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FACTORS AFFECTING TECHNICAL EFFICIENCY TO OPTIMIZE CASSAVA PRODUCTION IN DRYLANDS

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ABSTRACT

Improving the technical efficiency of cassava is essential, as it enhances resource use, boosts, and drives broader economic growth. This study aimed to estimate the technical efficiency of cassava production as a contribution to food security, job creation, and sustainable agriculture-based development. Trenggalek Regency was chosen as the research location, considering that the regency is in the centre of cassava production in East Java Province, as a key factor in achieving sustainable agricultural development. The data were obtained through interviews with 70 cassava farmers, selected using stratified random sampling across two sub-districts. The data used in this study were primary and secondary data, while the data analysis used the stochastic frontier production function. The results of the study on the efficiency of production factors include land area (89.31), cassava seeds (5.36), labour (34.20), NPK fertiliser (6.70), KCL fertiliser (0.69), SP36 fertiliser (0.51), urea fertiliser (-0.49), and pesticide (-0.09). In general, cassava farming in Trenggalek Regency is not technically efficient in utilising production factors. In fact, technical efficiency is an important factor that needs to be considered, and there is great potential to increase cassava production through efficiency improvements. Therefore, interventions are needed to improve the technical efficiency of cassava farming through intensive counselling and training programs, appropriate input use, technological development, and improved access to capital, aiming to positively impact farmers` income, food security, and sustainable agricultural development.

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INTRODUCTION

Cassava (Manihot esculenta) is a strategic food crop in Indonesia, ranking second only to rice and beans. In some areas, cassava serves as a major source of carbohydrates, especially in areas where it is not possible to grow rice. Its adaptability to dryland, tolerance to drought and resistance to pests and diseases make cassava an important component of food security strategies, especially in climate change conditions (Widodo et al., 2015; Rozi et al., 2021). In addition to its role as a subsistence crop, cassava has significant industrial potential. Cassava is processed into products such as tapioca, mocaf, chips, animal feed, and bioenergy. The potential for cassava production is supported by positive cassava productivity and continues to increase even though production and land area fluctuate (Nasir et al., 2021), especially from the growing industrial sector. Where cassava productivity in 2019 was 26.02 tons/ha, in 2020 it was 25.02 tons/ha, in 2021 it was 24.92 tons/ha, in 2022 it was 27.22 tons/ha, and in 2023 it was 27.11 tons/ha (Direktorat Jenderal Tanaman Pangan, 2023). The increasing demand is driven by population growth and evolving consumption patterns, underlining the importance of cassava as a food and industrial commodity (Adefunsho et al., 2022). In addition, the development of the food processing and animal feed industry has encouraged an increase in demand for cassava. The vast market potential provides opportunities for farmers to increase their income and welfare. Due to the high demand for cassava for industry, households, and favourable climatic and soil conditions (Teguh et al., 2022a). In addition, cassava has great potential as the main food crop in the future and is resistant to climate change and various soil conditions, even though cassava has not been utilised optimally (Ashebir, 2022). Cassava can grow in dryland conditions, is tolerant of drought, is tolerant of various rainfall patterns, and has relatively easy production poses. Cassava's ability to withstand climate change and drought will be useful for food security (Onyediako & Adiele, 2022). Despite having durability and growing market opportunities, cassava is still underutilised, especially in dryland agroecosystems.

Cassava cultivation is traditionally found in dryland agroecosystems and drylands with wet climates, especially in dry climate conditions, dryland and optimal land (Ngongo et al., 2022). Cassava shows an extraordinary ability to adapt and grow in dryland where other food crops cannot grow well, but for its high yield and productivity (Adejuwon & Agundiminegha, 2019). Although cassava is able to tolerate low nutrients, its availability makes it a staple crop for resource-poor farmers (Mtunguja et al., 2019). In addition, cassava properties related to resilience are able to adapt to various ecosystems, soil types, drought tolerance, resistance to pests and diseases, and low input requirements as the main traits for variety improvement (Olaosebikan et al., 2023). The economic potential of cassava is huge, especially in supporting food security and increasing farmers' incomes, especially in marginal areas (Ngongo et al., 2022). Therefore, a large area of dryland is needed as a large resource but has not been utilised optimally, related to the fertility status of the soil, resulting in low land productivity (Sukerta et al., 2020). To increase cassava productivity in dryland, proper land management is needed, such as the selection of superior varieties, proper fertilisation, and pest control.

Cassava plays a crucial role in food security, not only as a source of cheap food but as an income for farmers in reducing rural poverty (Edet et al., 2019). Cassava is grown by small-scale farmers on poor soils using traditional methods, so that it is very suitable for agricultural systems to support food security (Saediman et al., 2019). Apart from being the main source of carbohydrates, cassava can also be processed into various high-value processed food products, so that it can increase farmers' income and diversify food (Wulandari et al., 2023). Plants that can withstand climate change and provide higher productivity are needed to overcome food security problems, such as cassava, making food security crops important for the future (Feyisa, 2022). To increase the added value of cassava, it is necessary to develop the right processing technology so that cassava-processed products can compete in the market. This means that cassava is easily damaged, and there is no loss when sold in dry form to increase economic income and food security (Ouma et al., 2021). Cassava is very important as a food crop to increase the source of income for rural communities by expanding production (Akomolafe et al., 2023). Therefore, it is necessary to handle food security with recognition of smallholder farmers for their role in achieving hunger and poverty reduction through increasing cassava production.

Speculation about the increasing demand for cassava has many challenges, both in terms of supply and the market. One of the crucial challenges that has not been adequately addressed is the technical inefficiency of cassava agriculture, especially in dryland. This is because dryland has great potential for cassava development, considering the good adaptation of cassava plants to any conditions. Technical inefficiencies are reflected in production costs that are high compared to low yields, and production orientation is still dominated by fulfilment towards living needs rather than commercialization, the potential for local varieties to be genetically low, and the price of cassava is cheap (Msuha, 2019). In addition to the challenges of technical inefficiencies, cassava production faces various complex challenges involving age, socioeconomic factors, and technical efficiency (Yisa et al., 2020). Limited access to resources such as fertilizers, labour, lack of innovation and adoption of agricultural technology, and increasingly extreme climate change are also obstacles in increasing cassava production (Akpaeti & Frank, 2021). Climate change can cause prolonged droughts and erratic rainfall to negatively impact cassava yields in drylands.

Cassava production has ebbed and flows; one of the causes of low productivity is ineffective resource allocation and environmental factors (Isonguyo et al., 2021). The problem of cassava production that is not balanced with demand is a big challenge that can exacerbate food insecurity if not handled appropriately. The increasing demand for cassava is due to population growth and the expansion of cassava-based industries. So that by increasing production efficiency, product diversification, and market development, we can reduce food insecurity and improve the welfare of farmers. In addition, cassava farmers in drylands have not achieved optimal technical efficiency in their production process, due to the use of improper inputs, a lack of farmers' knowledge of modern technology, and limited access to resources. Therefore, this study aims to analyze the factors that affect the technical efficiency in cassava production in dryland and formulate the right strategy to optimize productivity. These findings are expected to contribute to a more sustainable and economically viable cassava farming system, while supporting national food security and rural development goals.

RESEARCH METHOD

A series of structured interviews based on questionnaires related to cassava productivity in two sub-districts, namely Tugu and Trenggalek sub-districts, from July to September 2024. The selection of these two sub-districts is based on a significant contribution to the total cassava production in Trenggalek Regency. The research chose Tugu District and Trenggalek District as the research location because the two sub-districts are the centre of cassava production in Trenggalek Regency, making them representative of the cassava farming conditions in East Java. Moreover, Tugu District has a total cultivation area of 1051 ha and cassava production of 2,620,534 tons, while Trenggalek District has an area of 951 ha and cassava production of 1,950,678 tons. The high production figures in both sub-districts show that cassava farming is an important economic activity for the people of Trenggalek Regency. The stratified random sampling method based on the area of cassava plantations was applied in accordance with the list provided by the Agriculture Office of Trenggalek Regency, to categorise respondents into three groups, including farmers who own land, rent land, and share profits for cassava production of less than 1 ha or more than 1 ha. The total cassava farmers in Tugu and Trenggalek Districts is 500 cassava farmers. We interviewed farmers involved in cassava farming, with a total of 70 respondents, with the following details.

Table 1. Allocation of Cassava Farmer Respondents

No	Information	Population farmers	Propose	Sample farmers
1	Own land < 1 ha	150	0.30	21
2	Own land > 1 ha	100	0.20	14
3	Rent land < 1 ha	80	0.16	11
4	Rent land > 1 ha	50	0.10	7
5	Share profits < 1 ha	70	0.14	10
6	Share profits > 1 ha	50	0.10	7
	Total	500		70

The analysis method was used to determine the production factors that significantly affect frontier production and to analyze the efficiency of using inputs from cassava production factors in the research area. Output-oriented technical efficiency of cassava producers using parametric eco`nometric techniques using a stochastic frontier production approach. The production function used in this study is the Cobb-Douglas production function. The method of measuring production efficiency used in the study refers to (Battese & Coelli, 1995), where the equation is as follows:

$$TEi = \frac{y_i}{y_i^*} = \exp(-\mu_i) \ldots\ldots\ldots\ldots\ldots\ldots\ldots(1),$$

where: Tei: technical efficiency of the farmer to -i; Yi: Actual production of observations; YI*: the potential production obtained from the Frontier production function. For this production function to be estimated, the equation needs to be transformed into a linear form so that it becomes:

$$LnY = \ln b_0 + b_1 \ln \chi_1 + b_2 \ln \chi_2 + b_3 \ln \chi_3 + b_4 \ln \chi_4 + b_5 \ln \chi_5 + b_6 \ln \chi_6 + b_7 \ln \chi_7 + b_8 \ln \chi_8 + ei + Ui \quad ....(2),$$

where: Y: Cassava production (kg); b0: Intercept; bi,b2,..bn: Parameter variable estimation; X1: Land area (ha); X2: Seed (kg); X3: NPK fertilizer (kg); X4: Urea fertilizer (kg); X5: SP36 fertilizer (kg); X6: KCL fertilizer (kg); X7: Pesticides (liter); X8: Labor (HOK); ei: error; Ui: Factor inefficiency technis.

The technical efficiency value ranges between 0 and 1, or 0 ≤ Tei ≤ 1. If the TE value is getting closer to 1, cassava farming in Trenggalek Regency can be said to be more efficient. If the TE value is close to 0, cassava farming in Trenggalek Regency is said to be technically inefficient. In the context of this study, the TE value obtained from the stochastic frontier analysis model will show the level of efficiency of cassava farming in Trenggalek Regency, which will be used to identify areas where improvements can be made to increase the production and welfare of cassava farmers.

RESULT AND DISCUSSION

Characteristics of cassava farmer respondents in Trenggalek Regency include age, education, and farming experience. The age range of respondents was divided into the youngest age of 29 years and the oldest age of 85 years. The majority of respondents were in the age group 51-61 years, as many as 27 people who are included in the productive age according to BPS (15-65 years). This is in line with research (Teguh et al., 2022b) that productive age groups generally have high enthusiasm and responsibility in developing their farms. In terms of education, the majority of respondents, 69.5 per cent, only completed elementary school, indicating that the education level of farmers in the study area is low. Education plays an important role in the ability to read, write and access information that increases access to cassava cultivation (Awotide et al., 2019). The experience of cassava farming ranges from 2 years to 70 years, with a majority of 44 per cent having 30-43 years of experience. This identifies that most farmers have long experience gained from generation to generation, which has the potential to positively influence the level of commercialisation and productivity of cassava farming (Hussayn et al., 2020). (Hussayn et al., 2020).

Determine how much influence the production factors of cassava farming (land area, seeds, fertilizer, and labour) have on cassava farming production using Cobb-Douglas analysis. The main purpose of this analysis is to identify the most dominant production factors affecting cassava productivity and regulate the level of production elasticity against the changes of each production factor. The results of the analysis of the influencing production factors affect the production variables of cassava farming (Y). The interpretation of regression analysis to facilitate the reading of the results is used in the form of equations containing constants and regression coefficients obtained from the results of data processing. Knowing the influence of each independent variable on cassava farming production can be seen from the regression coefficient, with statistical tests in Table 2, as follows.

Table 2. Regression Coefficient of Cassava Farming Production Function

Model	Unstandardized Coefficients		Standardized Coefficients	t_{stat}	Sig.
	β	Std. Error	Beta		
Constant	6.152	15.342		0.398	0.680
Land Area	0.245	5.204	0.625	4.374	0.000
Seed	0.025	0.039	0.043	1.237	0.314
Fertilizer					
KCL	0.033	0.036	0.040	0.327	0.312
NPK	0.035	0.030	0.072	1.221	0.224
Urea	0.027	0.021	0.050	0.743	0.383
SP36	0.021	0.036	0.041	0.425	0.443
Pesticides	0.028	0.198	0.183	0.130	0.777
Labor	0.125	0.140	0.114	1.042	0.282

Based on Table 2, the significant land area (sig. = 0.000 < 0.05) means that only the land area has a significant influence on cassava production, where every increase in land will increase output consistently. This is in accordance with (Akerele et al., 2019) that the expansion of production is due to an increase in land area. The variables of cassava seeds, KCL fertilizer, NPK fertilizer, urea fertilizer, SP36 fertilizer, pesticide, and labour were not statistically significant. The insignificance of the input is due to several factors, including the application of fertilizer that is not appropriate, dosage, and time (Alam et al., 2024), uneven seed quality, untargeted use of pesticides, and low labour productivity due to a lack of skills. The research (Widyawati, 2020), that the inefficiency of seed use is due to low seed quality and inappropriate fertilization. Therefore, a production increase strategy is needed that focuses on optimizing existing land use through intensification. Meanwhile, it is still improving the quality and precision of using other inputs through proper agricultural extension and the application of agricultural technology that is more pressing to sustainability.

The results of the estimation of the cassava farming production function model with the frontier stochastic production function approach in this study is

$$LnPd = 6.152 + 0.245LnLa + 0.25LnS + 0.35LnPn + 0.27LnPu + 0.021LnPs + 0.036LnPk + 0.028LnPes + 0.125LnL \ldots\ldots (3),$$

R^2: 0.86; SignificanceF: 0.000

Based on the model, it can be explained that the constant value of 6.152 shows the average effect of all exogenous variables on cassava farming production variables 6.152. The value of the determination coefficient (R2) of 86 per cent variation in the production variable of cassava farming (Y) can be explained by the variable of land area (X1), where an additional input of 1 per cent of land area will increase production by 0.245 per cent, assuming ceteris paribus. This indicates that land expansion is still relevant to increase the scale of cassava production, albeit with relatively low elasticity that may be due to limited land quality or suboptimal cultivation techniques. Expanding the use of inputs will increase total cassava output

(Tafesse et al., 2021). Seedlings (X2), where there is an addition of seed input of 1 per cent, will increase production by 0.25 per cent, emphasizing the importance of using superior seeds as the foundation of productivity. NPK fertiliser (X3). Suppose there is an addition of NPK fertilizer input of 1 per cent. In that case, it will increase production by 0.35 per cent, reflecting its role as a compound fertilizer that provides essential macronutrients (N, P, K) in a balanced form. Urea fertilizer (X4) if there is an addition of urea fertilizer input by 1 percent, it will increase production by 0.27 percent, SP36 fertilizer (X5) if there is an addition of SP36 fertilizer input by 1 percent will increase output by 0.021 percent, KCL fertilizer (X6) if there is an addition of KCL fertilizer input by 1 percent will increase production by 0.036 percent. The low impact of SP36 fertiliser and KCL fertiliser is due to the incompatibility of the application with the needs of the soil or plants.

Pesticide (X7): If there is an increase in pesticide input by 1 per cent, it will reduce production by 0.028 per cent, which can be explained by improper use (overuse or incorrect timing) that causes pest resistance or plant damage. According to Paul et al. (2022), the low use of pesticides among cassava farmers has a negative impact when applied without adequate knowledge and improper use. Labour (X8), where there is an increase in labour input by 1 per cent, will increase production by 0.125 per cent, assuming ceteris paribus. Because its value is not too high, it indicates that the addition of the workforce without increasing skills or work efficiency does not have the maximum impact. So that farmers show that they are quite efficient in producing cassava at a certain output level using input ratios that minimize costs (Igbaifua et al., 2021). At the same time, the remaining 14 per cent is influenced by other variables that have not been included in the model, among others, climate and technology. These findings confirm that the optimisation of specific inputs (especially NPKs and seeds) is more crucial than simply increasing the number of inputs, and that technical training is needed to avoid inefficiencies in pesticide variables.

Technical efficiency is a measure that shows the comparison between actual production and maximum production. Technical efficiency can be interpreted from two perspectives, namely from the input point of view, to the extent to which production can be increased by using fewer inputs, and from the output point of view, where it can be increased by still using the same input level. The results of the calculation of technical efficiency obtained an average value of 0.313 or 31,3 per cent, so it can be explained that cassava farming in Trenggalek Regency is not efficient based on technical aspects. This means that farmers in Trenggalek Regency have only taken advantage of around 31,3 per cent of the production potential that should be achievable with the resources that farmers have. This identifies the potential for a considerable increase in production through improvements in the use of production factors (Bondina et al., 2022). Cassava farmers have not been able to combine the use of production factors of land area, seeds, NPK fertilizer, KCL fertilizer, SP36 fertilizer, urea fertilizer, pesticides, and labour to get optimal cassava production. As a result, the results of the study show all factors of cassava farming production inefficiency. Because the addition of seeds, NPK fertiliser, SP36 fertiliser, and urea causes a decrease in production, in addition to limited capital and limited information about land conditions related to the need for fertiliser on the land (Widyawati, 2020). Many farmers stated they could not understand the impact of a single production factor, such as fertiliser, on overall crop productivity, clearly stating that they understood the importance of fertiliser but lacked knowledge about balanced applications (Aryal et al., 2021). Cassava farmers still have the opportunity to increase production by 68.7 per cent by combining production factors through the addition of labour and seed production factors and reducing fertiliser production factors.

The results of the study show that the technical efficiency value of the use of production factors of land area, seeds, labour, NPK fertiliser, KCL fertiliser, SP36 fertiliser, urea fertiliser, and pesticide is presented in Table 3.

Table 3. Technical Efficiency of Cassava Farming in Trenggalek Regency

No	Factors Production	Average Input Usage	Regression Coefficient (bi)	Technical Efficiency	Result
1	Land area	0.50	0.245	89.31	Inefficiency
2	Labor	23.26	0.125	34.20	Inefficiency
3	Seed	10,000.00	0.250	5.36	Inefficiency
4	NPK fertilizer	86.12	0.350	6.70	Inefficiency
5	Urea fertilizer	14.36	0.270	-0.49	Inefficiency
6	SP36 fertilizer	9.23	0.021	0.51	Inefficiency
7	KCL fertilizer	54.21	0.036	0.69	Inefficiency
8	Pesticide	16.44	-0.028	-0.09	Inefficiency

Cassava farming production can be said to be efficient if it can produce the desired amount by using fewer inputs or if it can achieve maximum production by using the best inputs. The criteria for determining whether a farmer is said to be efficient refers to the opinion (Timothy et al., 2005) which states that if the efficiency inex value is equal to or greater than 0.7 then cassava farming production is said to be technically effective, on the other hand, if the efficiency index value is less than 0.7 then cassava farming production is sconsidered ineffective. The results of the technical efficiency analysis in this study show that the average efficiency index of cassava farmers in Trenggalek Regency is still below the efficiency threshold of 0.313. This indicates that there is a huge potential to increase cassava productivity through improving technical efficiency. Low technical efficiency values are often related to low input elasticity, especially improper labour at various stages of cassava production and the use of improper fertiliser dosages. Low elasticity means that changes in the use of such inputs do not result in a proportional change in the output. The results of this study are in line with research (Sinaga et al., 2021), which shows that the technical efficiency of cassava farmers in Indonesia is still relatively low, so there is a need for sustainability efforts to improve cassava production efficiency. So that the strategy implemented for cassava farmers in Trenggalek Regency can be increased, a large output of 68.7% can be achieved and will have a positive impact on increasing farmers' income and food security in Trenggalek Regency.

Table 4. Distribution of Technical Efficiency Values of Cassava Farming

Efficiency Technic	Farmer	Percentage (%)
<0,7	40	57.14
0,7-0,8	20	28.57
0,8-0,9	6	8.57
>0,9	4	5.72
Total	70	100.00
Low Scores = 0.213		
Highest Scores = 0.412		
Average = 0.313		

Based on Table 4, it is known that the number of respondents of 40 farmers with a percentage of 57.15% is dominated by inefficiency < 0.7, which means most farmers have not been optimal in managing production inputs (land, fertiliser, and labour). Meanwhile, the average value is 31.3 per cent, which is far below 70 per cent, showing a massive waste of resources. This is due to the poor use of modern inputs such as fertilisers, superior seeds, and extension services, which partly explains the low productivity of the sector and the inefficiency of farmers in using available agricultural resources such as land and labour (Gemeyida et al., 2019). Meanwhile, the level of technical efficiency is in the minority > with 0.8 or above, as many as 14.29% of farmers whose efficiency is above 80%. This shows that cassava cultivation and agricultural management have indeed been applied by a small number of farmers, but it has not been widely adopted by all other farmers. It is in line with a better understanding of farmers' preferences that the introduced cassava varieties have traditionally desirable traits such as yield potential, disease resistance, and early ripeness (Mondo et al., 2019). In the short term, the average cassava farmer in Trenggalek Regency has the opportunity to increase their production by 38% to achieve the potential to increase cassava production.

Cassava plants have the potential to be cultivated. They are valued higher than other tuber crops due to their exceptional ecological adaptation, low labour requirements, ease of cultivation, pest resistance, and high productivity as starch crops (Feyisa, 2021). Several efforts need to be made, including intensive agricultural counselling, training in good cultivation techniques, and providing access to the right agricultural technology (Norton & Alwang, 2020). In addition, local governments need to provide support in the form of policies that support the development of the cassava agricultural sector. Improved skills and the ability to adopt the most efficient cultivation and combine the most appropriate production inputs for cassava farming production by improving farming management (Uzochukwu et al., 2021).

CONCLUSION

This study found that among the various input factors, only land area has a statistically significant and positive effect on cassava production in Trenggalek Regency. Other inputs, such as seeds, fertilizers, pesticides, and labour, did not show a significant influence. The technical efficiency of cassava farming remains low, with an average efficiency score of only 31,3 per cent, indicating that farmers are utilizing less than one-third of their potential output. The majority of farmers operate below the efficiency threshold, primarily due to suboptimal input use and limited knowledge of balanced input application. The inefficiency suggests a significant opportunity to enhance cassava productivity through improved input management, capacity building, and adoption of best agricultural practices. Enhancing technical efficiency is critical not only for increasing production but also for strengthening household food security and promoting sustainable agricultural development in the Trenggalek Regency. The government can provide fertilizer subsidies to help cassava farmers access quality fertilizers at affordable prices. However, the use of fertilizers must be carried out appropriately and efficiently to avoid waste and negative impacts on the environment. In addition, agricultural training and counselling related to cassava cultivation need to be improved to increase productivity. In addition, the existence of a training program on the use of balanced fertilizers that has been successfully applied to cassava farmers in Trenggalek Regency can also be applied to cassava farmers in other areas by modifying the type and dose of fertilizer according to the needs of cassava. An effective integrated pest control program for cassava can be adapted for control on other food crops outside Trenggalek Regency.

AUTHOR CONTRIBUTION STATEMENT

[Author 1]: research designed, data collection, the initial manuscript draft, and responsible for the funding; [Author 2]: research supervision, analytical guidance, edited the manuscript; [Author 3]: research conceptualization, data analysis, addressed reviewer's comments; [Author 4]: Review the results of the analysis and provide input in the final editing process. All authors reviewed and approved the final version of the article.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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ETHIC STATEMENT

Ethical review and approval were waived for this study as it did not involve any intervention and posed minimal risk to participants. Nevertheless, informed consent was obtained from all respondents prior to participation, and all data were anonymised and kept confidential.

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