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Efficiency of corn cultivation to enhance food self-sufficiency in Indonesia

Eficiência da cultura do milho para aumentar a autossuficiência alimentar na Indonésia

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ABSTRACT

Corn farming is crucial for achieving national food self-sufficiency in Central Java Province, because it contributes to structural changes in the economy. This research aimed to evaluate the effectiveness of the methods used and to study the factors involved in the production of corn. A Stochastic Frontier (SFA) model as used to assess the efficiency and production factors. The findings indicate that farmers operate at a technical efficiency of 77%, an allocative efficiency of 63%, and an economic efficiency of 56%. To enhance efficiency, farmers are encouraged to optimize corn farming. Notably, the production factors of land area, seeds, urea fertilizers, NPK fertilizers, KCI fertilizers, pesticides, and labor have positive effects. The evaluation of business size suggests growing returns to scale, emphasizing the beneficial effect of increasing production inputs on of corn production. However, neglecting production factors may lead to additional inputs and reduced crop yields. Optimizing the use of inputs can increase the production scale of corn farming, improve efficiency as well as national food self-sufficiency. This research provides valuable insights for farmers seeking to enhance efficiency through the effective input use. Moreover, these findings are instrumental to the government's development of agricultural plans aimed at advancing farming and implementing policies to boost efficiency and attain food self-sufficiency.

KEYWORDS: assessing performance; efficiency of corn farming; achieving food self-sufficiency; factors of production; analysis using stochastic frontier.

RESUMO

O cultivo de milho é fundamental para alcançar a autossuficiência alimentar nacional na província de Java Central, pois contribui para mudanças estruturais na economia. O objetivo deste estudo é avaliar a eficiência e analisar os fatores de produção do cultivo de milho. A análise implementou o modelo Stochastic Frontier (SFA) para avaliar a eficiência e os fatores de produção. Os resultados revelam que os agricultores têm um nível de eficiência técnica de 77%, eficiência alocativa de 63% e eficiência econômica de 56%. Para aumentar a eficiência, os agricultores são incentivados a otimizar os insumos agrícolas do milho. Em especial, os fatores de produção de área de terra, sementes, fertilizantes de ureia, fertilizantes NPK, fertilizantes KCI, pesticidas e mão de obra apresentam efeitos positivos. A avaliação da escala de negócios indica retornos crescentes à escala, destacando o impacto positivo da adição de fatores de produção na produção de milho. No entanto, negligenciar os fatores de produção pode levar a insumos adicionais e reduzir a produtividade das culturas. A otimização do uso de insumos pode levar ao aumento da escala de produção no cultivo de milho, à melhoria da eficiência e à autossuficiência alimentar nacional. Esta pesquisa pode fornecer informações valiosas para que os agricultores aumentem a eficiência por meio do uso eficaz de insumos. Além disso, as descobertas são fundamentais para o desenvolvimento de planos agrícolas pelo governo com o objetivo de promover a agricultura e implementar políticas para aumentar a eficiência e alcançar a autossuficiência alimentar.

PALAVRAS-CHAVE: avaliação de desempenho; eficiência da cultura de milho; autossuficiência alimentar, fator de produção; análise de fronteira estocástica.

INTRODUCTION

The development of food self-sufficiency is crucial to ensure that food production meets local needs using area resources (the capacity of local production to meet the needs of individuals) (GISLON et al. 2020). The Indonesian government is intensifying efforts to increase corn production to meet the country's food and feed demands. The current circumstances require change because the economic and food needs of the community are no longer met by small-scale agriculture (ZHANG & QIN 2019). As part of the ongoing process of achieving food self-sufficiency, the community's economy is undergoing dynamic structural changes, particularly within the agricultural sector (ILHAM et al. 2021).

Our research focuses on the close relationship between economic production in agriculture and natural processes and how government policy measures to achieve food self-sufficiency can affect farmers' productivity and increase production. Specifically, we analyze the main corn product in Indonesia, particularly in Central Java. Despite a corn production of 2,259,593 tons per year in the province of Central Java, productivity is lower than in other regions. Farmers in this area consistently increase production and technological inputs, prioritizing yields and profits from their agricultural activities (PREZA-FONTES et al. 2021). Productivity levels are assessed using inputs such as agricultural resources (BPS 2023). We are also exploring the concept of resilience, which refers to the ability of agriculture to adapt to all impacts, learn from prevailing conditions, and transform and change the agricultural system. In this context, the transformation involves resisting the forces of development to achieve sustainability for local farmers (SCHÖNLEBEN et al. 2020, ZHANG et al. 2018).

RAHAYU et al. In 2019, it was discovered that corn agribusiness significantly affects the economy of Central Java province through a dynamic corn supply chain. This impact led to an increase in income of Rp. 15,713,772.81/ha compared with the previous increase in production inputs and technology of Rp. 8.255.109.14/ha. Despite a 22.01% increase in costs, there was a 48.61% increase in revenues, resulting in a positive overall impact. Wang and Hu (2021) also revealed the impact of rising input production prices and climate change on agriculture. A total of 52% of farmers saw a decrease in their agricultural production, with 58% experiencing a reduction of 30% and the remaining 42% experiencing a reduction of 45%.

Corn in Central Java province is a significant raw material for animal feed factories, representing more than 68% of the total raw material needed (RAHAYU et al. 2019). The need for corn as a raw material in the food and feed industries has increased, as stated by BECKER et al. (2023). Corn is used as animal feed and can be processed into different derivative products in small and large scale industries in Central Java. The province has 24 large-scale animal food industry units, and there are expectations of further increase (BPS 2023). Farmers in the region tend to sell corn to collectors or through contract systems with factories or processing industries (MISHRA et al. 2022), since the price offered by collectors is generally higher than the market price (ALQAISI et al. 2019), improving the ability of corn to compete at the level of farmers.

The local corn availability program and the corn economy are crucial for achieving food self-sufficiency in Indonesia. This program highlights the importance of considering all factors when making decisions related to agricultural system development, including the optimal use of inputs. It is crucial to balance corn production with farmers' understanding of applying the correct production elements (JAHANGIRPOUR & ZIBAEI 2023). Unfortunately, many farmers do not understand the correlation between inputs and outputs, causing them to use inputs that deviate from the recommended guidelines. Consequently, this inefficient use of input leads to lower production (DRASTIG et al. 2016). Therefore, it is essential to identify the factors that affect agriculture to maximize efficiency.

In addition, production-related expenses, especially for chemical fertilizers and pesticides, tend to increase annually due to factors such as inflation, changes in market demand, and the need for more advanced technologies (HUFFMAN et al. 2018). When resources and the rate of technology adoption are limited (GEFFERSA et al. In 2019, efficiency will become crucial for improving productivity growth. Due to low productivity levels (HRYHORIV et al. 2022), achieving the corn food self-sufficiency program remains unattainable.

There is a need for a study on economic activities, focusing mainly on corn production and agriculture in Central Java. The corn agribusiness is a dominant commodity in this area, and it is essential to understand its impact on the rapidly growing and productive economic sector. The goal is to increase productivity and achieve food sufficiency. Furthermore, this study evaluates the impact of corn agribusiness on the income levels and well-being of farmers. In addition, this study determines the efficiency and influencing factors of corn production in the province of Central Java. This research will include new methodological approaches, model specifications, and broader site coverage.

MATERIALS AND METHODS

Research Design

A comprehensive survey was conducted between August and September 2023 in three regions known for high corn production: Grobogan, Blora, and Wonogiri Regencies. This study employed a short-duration survey as its research method. The research was conducted in person through direct interviews with corn producers, ensuring a complete data collection on the use of corn cultivation inputs, such as land use for production, corn seeds, urea fertilizers, KCl fertilizers, NPK fertilizers, pesticides, labor, and the prices of each input. The interviews also included questions about corn cultivation. Farmers voluntarily participated as respondents with permission, and their data were protected to ensure that it was not abused (PRIYANTO et al. 2023).

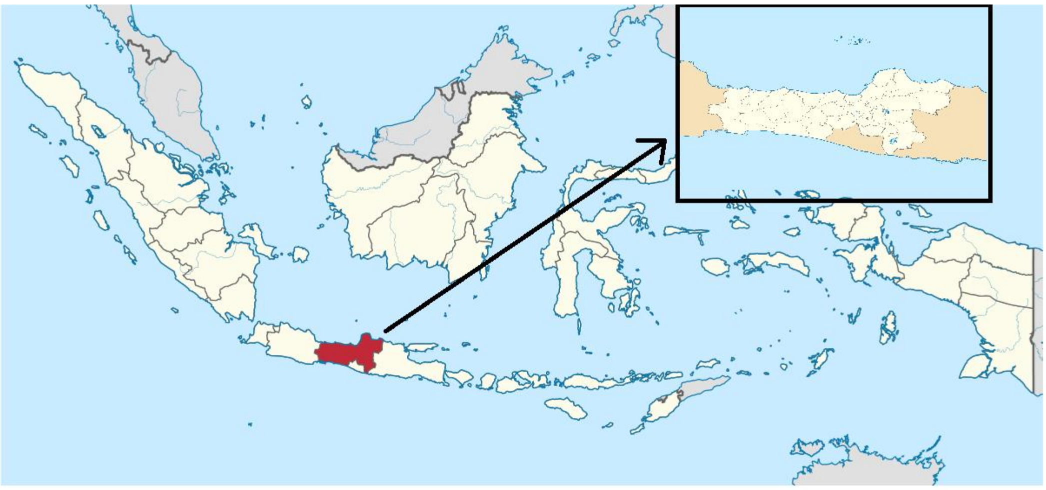

Figure 1: Research locations for improving corn farming efficiency.

Population and sampling

The provinces and districts were selected as research samples using a stratified random sampling method over several stages. As the population data of corn producers in the province are still being determined, we will use the formula developed by SANTA et al. (2021) to determine the number of samples.

$$n = \frac{z^2 1 - \alpha/2 \mathrm{p}(1 - \mathrm{p})}{d^2}$$

When n represents the sample count; Z represents the z value at a 95% confidence level, which is exactly 2.68; P is the maximum estimate, set at 0.5; and d is equal to alpha (0.10) or a sampling error of 10%. By using this precise formula, we can confidently determine the sample size.

$$n = \frac{2{,}01 - 0{,}5(1 - 0{,}5)}{0{,}01}$$

$$n = 201$$

Researchers often need to avoid data loss due to the possibility of non-response from respondents, which can range from 5-25% of the total (JAHANGIRPOUR & ZIBAEI 2023). If a maximum of 25% of the 201 farmers in the sample did not respond, it would mean that 50 farmers did not respond. To mitigate this risk, the total sample size was adjusted to account for non-response, resulting in a final sample of 268 corn producers. These farmers were proportionally divided into three districts, with each district consisting of 90 corn farmers as the research sample.

Stochastic frontier

The data were obtained using a production function in Frontier software version 4. This phase of the study assumed that agricultural production inputs can be increased using agricultural technology-based production inputs (WANG et al. 2023). The production function parameters and technical efficiency were estimated simultaneously using the Maximum Likelihood Estimation (MLE) model (MISHRA et al. 2022).

The production function was estimated using an observed model representing the production function described by Cobb-Douglas (ZHANG et al. 2018). This particular model consisted of the production of corn (Ln Y) measured in kilograms, a constant term (βo), parameter estimates (β1-β6), a stochastic variable/error term (vi), and the influence of technical inefficiency (μi). The variables X1-X7 represent various traditional agricultural inputs, including land area in halves, seeds in kilograms, urea fertilizer in kilograms, NPK fertilizer in kilograms, KCL fertilizer in kilograms, pesticides in liters, and labor in hours (HOK). The model can be represented as follows.

Economic output (Y) is modeled as a function of the natural logarithm of several input factors (X1 - X7) multiplied by their respective estimated parameters (β0 - β7) and subtracted by the technical inefficiency term (vi - ui). The positive average values of the estimated parameters β1-β7 suggest that the increased use of production factors may lead to a higher yield of corn.

When evaluating technical efficiency, one can compare actual production (Yi) with potential production (Yi^*), as suggested by (BERK et al. 2022).

$$TE = \frac{Y}{Y^*} = \frac{E(Yi\ I\ Ui.Xi)}{E(Yi\ I\ Ui = 0, Xi)} = [\exp(\pi)]$$

The expected technical efficiency is represented by the phrase (-μi) in the text, where the technical efficiency of the i-th farmer is limited to 0 < TEi < 1. Assuming that distribution parameter (μi) is unlimited and typically truncated by N(μiσ^2), the parameter is found. This work assesses the consequences of individual study failures under specific conditions.

The stochastic frontier cost function is reduced to analyze economic efficiency. This function includes the prices of agricultural inputs, such as corn production in kilograms, seed price per kilogram, urea fertilizer price per kilogram, KCL fertilizer price per kilogram, NPK fertilizer price per kilogram, pesticide price per liter, and salary rate per HOK. The production costs of corn are denominated in IDR, parameter estimates are marked as β1-β7, random variables/noise are represented as vi, technical inefficiency effects are marked as μi, and P1-P2 are included in this function. The following is the formula for the corporate agricultural cost function of corn.

Ln. C = (X0] + [X1lnP1] + [X2lnP2] + [X3lnP3] + [X4lnP4] + [X5lnP5] + [X6lnP6] + [X7lnP7])

Economic efficiency is an essential concept in practice that compares the total cost of production (C) with the minimum observable total cost of production (C*).

$$EE = \frac{C}{C^*} = \frac{E(Ci\ I\ Ui = 0, Yi, Pi)}{E(Yi\ I\ UiYi, Pi)} = E[\exp(Ui\mathrm{I}\Sigma)]$$

The cost efficiency was calculated using the boundary calculation software 4.1c. Thus, economic efficiency is determined using the equation below.

$$EE = \frac{1}{\text{Cost Efficiency (CE)}}$$

Given the relationship between technical and economic efficiency, the following formula can be used to calculate the attributive efficiency (EA).

$$EE = \frac{\text{Economic Efficiency (EE)}}{\text{Technical Efficiency (TE)}}$$

RESULTS AND DISCUSSION

Corn Farming Efficiency

An efficiency assessment was conducted to evaluate the management of corn production. The results in Table 1 of the Stochastic Frontier analysis indicate that a typical farmer achieves a technical efficiency rate of 77%, suggesting that 23% of the inputs could be improved for greater technical efficiency. Under VRSTE, only 18 farmers (6.72%) were fully efficient at 1,000. Most farmers (2.62%) had an efficiency value of 0.30-0.50, indicating low efficiency.

An analysis was conducted to evaluate the effectiveness of corn production management. According to the findings in Table 1 of the Stochastic Frontier analysis, a typical farmer operates with a technical efficiency rate of 77%, which implies that 23% of inputs require more efficient use. It is assumed that 18 farmers (6.72%) are fully efficient in 1,000 according to the VRSTE model. Moreover, most farmers (2.62%) had an efficiency value that ranged from 0.30 to 0.50, indicating low efficiency.

The results of the input-oriented model in the stochastic frontier analysis of this study show that farmers demonstrate technical efficiency. The range of technical efficiency varies from 48.51% to 100%, indicating potential for enhancement. WANG & HU (2021), XU et al. (2021), discovered that farmers can improve technical efficiency with existing production resources. FAN et al. (2018), LOHOSHA et al. (2023) suggested that increasing agricultural productivity is crucial for economic improvement and reducing vulnerability to poverty. A national program for food sufficiency can be achieved through the implementation of technical modifications in agricultural systems with support for knowledge transfer.

In Central Java province, corn producers have an efficiency rate of 0.63% or 63% (Table 1). Farmers can reduce the current average production cost by 37% to reach the minimum cost. Efficiency indicates that only 10.09% of farmers are operating at their maximum efficiency, whereas most farmers (51.48%) have low or inefficient efficiency. Efficiency is linked to the price of each input used by farmers. Most farmers buy seeds; however, the quality of the seeds subsidized by the government is still low, so farmers prefer to buy higher-priced seeds.

Table 1. Distribution of agricultural efficiency of corn.

Classification	Technical Efficiency		Allocative Efficiency		Economic Efficiency	
	Total	Percentage	Total	Percentage	Total	Percentage
0.30≤ E ≤ 0.40	2	0.75	11	4.1	43	16.04
0.40≤ E ≤ 0.50	5	1.87	13	4.85	54	20.14
0.50≤ E ≤ 0.60	11	4.10	2	0.74	111	41.41
0.60≤ E ≤ 0.70	21	7.84	112	41.79	44	16.45
0.70≤ E ≤ 0.80	130	48.51	103	38.43	3	1.11
0.80≤ E ≤ 0.90	81	30.22	23	8.72	13	4.85
0.90≤ E ≤ 1.00	18	6.72	4	1.37	0	0
	268	100	268	100	268	100
Minimum	0.35		0.32		0.32	
Maximum	0.97		0.94		0.87	
Mean	0.77		0.63		0.56	

In addition, problems arise in the pricing of NPK fertilizers and urea, which affect the input costs incurred by farmers due to the price difference between subsidized and non-subsidized fertilizers. Only a few corn producers can access subsidized fertilizers, and their availability only occasionally matches that of when they are needed for corn production. Farmers must buy unsubsidized fertilizers to ensure that they can continue farming and meet the nutritional needs of corn plants.

The provision of sufficient support for the agricultural sector. This will help the country recover and grow stronger, promote rural development, improve food security, and stabilize global prices. A political recommendation for achieving food self-sufficiency is to provide subsidies for agricultural inputs. These subsidies help reduce farmers' costs, allowing them to use inputs optimally without being limited by availability or price. In Central Java, most corn producers are not economically efficient, with only 5.96% of producers achieving an efficiency level of 0.70-0.90. With appropriate support, resilience can be developed. Therefore, the achievement of food security depends on the efficient use of resources.

It is crucial to manage agricultural systems and natural resources effectively to ensure sustainable agriculture. The availability of natural resources significantly affects the well-being of farmers and their ability to achieve food sufficiency. Natural resources must be used efficiently to maximize production, leading to positive economic changes for farmers and the community (ZHANG et al.) 2018). These efforts improve farmers' economies and achieve food sufficiency. In Central Java province, the economic landscape of corn producers is undergoing structural changes due to government policies that influence agricultural yields and farmers' perceptions of agricultural and food conditions.

Factors that affect corn production

The agricultural inputs for corn include seeds, fertilizers, and pesticides. Seeds are necessary for agriculture to allow cultivation. Fertilizer is used to provide nutrients to plants to meet their nutritional needs. The fertilizers used in corn cultivation include urea, NPK, and KCl fertilizers (Table 2). The average area of land owned by corn producers in Central Java province is 2.08 hectares.

Table 2. Input assignment of production factor for corn cultivation.

Input Production	Unit	Mean Cost/MT	Mean Usage/MT
Corn Seeds	(kg/ha)	2.092.671	25
Urea Fertilizer	(kg/ha)	4.449.780	247,21
NPK Fertilizer	(kg/ha)	6.248.810	304,82
KCl fertilizer	(kg/ha)	1.877.760	78,24
Herbicides	(l/ha)	127.500	1,5
Insecticides	(l/ha)	58.500	0,25
Fungicides	(l/ha)	1.375	0,025
Total Labor (DK+LK)	(HOK)	1.090.000	109

The relationship between the elasticity of corn production and the average use of inputs in corn cultivation can be examined. The objective of production efforts is to maximize profits through efficient use of various inputs. To achieve maximum profit, two conditions must be satisfied: the necessary and sufficient conditions. The necessary conditions are factual and are met when achieving a more excellent output using the same inputs or when production elasticity varies from zero to one is no longer viable.

Urea, KCL, and NPK were used at average rates of 247.21, 78.24, and 304.82 kg/ha, respectively. However, this exceeds the recommended amount for the Central Java Province; the recommended application rates for urea, KCL, and NPK are 250, 75, and 50 kg. It is crucial for farmers to understand that using more fertilizers than recommended can lead to higher expenses and soil acidity (HETMANENKO et al. 2021). Excessive use of fertilizers negatively affects soil nutrient absorption, even though plants only absorb nutrients based on their needs (SIAGIAN et al. 2021).

Farmers typically use approximately 1,775 liters of pesticide per hectare to combat spines. Excessive use of pesticides can harm plants and the environment because they reduce the natural enemies of pests, leading to an increase in attacks (RAHAYU et al. 2021, RIYANTO et al. 2021). In the designated geographical area, the average labor allocation for corn cultivation is 109 HOK. Among local families, 18% of labor resources are allocated to agricultural enterprises, with the remaining 82% dedicated to non-agricultural occupations.

The production factors of each input can be observed from the results of the stochastic frontier analysis of Cobbs-Douglas production to examine the impact of inputs or production factors (Table 3).

Table 3. Production function model with estimation method using maximum likelihood.

Parameters	(MLE) Maximum Likelihood Estimation		
	coefficient	Sig	Error
Constant (X0) (+/-)	5.48	5.53	0.98
Land Size (X1) (+)	0.49***	3.86	0.88
Corn Seeds (X2) (+)	0.30***	3.17	0.17
Urea Fertilizer (X3) (+)	0.26**	2.17	0.09
NPK Fertilizer (X4) (+)	0.18*	2.07	0.91
KCL Fertilizer (X5) (+)	0.00	1.30	0.00
Pesticide (X6) (+)	0.05*	1.50	0.04
Work (X7) (+)	0.04	0.41	0.05
Sigma Square	0.02	2.25	0.09
Gamma	0.68	2.05	0.27
OLS Probability	24.84		
MLE Probability	20.49		
RTS	1.15		
LR Test of the error on one side	14.83		

***: 1%. **: 5%. *: 10%

Based on the role of corn production, the factor with the most substantial impact on corn production is land area (X1), with a regression coefficient of 0.49. The coefficient for land area implies that a 1% increase in land area leads to a 0.49% increase in corn production. On the other hand, the factor with the most negligible impact on corn production is KCl fertilizer (X5), with a regression coefficient of 0.00. This indicates that a 1% increase in KCl fertilizer does not significantly affect the increase in corn production.

The production factor for corn seeds (X2) is 0.30, which has a positive impact on corn production in Central Java province. A 1% increase in the seed production factor will lead to a 0.30% increase in corn production, assuming that all other factors remain constant (ceteris paribus). The urea fertilizer (X3) has a production factor of 0.26, indicating that a 1% increase in fertilizer production will result in a 0.26% increase in corn production, assuming that other factors remain constant (ceteris paribus). Similarly, the production factor of the NPK fertilizer (X4) was 0.18. This means that a 1% increase in NPK fertilizer production will result in a 0.18% increase in corn production, assuming that the other factors remain constant. The pesticide (X6) had a positive regression coefficient with a production factor of 0.05. A 1% increase in pesticide production will lead to a 0.05% increase in corn production, assuming that the other factors remain constant. The labor production factor (X7) had a value of 0.04 and did not have a significant effect. This suggests that a 1% increase in labor usage does not significantly affect the increase in corn production.

The production factor (area) is 0.49. In Region I, the production factor is more significant than one (Ep>1), indicating that an increase in land area by 1% will increase corn production by more than 1%. This region demonstrates increasing returns to scale, as the addition of production factors consistently increases output over time. As a result, a maximum profit has not yet been reached in this region, as production can still be increased by adding inputs. The production process is categorized into three segments according to the factors of production used: Segment I (production factor > 1), Segment II (production factor between 0 and 1), and Segment III (production factor < 1).

The values of all factors except for the fertilizer KCl, is more significant than zero but less than 1. The results of the study revealed that the work, seeds, and pesticides affected corn production, but the seeds and pesticides had negative factor values. In contrast, the values of this study were positive. (ILSAN & HASAN 2022) shows positive results for the workforce. However, the use of fertilizers has adverse effects, suggesting that the distribution and use of these inputs are irrational during excessive production.

An increase in 1% production factors can increase production that varies from 0% to 1%. At a specific point, the total use of inputs results in maximum profits, indicating that the use of production factors, such as land, seeds, urea fertilizers, NPK fertilizers, KCI fertilizers, pesticides, and labor, has been rational and has produced benefits and profits.

Corn, identified by FAO in 2022, is a crucial product for national development. The primary activities of farmers and the livelihoods of their families revolve around the production of corn. Corn farming creates jobs and business opportunities and has a substantial multiplier effect, promoting economic transformation. The development of agricultural economies can capitalize on relative comparative advantages under different conditions by using local resources and increasing agricultural productivity through inputs, thus reducing poverty and raising farmers' incomes (LOHOSHA et al. 2024). According to Li et al. (2022), efforts to boost corn production increased output and stimulated the national economy.

Efficiency is a fundamental goal in corn production in Central Java. An opportunity exists to improve efficiency by optimizing inputs and minimizing costs. The global input levels used in corn production indicate increased yields at scale, suggesting that farmers can still achieve maximum profit by increasing inputs in a fixed proportion. The use of local resources as inputs in agriculture clearly demonstrates the industry's adaptability and commitment to efficient use of resources. The impact of natural conditions on plant growth and the availability of agricultural production factors can drive economic development, especially in rural areas. Leveraging the dependence of agricultural land on natural conditions can be essential for efficiently optimizing resources to increase productivity—a crucial step toward achieving food self-sufficiency in corn farming.

CONCLUSION

This study examined the factors of efficiency and production of corn cultivation in Central Java. According to the stochastic frontier analysis (SFA), the average technical efficiency is 77%. The analysis also showed that farmers can increase their efficiency by using corn cultivation inputs. Regarding assignment efficiency, farmers are operating at a rate of 63%, indicating that they can reduce their current production cost by 37% to achieve the potential minimum cost. The study also suggests room for improvement in economic efficiency, particularly in the ideal allocation of inputs based on price considerations.

The results regarding production factors indicate that all factors, such as land area, seeds, urea fertilizers, NPK fertilizers, KCI fertilizers, pesticides, and labor, had a positive impact. All production factors except pesticides and labor are efficiently used. The term "efficient" means that its use resulted in benefits and advantages for achieving food self-sufficiency goals. Efficiency results refer to the ability of a farm to achieve maximum production with specific inputs. The assessment of agricultural efficiency levels allows farmers to make informed decisions. Using inputs as a resource is crucial for agricultural production and productivity. Therefore, farmers' decisions when determining the use of inputs are crucial. The cost of each input factor affects the assignment efficiency or cost efficiency. Thus, farmers must find the most efficient input at the lowest cost to maximize corn production.

The incorporation of production factors positively influences corn production. However, if farmers do not make correct input decisions, then inputs increase and production decreases. Increased production can be achieved by using inputs as resources. The results demonstrate opportunities to improve corn production efficiency. Such circumstances foster the improvement of efficiency to accelerate national food self-sufficiency and promote more equitable economic activities and income distribution among farmers. This research can be developed for future studies using alternative methods such as data envelope analysis (DEA), which is a non-parametric method used in operations research and economics to assess the relative efficiency of decision-making units. Additional variables related to agricultural inputs can be integrated into the model to examine efficiency determinants. Research development efforts could explore a broader scope by analyzing corn outside the farm.

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