawijaya et al., 2022) demonstrates that data analytics platforms in agriculture have become essential tools for supporting data-driven decision-making. The digital era has enabled various innovative approaches to agricultural management, including the implementation of Business Analytics, the systematic process of collecting, processing, and analyzing data to support more effective, evidence-based decision-making. In the farming context, Business Analytics can be utilized to analyze production efficiency, identify causes of inefficiencies, and design performance improvement strategies.

The application of business analytics in the agricultural sector is part of the transformation toward digital farming or precision agriculture, which encourages real-time, data-driven decision-making. Farmers now have access to a variety of digital tools, such as agricultural applications, soil sensors, geospatial information systems, and cloud-based analytics, which can improve both technical and economic efficiency (Wolfert et al., 2017) .

One of the main methods in Business Analytics that is widely used to measure technical efficiency is Data Envelopment Analysis (DEA). DEA is a non-parametric approach that evaluates the relative efficiency between production units (Decision Making Units/DMUs) based on a combination of inputs and outputs. In this study, the inputs used were land (m^2), seeds (kg), chemical fertilizer (kg), manure (kg), solid pesticides (kg), liquid pesticides (L), and labor (HOK), while the output was harvest yields (production).

With the support of software such as DEA, Excel, and the integration of artificial intelligence (AI), the analysis process is now faster, more flexible, and more accurate (Barki & Rachmah, 2024) . Therefore, this study aims to analyze the technical efficiency of potato farming in Wonokerso Village using the DEA approach as part of the implementation of Business Analytics in the digital era, thereby providing empirical insights and data-driven solutions for developing smarter and more efficient local agriculture.

LITERATURE REVIEW

The Concept of Technical Efficiency in Enterprises

Technical efficiency refers to the ability of a production unit to maximize output with a given amount of input or minimize input for a given level of output. In the context of farming, technical efficiency indicates the extent to which farmers are able to manage production factors such as land, labor, fertilizer, and seeds to produce maximum yields. (Wassihun et al., 2019) state that technical efficiency is important for measuring the

potential for increased production, where inefficiency can lead to significant yield losses even with the availability of technology and inputs.

Data Envelopment Analysis (DEA) Method

Theoretically, DEA is an effective analytical tool for measuring technical and scale efficiency in smallholder farming. This study confirms that the input-oriented DEA approach can identify potential input savings without sacrificing output, making it highly relevant to support data-driven efficiency improvement strategies (Boakye et al., 2024) .

Data Envelopment Analysis (DEA), also known as a non-parametric method, is used to measure the relative efficiency of decision-making units (DMUs) based on the inputs and outputs used. DEA is particularly well-suited to farming contexts because it captures the complexity of using multiple inputs simultaneously without the need to define a production function (Camanho & Dyson, 2006) .

Business Analytics in the Agricultural Sector

Business analytics is a data-driven approach to analyzing and improving decision-making processes. In the agricultural sector, business analytics is used to evaluate performance and efficiency, and develop productivity improvement strategies through the use of historical data and digital technology. This approach enables farmers and policymakers to make data-driven decisions in managing their farms (Chowhan & Ghosh, 2020) .

The Digital Era and Agricultural Transformation

Digitalization has brought about significant changes in the agricultural sector, from the implementation of the Internet of Things (IoT), the use of data-driven applications, to satellite-based mapping technology. The digital era enables agriculture to be more precise, efficient, and adaptive to climate and market changes. The use of information technology supports technical efficiency and accelerates the adoption of innovations at the farmer level (Schroeder et al., 2021).

METHODOLOGY

Sampling Method

This study, which examined the technical efficiency of potato farming in Wonokerso Village, Probolinggo Regency, used multistage sampling. Respondents were potato farmers cultivating the Granola potato variety on land plots of less than or equal to 1 hectare. The sampling method used in this study was simple random sampling.

The sample size was determined using the Slovin formula. According to village officials, the sample size in Wonokerso Village was 626. The number of farmer samples was obtained using the Slovin formula, as follows:

$$n = N / (1+Ne\ 2)$$

Where:
n = sample size
N = population size
e = error (degree of error of respondent data)

Using a margin of error of 15%, or 0.15, which means a confidence level of 85%. Based on this calculation, the number of potato farmers sampled in Wonokerso village is 41.4 or 42.

Data Analysis Methods

Analysis of the technical efficiency level of potato farming in Wonokerso Village, Probolinggo Regency was carried out using a data envelopment analysis (DEA) approach using DEAP software version 2.1 , assuming Variable Returns to Scale (VRS) which is a variant of the DEA method that allows for measuring the relative efficiency of decision-making units by allowing for different scales between these units.

In this study, potato production was used as the output variable (Y), which was influenced by several input variables. The input variables used included: land area (X_1), number of seeds (X_2), chemical fertilizer (X_3), manure (X_4), solid pesticide (X_5), liquid pesticide (X_6), and labor (X_7).

This research specifically uses an input-oriented approach, which focuses on minimizing input usage to produce a specific output. This approach is considered appropriate because, in the context of farming, farmers have more control over inputs than outputs, which are often influenced by external factors. The DEA formula with VRS is as follows:

$$\begin{aligned} &\text{Min}_{\theta,\lambda}\,\theta \\ &\text{St} - \text{yi} + \text{Y}\lambda \geq 0, \\ &\theta_{\text{xi}} - \text{X}\lambda \geq 0, \\ &\text{N1}'\lambda = 1 \\ &\lambda \geq 0 \end{aligned}$$

Information:
N1'λ=1 is a convexity constraint

RESEARCH RESULT

Technical Efficiency Analysis of Potato Farming in Wonokerso Village

DEA is used to analyze the technical efficiency of input factor use in potato production by farmers. The DEA approach, using the Variable Return to Scale (VRS), allows us to identify whether farmers are in a state of Increasing Return to Scale (IRS), Constant Return to Scale (CRS), or Decreasing Return to Scale (DRS). The VRS approach

is important because it reflects the reality that scale efficiency can vary, meaning that technical efficiency can differ at different levels of production scale.

Table 1. Distribution of Potato Farming Production Scale

Production Scale	**Number of Farmers**	**Percentage (%)**
Decreasing Return to Scale (DRS)	6	14%
Constant Return to Scale (CRS)	24	57%
Increasing Return to Scale (IRS)	12	29%
Total Sample	**42**	**100%**

Source: Primary Data, 2025

The difference in technical efficiency values between the CRS and VRS models can be used to determine scale efficiency and group them into Constant Return to Scale (CRS), Increasing Return to Scale (IRS), or Decreasing Return to Scale (DRS) categories. In the IRS category, the resulting increase in output is greater than the increase in input provided. Conversely, in the DRS category, the resulting increase in output is smaller than the increase in input. Meanwhile, in the CRS category, each increase in one unit of input will result in an equally large increase in output constantly. Based on the results of data analysis using DEAP software version 2.1 with the VRS (Variable Return to Scale) model, the technical efficiency level value is obtained, which can be seen in Figure 1, while the distribution of technical efficiency values is presented in Table 2.

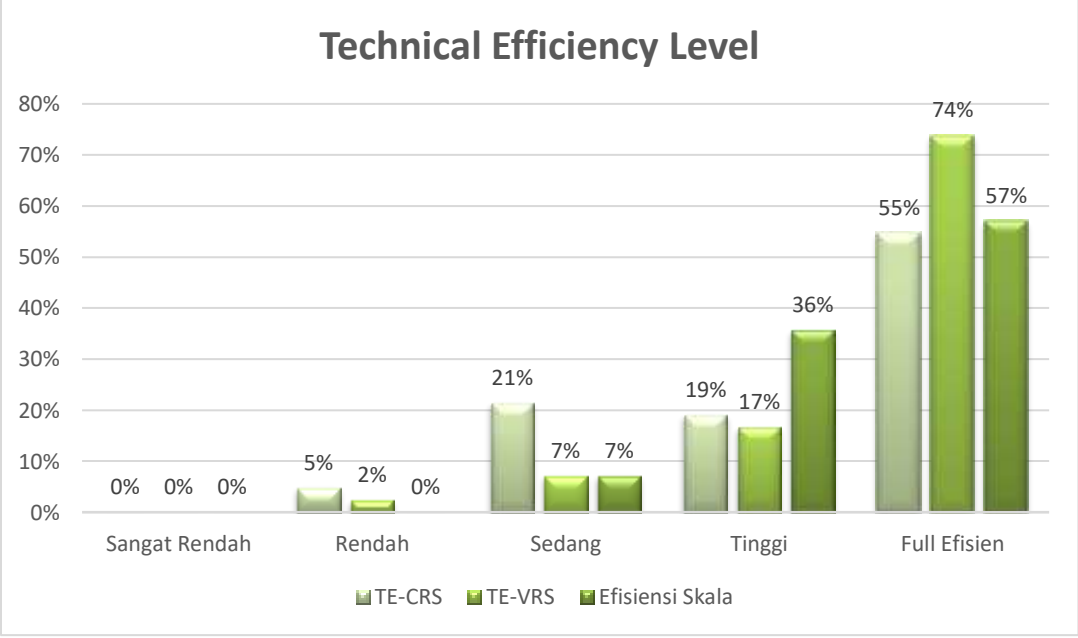


Figure 1. Technical Efficiency Level of Potato Farming

Table 2. Distribution of Technical Efficiency Values of Constant Return to Scale (CRS), Variable Return to Scale (VRS), and Scale Efficiency (SE)

Efficiency Level	Technical Efficiency Value	TE-CRS		TE-VRS		Scale Efficiency	
		Amount	%	Amount	%	Amount	%
Very Low	0.000 - 0.249	0	0%	0	0%	0	0%
Low	0.250 - 0.499	2	5%	1	2%	0	0%
Currently	0.500 - 0.749	9	21%	3	7%	3	7%
Tall	0.750 - 0.999	8	19%	7	17%	15	36%
Full Efficient	**1**	**23**	**55%**	**31**	**74%**	**24**	**57%**
Amount		42	100%	42	100%	42	100%
Average TE		**0.867**		**0.939**		**0.917**	
Maximum TE		**1**		**1**		**1**	
Minimum TE		**0.341**		**0.394**		**0.588**	

Source: Primary Data, 2025

These results indicate that most potato farmers have optimized their input use to achieve maximum efficiency. The average technical efficiency score indicates a high level of efficiency, at 0.867 for TE-CRS and 0.939 for TE-VRS. Scale efficiency also showed good results, with 57% of farmers in the Full Efficient category.

Applying Business Analytics to Formulate Efficiency Improvement Strategies in the Digital Era

In the digital era, a business analytics approach allows for systematic processing of analysis results to produce more applicable, visual, and prescriptive recommendations. To support this, a systematic literature review was conducted to identify the application of business analytics in agriculture as a basis for intelligent and efficient decision-making. The results of this systematic review indicate that the application of business analytics following a technical efficiency analysis using DEA yields three key findings:

a. **Business analytics helps transform DEA technical results into data-driven strategies.**
   The DEA efficiency score results can be used as a basis for designing recommendations for input improvements (such as reducing fertilizer or increasing the use of skilled labor) through a prescriptive analytics approach (Nyoman Kutha Krisnawijaya et al., 2022).
b. **Efficiency visualization and segmentation facilitate decision-making at the farmer and policy-making levels.**
   Farmers can be classified based on their efficiency levels (efficient vs. inefficient) and each group is given different strategies, supported by digital tools such as dashboards or Excel/Power BI-based applications (Nyoman Kutha Krisnawijaya et al., 2022) .
c. **Integration of analytical approaches with digital technologies drives data-driven agriculture in the digitalization era.**

DEA-based recommendations can be integrated into digital agricultural platforms (e-Agriculture, mobile apps) to support real-time farmer decisions and accelerate the adoption of technological innovations in rural areas. (Barki & Rachmah, 2024) also discuss how the adoption of digital technologies (IoT, big data, AI) accelerates efficiency and data-driven decision-making—key in real-time and the development of modern agricultural systems.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The analysis results show that the technical efficiency of potato farming in Probolinggo Regency is already in the optimal category, with an average efficiency of 93.9%, with the majority of farmers having achieved full efficiency. This achievement reflects the well-managed and meticulous management of the production process. These optimal results are also inseparable from the use of a business analytics approach in the digital era, where farm data is systematically analyzed to support decision-making. With data-driven analysis, farmers can manage inputs efficiently and adjust farming strategies precisely, resulting in more adaptive, measurable, and competitive production performance.

Applying business analytics after a DEA technical efficiency analysis allows data to be processed into more applicable efficiency improvement strategies. The study showed that this approach can transform DEA scores into prescriptive recommendations, simplify decision-making through efficiency visualization and segmentation, and encourage the integration of digital technologies in data-driven agriculture.

Recommendations

Farmers are advised to optimize input use based on DEA results and learn from efficient farmers. Training and digital technology support from the government and extension workers need to be increased to encourage the adoption of business analytics. Future research could examine external factors influencing efficiency and develop advanced data-driven analysis.

ADVANCED RESEARCH

Further research could be directed at analyzing the determinants of technical efficiency using a DEA regression approach (such as Tobit or truncated regression). Furthermore, developing machine learning-based predictive models or integrating DEA with geographic information systems (GIS) could provide a more detailed spatial picture of efficiency. Research could also be expanded to other horticultural commodities, including seasonal variations in planting to understand efficiency dynamics over a longer period.

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