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ECONOMIC EFFICIENCY OF CASSAVA FARMING

Purpose. *This research aims to analyze the level of economic efficiency of cassava farming and the determinants that affect the efficiency level in the Wonogiri Regency, Indonesia.*

Methodology / approach. *The research location was determined using the stratified random sampling method, and three sub-districts were selected in Wonogiri Regency, namely Ngadirojo, Jatiroto, and Puhpelem. Furthermore, this research used a random sampling method with respondents of 74 monoculture cassava farmers. The analysis method was the Data Envelopment Analysis (DEA) approach to analyze the economic efficiency of cassava farming and Tobit regression to analyze the determinants that affected it. Furthermore, primary data was obtained from respondents through interviews, and secondary data as a complement was obtained from relevant agencies.*

Results. *This research showed that the level of economic efficiency (EE) of cassava farming in the Wonogiri Regency was 68.3 %. From the results of economic efficiency, there was an opportunity to improve efficiency by reducing input inefficiency by 13.1 % and minimizing input costs by 21.1 %. The determinants of factors that affected cassava farming were considered from the socio-economic factors, namely experience, educational level, and participation of farmers in farmer groups.*

Originality / scientific novelty. *Studies on the effectiveness of cassava have never been conducted in Central Java, even though Central Java is one of the three centers of cassava production in Indonesia. The efficiency of farming cassava in this research was not only considered from the technical side but also from the allocative and economic side, as well as the socio-economic character of the farmer's environment. This research analyzed the efficiency of cassava farming with a nonparametric approach, namely Data Envelopment Analysis. Usually, efficiency research is approached with parametric analysis, namely production function analysis with Stochastic Frontier Analysis (SFA).*

Practical value / implications. *It is recommended to use optimal inputs, especially seeds and fertilizers, which can be applied in cassava farming to reduce inefficiency. The need for fertilizer is related to the land's condition, where the land in Wonogiri Regency has a steep slope, making it prone to erosion and sedimentation. Then, it affects the decline of the soil layer and the need for fertilizer. The role of the government is required because it is necessary to facilitate access to farmers and provide information about input use.*

Key words: *cassava farming, efficiency, Data Envelopment Analysis, Tobit regression, Indonesia.*

Introduction and review of literature. Cassava is one of the potential commodities in international trade, as the demand for cassava derivatives such as starch flour and tapioca has doubled over the past two decades [1]. The increasing population, livestock industry, and growing cassava-based industry have encouraged the development of this commodity. The demand for cassava for food, feed, and industrial raw materials will continue to increase in line with the growing population, livestock, and industry made from cassava. The need for cassava increases by 3.6 % per year, so increased production through increased productivity must be carried out, considering that the planting area is relatively fixed and even tends to decrease [2].

The role of cassava commodities at the national level can realize food sovereignty apart from being a source of carbohydrates. Cassava also plays a role in food diversification with various processed derivatives. Based on data on the development of cassava production in Indonesia in 2018, eight central cassava provinces had high production. Three of them were Lampung, with production reaching 6,683,758 tons. Central Java Province ranked second with a production of 3,267,417 tons. Meanwhile, East Java province was in third place, producing 2,551,840 tons [3].

Wonogiri Regency is an area in Central Java with the highest production rate and harvest area in 2021. Although the amount of production and harvest area in Wonogiri Regency was the highest, the cassava productivity was the lowest among the ten highest regions in Central Java [4]. The productivity level of cassava in Wonogiri Regency was only 18.41 tons/ha. This level of productivity was lower than the national productivity level in 2019 of 25.95 tons/ha [3]. The level of productivity was related to the area of harvest and the production level. The harvest area of cassava in Wonogiri has decreased from 45,563 ha in 2020 to 40,192 ha in 2021 [5]. The decrease in the land area could be related to environmental issues in Wonogiri Regency, namely erosion and land sedimentation. According to [6], cassava commodities in Wonogiri Regency are often associated with environmental issues because the nature of this commodity is widely cultivated in the watershed area. In the management technique of cassava farming, it can decompose the soil so that it is easily degraded and causes the impact of erosion and sedimentation. The decreasing land area can affect the input needs for cassava farming. The reduction in land area can affect the resource requirements for cassava farming.

The suboptimal yield problem of cassava in Indonesia is caused by several factors, namely uneven knowledge about appropriate cultivation techniques. Besides, it can be caused by environmental factors that cannot be controlled, such as climate change, pests, and plant diseases [7]. One way to achieve optimal productivity is to increase the efficiency of cassava in the research area. Farmers will be guided on inputs as their focus is to improve resource use efficiency in cassava farming [8]. Knowledge of optimal resource allocation and productivity of cassava farmers will benefit farmers as producers in allocating resources for maximum results. It will provide for the development of policies on the fair use of resources and allocation of resources in all sectors of the economy [9]. The results of research [10] show that improving production efficiency can be done through the use of better management practices or the improvement of agricultural technology. Management practices in farming can be considered from farmers' decisions to use the right combination of inputs. Farmer management skills are related to the capacities of farmers, such as experience, level of education, and farmer participation in farmer groups.

Research by Abdulkareem & Isgin [11], Gbigbi [12], and Okoye et al. [13], used a parametric approach with the Stochastic Frontier Production (SFA) method to analyze the efficiency of cassava farming. The results of the study with the SFA parametric approach have not shown a way that can be done to increase the value of efficiency. This study uses a nonparametric approach, namely Data Envelopment Analysis (DEA) that can determine the value of slack inputs and peer groups that can be used as a reference in increasing efficiency values. The most significant uses of the DEA model are its use in peer groups, the identification of specific goals, and input allocation [14]. The DEA approach provides information on a DMU level about excess input usage, specifying the directional distance of each inefficient DMU from the frontier line (which is formulated by the efficient DMUs) [15]. Therefore, the research questions for this problem include: what is the economic efficiency of cassava farming in Wonogiri Regency? Then what factors affect the efficiency of cassava farming in Wonogiri Regency?

The purpose of the article. This research aims to analyze the level of economic efficiency of cassava farming and the determinants that affected efficiency from socio-economic factors (land area, age, educational level, farming experience, and participation in farmer groups) in the Wonogiri Regency.

Methodology. This research was quantitative descriptive. Quantitative methods emphasize objective measurements and the statistical, mathematical, or numerical analysis of data collected through polls, questionnaires, and surveys or by manipulation of available statistical data using computational techniques [16]. The research results were described as departing from general theories. Then, with observation to test the validity of the theory, conclusions were drawn to answer the problem statement. The research site was selected by stratified random sampling method, with stratification based on low, medium, and high productivity levels. Based on data from the Agriculture and Food Service of Wonogiri Regency [5], the three sub-districts used as research sites were Ngadirojo District, which represents the district with a high level of productivity, Jatiroto District, which represents a moderate level of productivity and Puhpelem District, which represents a low level of productivity. There was no data on the number of cassava farmer populations in Wonogiri Regency, so the sampling determination based on the minimum sampling for DEA was 2 or 3 times greater than the input and output. Roscoe [17], for multivariate data analysis (e.g. regression analysis), the sample size should be 10 times greater than the number of variables. This study used 6 variables, so the minimum sample was 60 farmers. Researchers often face the risk of data loss. Data loss can be divided into respondents who do not respond and respondents who do not answer some questions. Respondents who do not respond are not interested in answering and the time is not suitable for collecting information from respondents.

The probability that respondents will not respond ranges from 5 to 25 % of the total number of respondents. [18]. If a maximum of 25 % of the total sample (60 cassava farmers) did not respond, the total sample that did not respond was 15 farmers. To ensure that the total sample obtained was optimal, the risk of non-responding samples was added so that the total number of samples used in this study was 74 cassava farmers. The selection of the sample was carried out using proportional stratified random sampling with stratification based on low, medium and high productivity. The share of each sub-district was 33 % of the total sample determined. Questionnaires were used to collect primary data through interviews with respondents, namely cassava farmers, and to collect secondary data to complement the data through agencies associated with the study, namely the Central Bureau of Statistics of Wonogiri Regency, Central Bureau of Statistics of Central Java Province, the Agriculture Office of Wonogiri Regency and the Agricultural Extension Center in Wonogiri Regency.

The efficiency analysis method used the Data Envelopment Analysis approach. The DEA is a widely accepted methodological approach to assessing productive efficiency or measuring relative deficiencies [15]. Data Envelopment Analysis is a nonparametric approach that does not require the assumption of a function to see the relationship between input and output. This method does not undergo multicollinearity and heteroskedasticity, so it can be used for more than one input and output (multiple). The DEA can determine the best combination of each decision-making unit and provide technical efficiency values of one to farmers and also determine the source of inefficiency through a potential measure of increasing each input and output. [19]. The benefits of the approach is that the technique does not require the specification of production function, which avoids the possibility of an incorrect functional form. It can also be used for many outputs and many inputs [19].

The efficiency used in this research referred to the efficiency proposed by Farrell [20] and Coelli et al. [19], where efficiency was classified into three: technical efficiency, allocative efficiency, and economic efficiency. Efficiency measurement in this research used a nonparametric DEA method with DEAP 2.1 software. The DEA model used in this research was input oriented because farmers found it easier to control input variables than output variables. This study used the Variable Returns to Scale (VRS) assumption because it was assumed that the cassava business had not reached its optimal scale.

Technical efficiency is related to the managerial ability of farmers to allocate production inputs. It is assumed that there are K inputs and M outputs for each period of N, and at the time of i will be represented by factors xi and yi. The input matrix, X, and the output matrix, Y, represent the data for the entire period N. The DEA with input orientation and assumption VRS can be formulated as follows:

$$\begin{gathered} min_{\theta,\lambda}\ \theta, \\ Subject\ to:\ -yi + Y\lambda \geq 0, \\ \theta xi - X\lambda \geq 0, \\ N1\lambda = 1, \\ \lambda \geq 0, \end{gathered} \qquad (1)$$

where θ is the technical efficiency score;

yi is the vector of the amount of cassava production, xi is the vector of the number of inputs of cassava production;

Y is the output in the form of the amount of production;

X is the production input;

λ is the Nx1 vector of the weighting.

The output in this research was the production of cassava (*Y*) in kg units, and the inputs used were the use of cassava seeds (X_1), organic fertilizer (X_2), NPK Phonska fertilizer (X_3), urea fertilizer (X_4), labor (X_5) and herbicides (X_6). Score efficiency was valued ≤ 1, with 1 indicating a point on the border indicating an efficient Decision-Making Unit (DMU). The efficiency score of 1 indicated the point on the frontier where the farming business run by the cassava farmer (DMU) was efficient. In contrast, the efficiency score of < 1 indicated the point on the frontier where the farming business run by the farmer is not efficient.

Allocative efficiency measurements could be made with input price information and cost minimization assumptions. Assuming VRS and cost minimization, the equation becomes as follows:

$$\begin{gathered} min_{\lambda,xi}\ Pixi^{*}, \\ Subject\ to{:}\ -yi+Y\lambda\ \geq 0, \\ \theta\ xi-X\lambda\ \geq 0, \\ N1\lambda=1, \\ \lambda\geq 0, \end{gathered} \tag{2}$$

where *Pi* is the input price vector for the *i*-th time;

*xi** is the cost minimization vector of the input quantity for the i time, with the output rate *yi*.

According to Farell [20]; Jotopaulus & Lau [21]; Soekartawi [22], economic efficiency can be achieved if technical and allocative efficiency is achieved. The economic efficiency of farming can be expressed as follows:

$$EE = TE\ x\ AE. \tag{3}$$

Economic efficiency (EE) is the result of the multiplication of technical efficiency (TE) and allocative efficiency (AE). With the criteria, if *EE* = 1, farming is efficient, and if *EE* < 1, farming is inefficient.

The method for analyzing determinants that affected the level of efficiency of cassava farming was Tobit regression because the efficiency value was the censored value used in this research, which was limited to between 0.00 and 1.00. When using Ordinary Least Square (OLS), it will be biased. Multiple linear regression is not appropriate for dependent variables that are subject to limitations, for example, efficiency values between 0 and 1 [19]. This is what causes the most effective Tobit regression to analyze the determining factors of efficiency. If only the value of a variable needed to be explained without the extreme concentration of observations, multiple regression using OLS would be the appropriate statistical technique. But with such concentration, the assumptions of the multiple regression model are not realized. According to that model, it should be possible to have values of the explanatory variables for which the expected value of the dependent variable is its limiting value [23]. Socio-economic factors that were suspected to affect efficiency based on various previous studies and adapted to conditions at the research site were land area, farmer age, farmer education, farming experience, and farmer participation in farmer groups. Farmers are the main stakeholders in the cassava farming business, so the farmer's self-capacity is a factor that can support the success of the farming business. The factors of the farmers' success include age, educational level, and experience in farming. The level of formal education, experience, skills, management, and age of farmers is essential indicators in measuring the quality of human resources. The farmers' increasing ability to adopt technology and manage their farming enterprises is expected to increase efficiency [24]. Non-farmer factors may include farmers' participation in farmer groups. Farmer groups are a form of peer learning and skill sharing that might increase the farmers' capacity to adopt innovations such as crop varieties, thereby increasing production efficiency levels in farming [25]. Tobit regression models [23] are:

$$y_i = Z_i\beta + u_i \quad if \quad Z_i\beta + u_i > 0,$$
$$y_i = 0 \quad if \quad Z_i\beta + u_i \leq 0, \qquad (4)$$

where i is the number of observations;

y_i is the dependent variable;

Z_i is a vector of independent variables;

β is a vector of unknown coefficients;

u_i is an independently distributed error term assumed to be normal with zero mean and constant variance σ^2.

The model assumes that there is an underlying, stochastic index equal to ($Z_i\,\beta + u_i$), which is observed only when it is positive, and hence qualifies as an unobserved, latent variable. Dependent variables are the efficiency of cassava farming, and independent variables are land area, age, farming experience, education, and dummy participation in farmer groups.

The limitation of the research was in terms of input variables: seeds, organic fertilizers, NPK Phonska fertilizer, urea fertilizer, herbicides, and labor. The input price of cassava farming was calculated according to the price in the research area.

Results and discussion. The efficiency level could be assessed by using inputs in producing production output. The output and input variables of the cassava farming business were used in the data analysis model to estimate the technical, allocative, and economic efficiency. The results of analysis in Table 1 showed that with an average land area of 1.25 ha, the average output value in the form of cassava production was 34,564.86 kg with a minimum of 1,800 kg and a maximum value of 474,000 kg. The average use of cassava seedlings was 11,162.16 number of stems.

Table 1

Descriptive results of input-output variables

Variable	Mean	Std. dev.	Min	Max
Cassava production (output), kg	34564.86	57585.1	1800	474000
Land area, ha	1.252703	1.348538	0.1	4
Seed	11162.16	12452.81	700	100000
Organic Fertilizer, kg	2359.459	2776.068	100	20000
NPK Fertilizer, kg	346.7568	403.8339	25	3000
Urea Fertilizer, kg	180.0676	204.8747	10	1500
Labour, man-days	42.28716	29.42115	19.5	255
Herbicides, liter	3.081081	3.988878	0	30

Source: descriptive analysis results (2022).

The average use of the largest fertilizer, organic fertilizer, was 2,359.459 kg. Organic fertilizer was also used as a primary fertilizer before the cassava planting period. Organic fertilizer was critical because it could increase groundwater carrying capacity and make the soil fertile [26]. Farmers who did not use organic fertilizers felt that NPK Phonska and urea fertilizers were sufficient. Land cultivation at the beginning of planting was considered enough to fertilize the soil. Cultivating the land was a way of improving soil structure by using tools such as tractors or hoes so that the soil became loose, then the soil aeration and drainage improved. The average use of labor in cassava farming is 42.28 man-days. The average use of herbicides is 3.08 liters.

Results of the research in Table 2 show that the average farmer had a technical efficiency level of 0.869 or 86.9 %, which indicate a technical inefficiency in the average use of inputs of 13.1 %. Farmers with an efficiency value equal to 1 or in fully efficient conditions were 27 (36.5 %), and the majority of farmers, as many as 43.2 %, had efficiency values in the range of 0.750–0.999 or efficient. 63.5 % of farmers in conditions that have not been fully efficient could increase their efficiency by using efficient inputs.

Table 2

Economic efficiency of cassava farming in Wonogiri Regency

Range	Technical efficiency		Allocative efficiency		Economic efficiency	
	Freq	%	Freq	%	Freq	%
0.250–0.499	0	0	0	0	10	13.5
0.500–0.749	15	20.3	30	40.5	38	51.4
0.750–0.99	32	43.2	39	52.7	21	28.4
1.000	27	36.5	5	6.8	5	6.8
Mean	0.869		0.789		0.683	
Min. efficiency	0.567		0.514		0.429	
Max. efficiency	1.000		1.000		1.000	

Source: DEA analysis results (2022).

Based on the DEA analysis results, the efficient use of inputs could be seen through slack or excess inputs. The average slack input on seed input was 492,694 number of stems; organic fertilizer was 65,442 kg; NPK Phonska fertilizer was 6,575, urea fertilizer was 8,511 kg, labor was 0,270 man-days and herbicides were 0,394 liters. To achieve a fully efficient condition, cassava farmers can reduce the use of excess inputs (slack inputs). The average technical efficiency of the VRSTE model of cassava farmers in Wonogiri Regency was higher than the Ajayi & Olutumise research [27], with an average efficiency of 0.83 and Houngue & Nonvide research [28] with 78 % efficiency in rice farming. Improving farmers' efficiency by efficiently using resources as inputs was an opportunity.

Peer Group was DMU with an efficiency value of 1.000 and was used as a reference for DMU that was still below or inefficient. Peer analysis could provide information on how efficient farmers were a reference (peer) for inefficient farmers. The greater peer count value indicated that the farmer was the most referenced compared to other efficient farmers [29]. In addition, peer analysis could provide information for farmers who have not been efficient (with an efficiency value of less than 1) to refer to efficient farmers without changing the output produced. The number of efficient farmers used as a reference (peer) can be more than one, adjusted to the situation and conditions of inefficient farmers in the process of becoming efficient. Thanassoulis et al. [30], target settings and peer identification are primarily the DEA analysis's purpose (besides the efficiency score).

Based on Table 3, the most prominent peer count was 22 in DMU numbers 1 and 9. It showed that DMU numbers 1 and 9 were the farmers who were used as the most reference for the 22 inefficient farmers. DMU number 33 took the third place with a peers count of 21. The use of inputs and outputs produced by the three DMU with the most significant order of peer counts varied. Each farmer had different farming conditions and levels of estimation in combining the use of cassava farming inputs.

Table 3

Distribution of Farmers Peers of Cassava Farming in Wonogiri Regency

DMU efficient	Peer count
1	22
2	0
6	0
8	10
9	22
10	6
17	0
19	8
25	4
30	2
33	21
34	15
36	1
37	1
38	3
40	10
49	5
51	0
52	16
57	2
58	12
59	8
65	6
66	9
69	3
70	0
73	5

Source: DEA analysis results (2022).

The selection of farmer DMU as a peer was based on the combination of resources most likely referred to by inefficient farmer DMU. Examples of inefficient farmer DMU were farmer DMU number 12 (Table 4) and DMU number 15 (Table 5). DMU 12 had a technical efficiency value of 0.769, so it was necessary to refer to DMU numbers 38, 34, 9, and 33 to achieve a fully efficient level with an efficiency value of 1.00. The inefficient DMU 15 needed to reference to DMU numbers 1, 33, 9, and 59. The four DMU had an efficiency value of 1 or had been efficient. Moreover, three of them were included in the DMU with the highest order of peer count. According to Table 3 DMU, a peer to other DMU, had the characteristics and resources that would most likely be considered inefficient DMU, such as using a combination of seed inputs, fertilizers, herbicides, and labor.

Table 4

DMU Number 12 Results from Cassava Farmers in Wonogiri Regency, which are Inefficient

Result for firm	12			
Technical efficiency	0.769			
Projection summary				
Variable	Original value	Radial movement	Slack movement	Projected value
Output 1	10,000.000	0.000	0.000	10,000.000
Input 1	5,000.000	-1,153.669	0.000	3,846.331
Input 2	1,000.000	-230.734	-32.184	737.082
Input 3	130.000	-29.995	-1.086	98.919
Input 4	50.000	-11.537	0.000	38.463
Input 5	31.000	-7.153	0.000	23.847
Input 6	0.000	0.000	0.000	0.000
Listing of peers				
Peer	Lambda weight			
38	0.128			
34	0.038			
9	0.320			
33	0.514			

Source: DEA analysis results (2022).

Table 4 describes the DEA results for DMU number 12 with the potential for inefficient reduction in input levels without changing their output levels. The calculation results of DEAP 2.1 shows that in DMU 12, with an efficiency value of 0.769 or 76.9 %, there was a potential decrease in input from input one to input 5. DMU 12 did not use Input 6 or herbicides because cassava plants did not require special maintenance, especially for pests and weeds. Input 1 (cassava seedlings) could be reduced by 1,153,669 number of stems (23.1 %) to 3,846,331 number of stems. Input 2 (organic fertilizer) could be reduced by 26.3 %. Input 3 (NPK Phonska fertilizer) can be reduced by 23.9 % from its original value of 130 kg to 98,919 kg. Input 4 (urea fertilizer) and input 5 (labor) must be reduced by 23.1 % of the original value. Urea fertilizer input needed to be reduced by 11,537 kg, and labor input was reduced by 7,153 man-days becoming 23,847 man-days. Reducing excessive inputs eventually resulted in a farmer's DMU of 12, as efficient as DMU 38, 34, 9, and 33 (as a reference set).

Table 5 describes the DEA results for DMU number 15 with the potential for inefficient reduction in input levels without changing their output levels.

Table 5

DMU Number 15 Results from Cassava Farmers in Wonogiri Regency, which are Inefficient

Result for firm	15			
Technical efficiency	0.596			
Projection summary				
Variable	Original value	Radial movement	Slack movement	Projected value
Output 1	16,000.000	0.000	0.000	16,000.000
Input 1	10,000.000	-4,042.385	-1,970.982	3,986.633
Input 2	1,800.000	-727.629	0.000	1,072.371
Input 3	200.000	-80.848	0.000	119.152
Input 4	100.000	-40.424	-3.819	55.757
Input 5	44.000	-17.786	0.000	26.214
Input 6	2.000	-0.808	-0.359	0.833
Listing of peers				
Peer	Lambda weight			
1	0.025			
33	0.115			
9	0.837			
59	0.023			

Source: DEA analysis results (2022).

The calculation results of DEAP 2.1 shows that in DMU 15, with an efficiency value of only 0.596 or 59.6 %, there was a potential decrease in the overall input from input one to input 6. Input 1 (cassava seedlings) could be reduced by 6,013,367 number of stems (60.1 %) to 3,986,633 number of stems. Input 2 (organic fertilizer), input 3 (NPK Phonska fertilizer), and input 5 (labor) needed to be reduced by 40.4 % to achieve a level of efficiency in cassava farming following the DMU, which was its peer. Input 4 (urea fertilizer) required to be reduced by 44.243 kg (44.2 %), and input 6 (herbicides) – by 58.4 %. Such excessive input reduction would eventually result in a farmer's DMU of 15, as efficient as DMU 1, 33, 9, and 59 (as a reference set).

The farmer DMU with the most peer counts, namely DMU 1, 9, and 33, had their respective contributions to each inefficient DMU. Farmer DMU 1 contributed 2.5 % to DMU 15. DMU 9 contributed 32 % to DMU 12 and 83.7 % to DMU 15. DMU 33 contributed 51.4 % to DMU 12 and 11.5 % to DMU 15 in improving the efficiency of cassava farming. Therefore, the inefficient DMU of farmers 12 and 15 could refer to the peer DMU or to which it was referred. The average number of seeds used for the three farmers as referrals or DMU with the most peer counts was 9,981.13 kg/ha. Organic fertilizer with an average use of 2,009.43 kg/ha, NPK Phonska fertilizer with an average use of 297.64 kg/ha, and urea fertilizer with an average use of 147.17 kg/ha. The average use of labor inside and outside the family was 28.16 man-days, and the average use of herbicides inputs was 2.83 liters. With an average production rate of 46,132.07 kg in one growing season, the average efficient use of inputs from DMU, especially seeds and fertilizers, was still appropriate for the amount recommended by the Ministry of Agriculture in the cultivation of cassava for Central Java land [2].

The Table 2 shows cassava farmers in Wonogiri Regency had an allocative efficiency rate of 0.789 or 78.9 %. It shows that farmers could reduce the current average production cost by 21.1 % to achieve minimum production costs. In line with Onubuogu's research [31] in analyzing the allocative efficiency of cassava farming in Nigeria, there was sufficient opportunity for improvement at the level of allocative efficiency in cassava production in the research area. The allocative efficiency of cassava farming in Wonogiri Regency showed that only 6.8 % of farmers were entirely allocatively efficient, while the majority (52.7 %) had allocative efficiency with a score range of 0.750–0.999. This research was in line with Effendy et al. [32] and Fatima et al. [33] that most cassava farmers have not been allocative efficient in their farming. Allocative efficiency was related to the price level of each of the inputs issued by the farmer. The problem mainly occurred in the price of NPK Phonska and urea fertilizers, which affected the input costs incurred by farmers because there was a price difference between subsidized and non-subsidized fertilizers. Hence, a significant price difference in the use of inputs results in inefficient farming because farmers cannot minimize the cost of cassava input. In line with Onubuogu's research [31], in analyzing the efficiency of cassava farming in Nigeria, there was an opportunity for improvement in the level of efficiency in cassava production through the efficient use of inputs.

The economic efficiency rate of cassava farming was 68.3 % higher than the results of Tafesse et al. [34] research on cassava in Southern Ethiopia by 66.0 % and the research of Okello et al. [35] on rice production with an efficiency of 58.8 %. The results of the economic efficiency analysis showed that almost all cassava farmers in Wonogiri Regency (93.2 %) have not been fully efficient economically because it had an economic efficiency value below 1,000.

The socio-economic variables used in Tobit regression in this research were land area (ha), age (years), educational level (years), experience of farming cassava (years), and participation in farmer groups (dummy) (Figure 1–5).

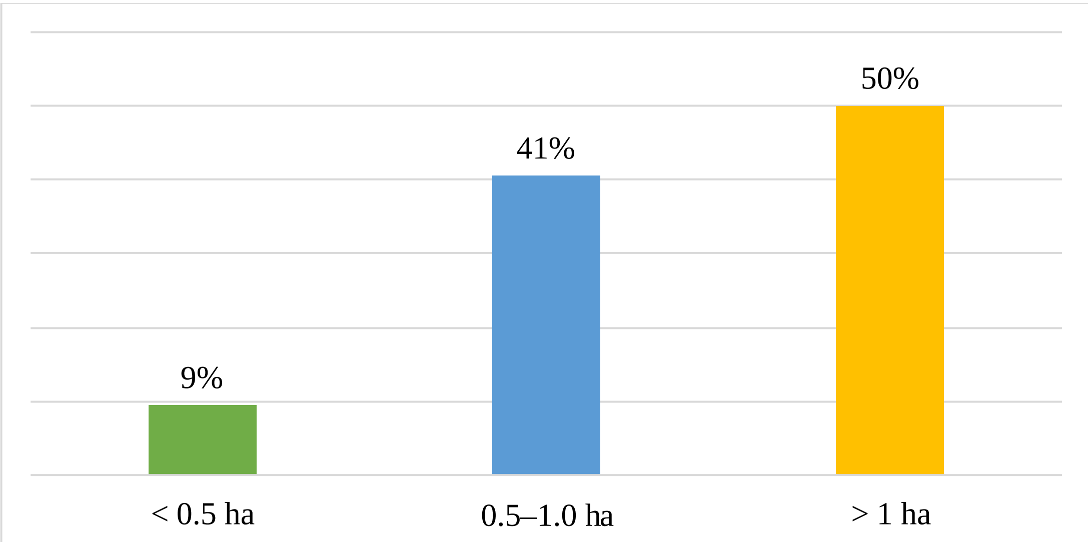

Figure 1. Percentage of farmers by land area, ha

Source: calculated by authors.

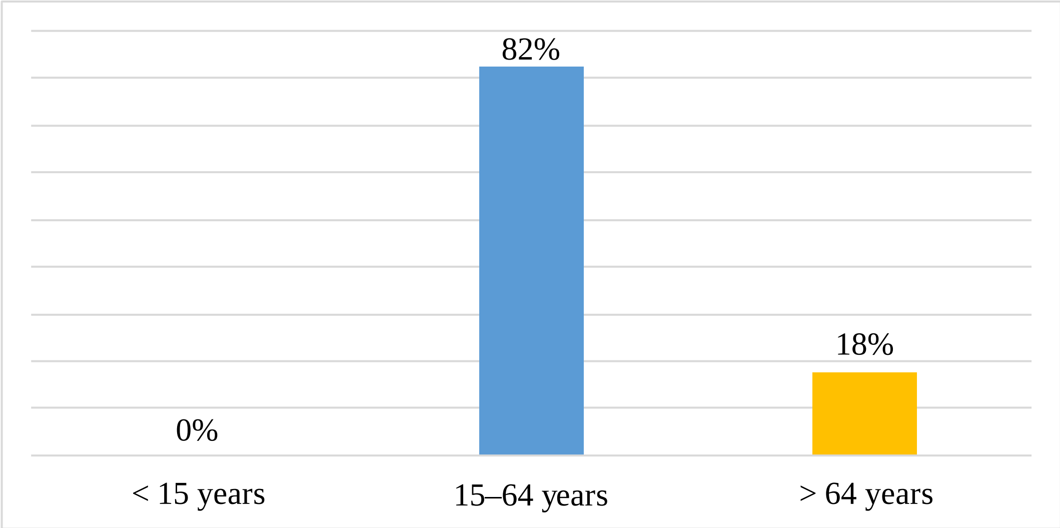

Figure 2. Percentage of farmers by farmer's age
Source: calculated by authors.

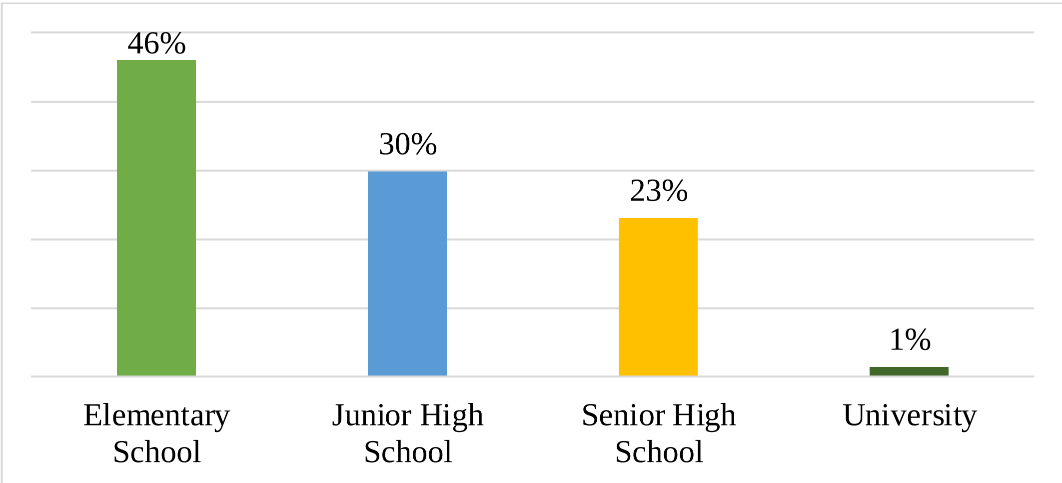

Figure 3. Percentage of farmers by education level
Source: calculated by authors.

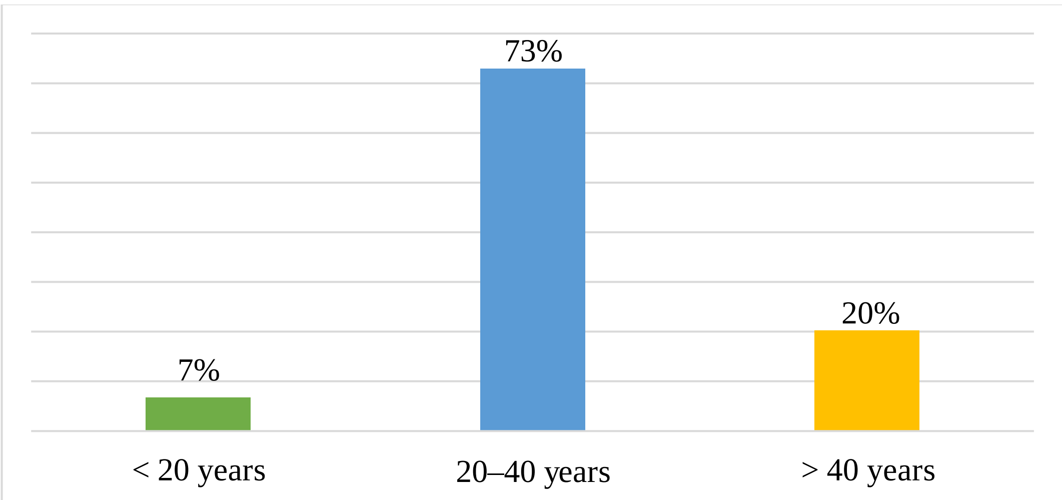

Figure 4. Percentage of farmers by experience
Source: calculated by authors.

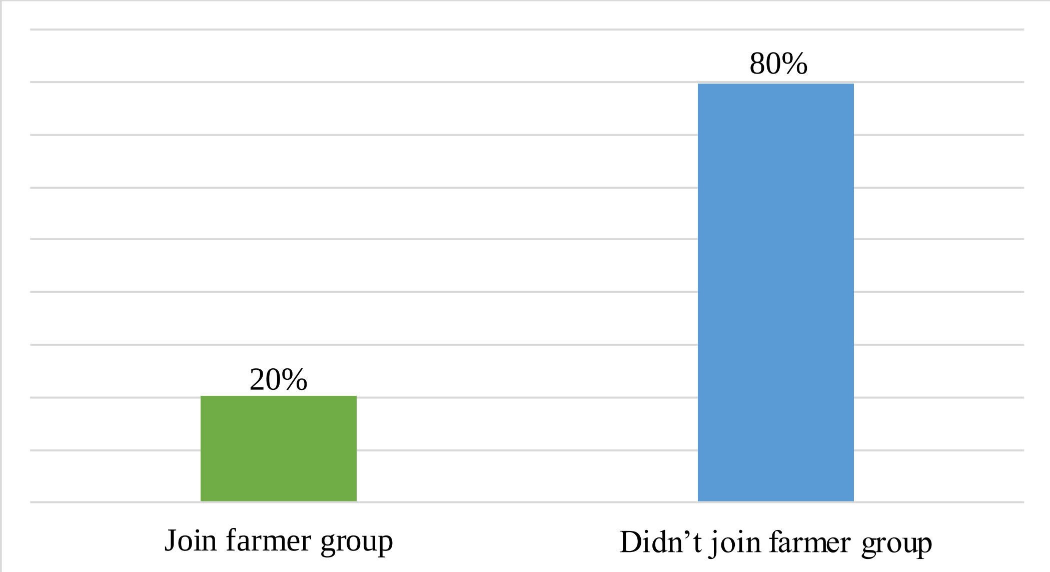

Figure 5. Percentage of farmers by participation in farmer group

Source: calculated by authors.

On average, respondent farmers in Wonogiri Regency had a land area of 1.25 ha and were 57 years old, with a majority educational level of 6 years or graduated from elementary school with a percentage of 46 %. Besides, they had an average experience of farming cassava at 33 years. A total of 15 farmers (20.3 %) did not join the farmer group, and 59 farmers (79.7 %) were members of the farmer group. Based on the Tobit regression analysis results, the factors affecting the technical efficiency of cassava in the Wonogiri Regency are presented in Table 6.

Table 6

Determinants that Affect the Efficiency of Cassava Farming

Variables	Coefficient	Std. error	P-value
Constant	0.3406829	0.2307059	0.144
Land area	0.0235385	0.0191767	0.224^{ns}
Age	0.0020075	0.0039659	0.614^{ns}
Experience	0.0055931	0.0025242	0.030^{**}
Education	0.0163955	0.0085421	0.059^{*}
Participant in farmer group *(dummy)*	0.1268166	0.0489753	0.012^{**}
Pseudo R^2	0.8633		
Prob > chi^2	0.0010		

Note. ** significant at 5 %, * significant at 10 %.

Source: Tobit regression analysis results (2022).

The results of the Tobit regression analysis (Table 6) shows that the variables of farming experience, education, and dummy participation in farmer groups positively affected the efficiency of cassava farming in the Wonogiri Regency. The farmer experience variable had a significant positive effect on technical efficiency. Farmers with extended cassava farming experience had a higher level of technical efficiency than less experienced farmers. The results of [36] and [37] stated that experience affected technical efficiency. The farming experience could help farmers in making decisions regarding the use of cassava farming inputs. Farmers have become more skilled in agronomic practices as they became experienced in farm production [38]. The farming management ability of more experienced farmers influenced decision-making on the combination of efficient use of inputs.

The positive coefficient value in the education variable indicated that farmers with higher educational levels had higher technical efficiency than farmers with lower educational levels. Farmers with a higher educational level had more comprehensive knowledge, so access to the information obtained could be broader and faster. These results are consistent with the research results of Attipoe et al. [39] and Iskandar & Jamhari [40]. Farmers with a higher educational level were more receptive to and applied innovations and technologies in agriculture due to the increasing likelihood of more educated farmers participating in other livelihood options besides farming, thereby reducing their time and knowledge input on cassava farming [34]. Increasing the involvement of more educated people in cassava production is expected to assist farmers in resource allocation to optimize productivity [41]. Education is related to a person’s knowledge of information, including managing inputs used in farming. Knowledge impacts decision-making in managing a farming business by determining the number of inputs used.

The variable participation of farmers in farmer groups positively affected the efficiency of cassava farming in Wonogiri Regency. The research of Soh et al. [42] and Tesema [43] also had similar results. Farmers who followed the farmer group had a higher technical efficiency value than farmers who did not follow the farmer group. Through various activities in the farmer group, farmers could exchange ideas and technologies with other members, training, and information from extension workers. The existence of farmer groups was significant because it could help farmers overcome various problems experienced related to farming. It was necessary to increase the role of farmer groups by activating various extension and mentoring activities in cassava farming so that the farmers’ participation to join farmer groups could increase.

When discussing the issue of variables, according to some researchers, it is better to include depreciation cost of equipment/tools in the model instead of pesticides. We did not include the equipment depreciation costs in the input because several cassava farmers in Wonogiri Regency also plant other commodities on other lands. The equipment they use is the same, and it is not enough to describe the efficiency level only for cassava farming. In Wonogiri Regency, the equipment used for cassava farming is included in simple equipment (it does not have much effect on farming), while the use of equipment such as tractor machines is carried out with a rental system, so farmers do not have their own tractor machines. In Indonesia, most labor used for farming brings their own equipment, so the calculation includes wages [44]. Pratiwi et al. [45] showed that the cost of depreciation of agricultural tools among respondents who has a land area of ≤ 0.5 hectares and > 0.5 hectares is not much different, as the workers generally bring their own farming equipment. At the same time, in other countries and regions, as research shows [46], the situation regarding these variables may be different.

Conclusions. The level of economic efficiency (EE) of cassava farming in the

Wonogiri Regency was 68.3 % and only 6.8 % of cassava farmers were fully economically efficient. There was an opportunity to improve the economic efficiency of cassava farming in the Wonogiri Regency by reducing input inefficiency by 13.1 % and minimizing input costs by 21.1 %. Using existing resources as inputs could increase efficiency, and output could be increased by reducing costs from the current input level. Minimizing input costs was related to the number of inputs used, so determining the optimal use of inputs was crucial in increasing efficiency. Recommendations for using optimal inputs could be applied in cassava farming to reduce their inefficiency. The determinant that influenced the efficiency of cassava farming in the socio-economic factor consisted of the experience, educational level, and farmers' participation in farmer groups.

The implications of the results of this research can be used as government recommendations in policies related to farmers' access to agricultural extension related to the combination of appropriate inputs and input prices. Non-formal education can be carried out through training and assistance from farmer groups. Increasing the role of farmer groups and cooperation with the Agricultural Extension Center can be well coordinated to become a farmer forum to access information that can be applied in cassava farming. Recommendations for using appropriate inputs, especially seeds, and fertilizers, can be applied in cassava farming, such as through demonstration plots so that farmers can prove that using the correct inputs can increase the efficiency of cassava farming.

Suggestions for further research include analyzing the efficiency of cassava farming with a broader research scope by optimizing the use of each input in cassava farming. There may be other variables added that were not observed in this study, and the efficiency analysis can be extended beyond not only to on-farm but also to efficiency at the off-farm level, such as supply chain and value chain.

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