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ENHANCING FARM HOUSEHOLD INCOME THROUGH EFFICIENT ARABICA COFFEE CULTIVATION IN SIMALUNGUN, NORTH SUMATERA

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ABSTRACT

North Sumatrea is the largest producer of arabica coffee in Indonesia with 29 percent. However, coffee farmers are always faced with various field problems such as high fertilizer prices, declining production and various traditional cultivation practices that cause low productivity levels. The variety of problems that exist is a problem to maintain the sustainability of the cropping system as a whole. So that in maintaining overall cropping it is necessary to know the efficiency of farm management with efficient coffee management it can increase farmer income, improve the quality of life of farmers, absorb labor, reduce costs and create a sustainable system. The method used in this research is to use the Data Envelopment Analysis (DEA) model to determine the efficient value and the Ordinary Least Squares (OLS) model to determine the efficient influence. These two models are used to complement each other and provide a more comprehensive analysis of efficiency and the factors that influence it. The results of this research with the DEA model show that from a total of 133 respondents, the inefficient value is 51%, low efficient 25%, medium efficient 13%, and low efficient 11%. While the OLS model shows that the total cost and total income of farmers can significantly affect the efficiency value, the total production of farmers has no influence on the efficiency value. The

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research findings imply that improving efficiency requires modernizing technology to overcome traditional management such as the use of superior seeds and fertilizer inputs to increase land production. It also requires the support of relevant policies and institutions that are able to guarantee the availability of production facilities such as superior seeds and fertilizers that are easily available to farmers at affordable prices.

Keyword: arabica coffee, efficiency, income contribution, indigenous people, smallholder plantations

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INTRODUCTION

Arabica coffee is one of North Sumatera's mainstay products in the world market. In terms of production, North Sumatra is the largest producer of arabica coffee in Indonesia, accounting for 2.8 percent of the country's arabica coffee production (Central Statistics Agency, 2016). Simalungun Regency is the second largest producer of arabica coffee in North Sumatra (Table 1) (North Sumatra Central Statistical Agency, 2022). However, the large area and production of coffee in North Sumatra face various problems of unsustainability, with farmers replacing coffee with other crops such as oranges. Various problems faced by farmers, such as high fertilizer prices, decreased production, and other problems related to land use cause low production, thus making coffee cultivation inefficient (Arief & Nurlina 2021) (Rahmi et al., 2022) (Ramefa et al., 2020).

In Simalungun, land management in indigenous communities is linked to a customary institution known as Tolu sahundulan. Tolu Sahundulan, as an institution, regulates daily life, including plantation land tenure. As is well known, the Tolu Sahundulan customary system strictly adheres to male lineage in property ownership, a practice known as strong patrilinealism (Martial and Asaad 2014). Men are the owners of the land they control, so they play a role in determining the farming model they manage. Men determine various work choices, decision-making processes, and the utilization of results. Meanwhile, in this system, women are subordinate to men. The management of the Arabica coffee plantation closely relates to this system of rules.

Table 1 Plantation Area and Production of Arabica Coffee Plantation by Regency

District/City	Crop Area (Ha)			Production (Tons)		
	2018	2019	2020	2018	2019	2020
North Sumatera	77,765	77,765	77,834	66,831	66,831	67,469
Mandailing Natal	3,554	3,554	3,564	2,332	2,332	2,533
South Tapanuli	4,608	4,608	4,606	2,098	2,098	2,103
North Tapanuli	16,467	16,467	16,468	15,213	15,213	15,220
Toba Samosir	4,784	4,784	4,788	4,187	4,187	4,403
Simalungun	8,217	8,217	8,233	10,324	10,324	10,523
Dairi	12,088	12,088	12,099	9,612	9,612	9,613
Karo	9,198	9,198	9,205	7,402	7,402	7,403
Deli Serdang	713	713	711	666	666	668
Langkat	75	75	75	78	78	78
Humbang Hasundutan	12,044	12,044	12,057	9,677	9,677	9,683
Pakpak Bharat	959	959	964	1,085	1,085	1,084
Samosir	5,058	5,058	5,064	4,157	4,157	4,163
Total	155,530	155,530	155,668	133,662	133,662	134,938
Progress			138			1276

Source: (North Sumatera Central Statistical Agency, 2022)

The land ownership system in traditional communities in Simalungun has various unique characteristics. The ownership system places land ownership in the hands of men, while women become a subordinate part of men in the household. Community institutions do not acknowledge the rights of women who are the main workers on coffee plantations. Local community institutions do not directly support women's ownership, whereas support based on institutional rules is crucial in maintaining one's access to land resources. Local institutional rules support such practices, as a system of rules prevails in traditional communities in Simalungun (Martial & Asaad 2014). Unclear recognition of women's tenure rights will raise doubts about the management of Arabica coffee plantations in Simalungun. This can lead to unsustainable management, as women are the main workers. Bambio & Bouayad Agha (2018) asserts that ensuring a harvest can boost land activities. Therefore, securing women's rights to their farm products can lead to an increase in technology adoption and land investment. The regulatory system should guarantee the rights of the community, with clarity on who will reap the benefits.

The inefficiency issue promotes the conversion of coffee plantation lands into other types that are believed to yield faster results. Farmers switch crops when they're more profitable. Understanding this efficiency is critical for maintaining sustainable coffee plantations, as the farming system's long-term sustainability depends on its ability to generate profitable income and satisfy

farmer households' needs (Hasibuan, Khairunnisyah, and Hendrawan 2020) (Herudin, Yurisinthae, and Suyatno 2021). Moreover, coffee is one of the leading commodities on plantations in Simalungun and is known as the largest Arabica coffee-producing area in North Sumatra. In rural communities, the primary goal of farming management is to provide a source of household income. When a farming system is deemed unprofitable, it motivates them to switch to a more profitable one. This has a negative impact on the sustainability of Arabica coffee plantations in Simalungun.

Many farming systems that do not apply a holistic approach to crop cultivation, such as monoculture planting and dependence on inorganic materials, use unsustainable practices (Gomori-Ruben & Reid 2023) (Eernstman & Wals 2009), and does not consider social and economic acceptance (Franco Gavonel et al., 2021) (Kyalo et al., 2019). Various crop production systems will encounter unsustainable practices when farming management fails to meet this holistic approach.

Traditional management among Arabica coffee farmers in Simalungun includes unsustainable practices like the ones mentioned above. The community's customary system specifically governs the land tenure system, where men, as the head of the family, own the land, and women primarily manage the crops in the field. The Tolu Sahundulan customary system links the management system to community behavior. This is intriguing because, on average, the traditional community here relies on agricultural land as their primary source of income. Therefore, the community's various socio-economic activities are closely associated with their land ownership and management practices. This behavior fundamentally influences the management of coffee plantations. Indigenous people generally manage coffee traditionally; therefore, it is important to see the efficiency of smallholder coffee plantation management and its impact on household income in the Simalungun region as a unit of the Tolu Sohundulan indigenous community.

Three main variables, namely physical (ecological), economic, and socio-cultural, theoretically determine farm sustainability. Various physical attributes, such as soil and crops, and the use of environmentally friendly inputs determine ecological sustainability. Socio-cultural sustainability, where the farming system is acceptable to the people in a particular community or landscape (Zeweld et al. 2019; Kumar & Sharma 2018; Adegbeye et al., 2020; Adenle, Wedig, & Azadi 2019). Economic and socio-cultural studies rarely examine these ecological variables, which are the focus of sustainability studies. The community's acceptance of a farming system determines its long-term survival (Kumar & Sharma 2018) (Kyalo et al, 2019). As a result, it is important to determine how much income from smallholder coffee farms contributes to household income. We will be able to ensure that coffee farmers maintain their farms and do not switch to other types of commodities.

According to the concept of sustainability mentioned above, income contribution is the most important variable in traditional Simalungun society. They will maintain a certain crop production system to guarantee a source of income from their farmland, such as Arabica coffee. However, the contribution of land with traditional management to increase household income has various obstacles in the field, generally related to the costs incurred. Effective management should be capable of lowering expenses, enabling farmers to reap the benefits of their land and bolstering the maintenance of the agricultural system. So far, there have been many community dynamics involved in managing their farmland in inefficient ways. Rural communities with traditional knowledge tend to underestimate the expenditures made in their efforts to increase their agricultural production (Byamugisha & Dubosse, 2023) (Cavalaris 2023) (Olutumise et al. 2024).

The Simalungun community faces a number of issues related to the Tolu Sahundulan customary-based land tenure system, which has unique characteristics in the management of traditional coffee plantations. These issues raise the question of whether Arabica coffee plantations are sustainable. To ensure a sustainable coffee plantation system, it is necessary to understand the conditions of its management in the field. We see that traditional farmers are strongly associated with land because they rely heavily on it as a source of income. One of the most important reasons for maintaining a coffee plantation system is that it is profitable for the farmer's household. In this case, the important question is whether the management system is efficient. A DEA model, which compares the inputs in agricultural management and the outputs that become agricultural products, is required to measure the value of efficiency. Next, to identify the factors influencing efficiency, we employ the OLS approach to determine which variable has the greatest influence on the efficiency of coffee plantations.

RESEARCH METHOD

The research was conducted in Simalungun Regency, especially among coffee farmers. The research was conducted during the period April-August 2023. The type of data used is Primary data, namely data obtained directly from sources or parties related to the problems to be studied using interview techniques, documentation and questionnaires (Sugiyono, 2019). The population in this study was 200 coffee farmers. The sample was determined using the Slovin formula (Slovin, 1960). The samples are located in 2 sub-districts with the area and production as shown in the following Table 2:

Table 2. Area And Production Data By Sub District

No	Subdistrict	Production (Tons)	Land Area (Hectares)	Total Sample
1	Pematang Sidamanik	280	22	42
2	Dolok Pardamen	1103	85	91
Total		1383	107	133

Source: Results of Field Observations

This research employs analysis to determine the efficiency of coffee farm management. We measured the efficiency of coffee farm management using the Data Envelopment Analysis (DEA) method, which employs an intermediation approach to compare output variables with input variables. The Data Envelopment Analysis model has strengths such as objectivity, the ability to provide efficiency ratings based on numerical data rather than subjective opinions, the ability to handle multiple inputs and outputs, the ability to measure in various units, and the absence of assumptions about the functional forms of inputs and outputs. However, its disadvantages include the need to solve a separate linear programme for each decision-making unit (DMU), the use of extreme point techniques, the significant impact of measurement errors, the sensitivity to even small errors, the difficulty of statistical hypothesis testing, and the difficulty of intuitively explaining the Data Envelopment Analysis (DEA) process when dealing with more than two inputs and outputs, which may lead to a perceived lack of transparency.

Furthermore, a multiple linear regression/ Ordinary least squares (OLS) model is required to address the shortcomings of the Data Envelopment Analysis (DEA) model (Winarso, Syafrial, and Widyawati 2021). Combining the Data Envelopment Analysis (DEA) model with multiple regression analysis allows for a more comprehensive analysis, as the regression model can measure the influence of factors that affect efficiency (Ramadhani 2011). In this study, we employed three variables to enhance efficiency: total farmer costs, total farmer production, and total farmer income. Additionally, we employed multiple linear regression to consolidate numerous inputs and outputs into a single variable. The Table 3 below displays the efficiency variables derived from the DEA model, which compares input and output factors.

Table 3. Research Input-Output Variables and Data sources

Research Input-Output Variables	
Definition	Source
Amount of output:	
Coffee production	Farmers
Coffee farmer income	Farmers
Amount of input:	
Capital	Farmers
Labor load	Farmers
Fertilizer	Farmers

Source: Nirmala & Hardjanto, 2022

DEA will calculate Farmers who use n inputs to produce m different outputs (Rahmawati, 2014) efficiency categories are divided into 3 categories (Table 4):

Table 4. Efficiency Levels and Categories

Efficient Level	Category
65-85%	Low Efficiency
86-96%	Medium Efficiency
97-100%	High Efficiency

Source: Hosen & Rahmawati, 2017

We have adapted the model specification from several previous studies to provide better results in explaining the efficiency factors of banks in Indonesia. We constructed a mathematical function to represent the model:

Effi = f (Total farmer income, Total Farm Cost, Total Coffee Production). The function can be modified into a model:

$$Eff_i = \alpha_0 + \alpha_1 PTP_i + \alpha_2 TBT_i + \alpha_3 TOK_i + \varepsilon_i$$

Where: Effi = Efficiency; PTP = Total Farmer Income; TBT = Total Farmer Costs; TPK = Total Farmer Production; and εi = Error Term

To the difference in units and magnitude of the independent variables, the regression equation must be made with the natural logarithm model. The rationale behind selecting the logarithm model is clear (Gujarati, 2006) is as follows :

a. Avoiding heteroscedasticity
b. Knowing the coefficient that shows elasticity.
c. Bringing the scale of the data closer.

From the above equation, the equation after being linearized will be obtained as follows:

$$Eff_i = \alpha_0 + \alpha_1 \ln PTP_i + \alpha_2 \ln TBT_i + \alpha_3 \ln TPK_i + \varepsilon_i$$

RESULT AND DISCUSSION

Sample Background Analysis

We conducted the research in Simalungun district, North Sumatra province, specifically in three sub-districts, Silimakuta, Sidamanik, and Pematang Sidamanik, which are the centers of people's arabica coffee plantations. The community generally manages arabica coffee plantations in a traditional manner, passed down from generation to generation. Simalungun arabica coffee is one of the mainstay commodities of this region, and it has a distinctive aroma compared to arabica coffee from other regions. However, Simalungun arabica coffee is less known than similar coffee-producing districts in North Sumatra, such as Sidikalang and Mandailing. Farmers typically rely on family members to carry out Simalungun arabica coffee cultivation. They occupy an average plantation area in an area with an altitude above 500 meters above sea level.

We deliberately selected the research location in three sub-districts, taking into account the production center and the characteristics of the local community that serves as the research's focus. We chose the location based on the characteristics of strong indigenous peoples, where the custom of Tolu Sahundulan functions as a social institution within the community. The custom of Tolu Sahundulan is generally known to the Batak Simalungun, who have a strong patrilineal system. This is done to understand the characteristics of management that is carried out traditionally with customary rules that tend to be binding in the ownership system that is dominated by men.

The background of the sample farmers aligns with Table 5, shows that Arabica coffee farmers in Simalungun district are primarily female, with an average age of over 45 years, middle-level education, and a narrow average land area below one hectare. Most female farmers participate in various aspects of coffee plantation management, including land preparation, planting, crop maintenance, and harvesting. The female labor force becomes the main backbone of coffee plantations. The average female farmer has a secondary education, and some reach the highest level of undergraduate education, but more have a lower education. The average land area is narrow below one hectare (0.8 ha), with a minimum area of only 0.1 ha and the widest 2.2 ha.

Table 5. Background of Sample Farmers

		Gender	Age	Education	Land_area
N	Valid	133	133	133	133
	Missing	0	0	0	0
Mean		1.6090	45.3609	2.6316	.8023
Median		2.0000	45.0000	3.0000	.8000
Mode		2.00	53.00	3.00	.20
Minimum		1.00	23.00	1.00	.10
Maximum		2.00	79.00	4.00	2.20

Source: Data Processing using SPSS ver 27 (2023)

Efficiency Using DEA Model

The analysis begins with an explanation of the efficiency of Arabica coffee plantation management in Simalungun. Figure 1 displays the results of data processing using the DEA model, which compares input variables (capital, labor, fertilizer) and outputs (production, income).

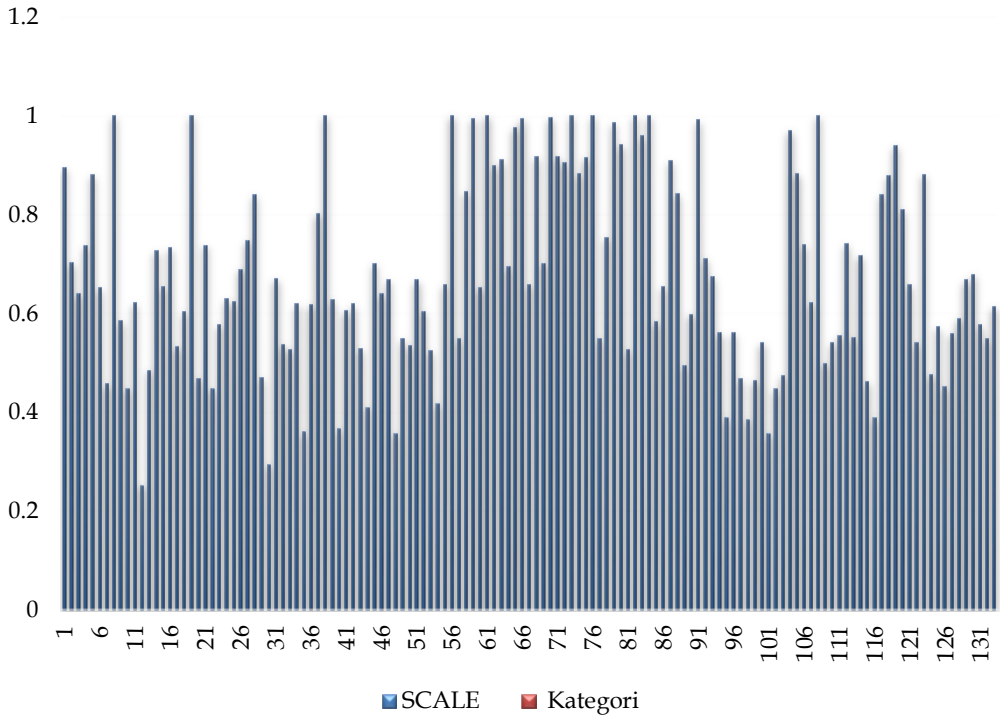

Figure 1.
Efficiency Level of coffee farmers in Simalungun

Source: Data processing with STATA13 application (2023)
Notes: The scale for efficiency is 0–1.2, while the sample number of coffee farmers in Simalungun is 1–133.

In Figure 1, there were only 11% (15 farmers) who were highly efficient, while 13% (17 farmers) were medium efficient, 25% (33 farmers) were low efficient, and 51% (68 farmers) were inefficient. This indicates that coffee farming in Simalungun remains unprofitable, resulting in frequent losses for coffee farmers. The following are the coefficients for the variables measured (Table 4).

Table 4. Variable Coefficients Using The DEA Model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	3.716038	0.555499	6.68955	0.0000
Total Farmer cost	-0.372507	0.030505	-12.2113	0.0000
Total farmer income	0.203723	0.056126	3.629726	0.0004
Total farmer product	-0.04347	0.042665	-1.018875	0.3102
R-Squared	0.537185	Mean Dependent Var		0.676007
Adjusted R-Squared	0.526421	S.D. Dependent Var		0.194516
S.E. Of Regression	0.13386	Akaike Info Criterion		-1.154428
Sum Squared Resid	2.311493	Schwarz Criterion		-1.0675
Log Likelihood	80.76947	Hannan-Quinn Criter.		-1.119104
F-Statistic	49.90961	Durbin-Watson Stat		1.708495
Prob(F-statistic)	0.0000			

Source: Data processing with STATA13 application, (2023)

From the test results above, an equation is obtained as follows:

$$Eff_i = 3.716038 - 0.372507 \ln PTP_i + 0.203723 \ln TBT_i - 0.04347 \ln TPK_i$$

Inefficiency

We sampled and tested 133 coffee farmers in Disimalungun on the efficiency of coffee plantation management using the DEA model. The DEA analysis revealed that there were only 11% (15 farmers) who were highly efficient, while 13% (17 farmers) were medium efficient, 25% (33 farmers) were low efficient, and 51% (68 farmers) were inefficient. Inefficient management can have further impacts, such as the conversion of coffee plantation land into other types, such as oil palm. Farmers tend to replace the type with a new crop when

it is considered more profitable (Zamhari et al., 2009) (Sarmo et al., 2021). The low level of efficiency in farming management indicates low crop productivity (Barus et al., 2021) (Sasrido et al., 2022).

In traditional societies with management that depends on natural resources, they usually tend to manage farming in a modest way. The use of superior seeds is often a barrier in plant manufacturing. Farmers prioritize the use of arbitrary seed sources and rarely prioritize the quality of seeds. Traditional farmers get their seed source from their own land by making the appearance of the plant a favorable seedling parameter. Farmers may meet crop expectations only in terms of vegetative growth. Meanwhile, generative growth, fruit products, and other plant products are difficult to fulfill because, genetically, the seeds used are not guaranteed quality (Wijaya et al., 2021) (Lubis & Saputra 2020).

However, a common obstacle to traditional agriculture in agricultural cultivation is farmers' limited knowledge of cultivation technology, which can be further exacerbated by other factors such as a lack of resources to improve agricultural land management. As explained above, the majority of workers in the people's coffee plantations in Simalungun are women and over 45 years old. This illustrates the shortage of competent resources in the management of these coffee plantations. Even though they are still of productive age, they cannot do all the work because women are also responsible for household work. Their ability to manage their coffee plantations is limited due to their lower secondary education level.

When combined with a low level of education, it will encourage farmers to cultivate their land based on their hereditary knowledge (Rahman et al., 2017). Traditional conditions also hinder farming innovation. To overcome obstacles in traditional agriculture development, management on a larger scale is required. The limited land that farmers typically own often hinders their ability to adopt new technologies efficiently. In other words, agricultural intensification aimed at increasing production often has the opposite effect, namely increasing unnecessary costs.

According to Ayamga et al., (2023) a relatively wide scale of land including various land use integrations, can support this intensification effort. Support from competent government policies and local communities with sufficient social capital is crucial for this activity. The rule changes will encourage wider involvement of various parties to achieve these intensification goals, including changes in social decision-making regarding men taking part in household chores and women's involvement in family decision-making (Ayamga et al., 2023).

Inefficient management of coffee plantations often occurs in traditional communities. Research Tamirat & Tadele (2023) Various resource-related variables, including age, gender, educational status, land ownership, livestock

ownership, credit use, extension use, off-farm activities, land ownership, seeds, and planted coffee varieties, influenced technical inefficiencies. The technical efficiency of coffee products is associated with coffee products, which play a role in the annual per capita income of coffee entrepreneurs. Therefore, efforts to increase coffee yield are important to increase technical efficiency, which is the basis for increasing production. In various farming situations, socio-economic conditions and farmers' knowledge can reduce the level of efficiency.

The issue of low education levels hinders Simalungun women farmers from increasing land productivity. Long-term farming does not make Simalungun women more capable of managing their coffee plantations. Santiasih et al (2021) demonstrates that an inexperienced workforce can significantly lower the level of management efficiency. Farming experience directly affects the work pattern in the farming area. Generally, farmers can work faster and more efficiently when they have knowledge and experience in plant cultivation activities. The low quality of knowledge and experience among farmers encourages them to increase the number of workers in order to increase their income from land (Ahdiningtyas et al. 2023). This strategy can increase crop yields, but it also increases farming costs. Increasing costs necessitate adding expenses to the production process. So efforts made to increase production can have the opposite impact on reducing the efficiency of farming management, in the sense of reducing the profits obtained.

Considering the various efforts made by farmers to improve efficiency, it appears to be a difficult dilemma to overcome. While an increase in input components aims to increase crop yields, it can also increase production costs, reducing management efficiency. To enhance farming efficiency, we require a variety of strategies. This is inevitable because various cases of inefficiency usually do not stand alone. Technical efficiency, allocative efficiency, and economic efficiency are the three important variations that relate to inefficiencies. Economies of scale determine overall successful farming, despite the three variables having different measurements. Economic efficiency is the final standard for determining whether farming is sustainable or not.

As shown by Sumarno et al., (2020) regulating work activities often achieves technical efficiency, but it lacks allocation and economic efficiency. Technical efficiency is related to farmer knowledge, so variables such as farmer education, farming experience, frequency of counseling, participation in farmer groups, access to credit, and technological assistance can have a direct impact on technical efficiency. The study also shows that economic and allocative efficiency are still low.

Inefficiency in management closely relates to the failure of agricultural development. Land problems, including land ownership, land leases, and other land-related issues, significantly influence the extent of inefficiency, along with activities conducted in various fields. Government policy interventions can

promote a range of technical activities, aiming to equip farmers with the necessary knowledge to carry out cultivation activities or enhance their skills, enabling them to manage land using diverse methods. However, the government's policy approach needs to consider the right targets according to the goals of sustainable agricultural development (Tamirat & Tadele, 2023) (Li et al., 2023). The policy needed is to emphasize the role of farmers in sustainable practices by prioritizing inclusive policies in accordance with local knowledge and farmers' needs to become their agricultural solutions (Petrescu-Mag et al., 2024).

Effect of Total Farmer Costs on Efficiency

The regression coefficient and P-value for the Total Cost of Farmers variable were 0.372507 and 0.000, respectively (P-value <0.05), so from the test it can be concluded that there is a negative and significant effect of the Total Cost variable on the efficiency of coffee plantations. This means that if the total cost variable increases by 1 unit, the efficiency variable decreases by 0.372507, and vice versa, if the total cost variable decreases by 1 unit, the efficiency variable increases by 0.372507.

The main variable causing inefficiency is the use of too high total costs. Total costs negatively affect the efficiency of arabica coffee plantations in Simalungun. An increase of 1 unit of total cost will decrease the efficiency level by 0.372507. This demonstrates that the management of Arabica coffee plantations in Simalungun spends excessive amounts of money on production. The use of high costs will directly reduce coffee farmers' income. (Paloma et al., 2020). Smallholder coffee management tends to be inefficient in terms of production costs such as labor, herbicides, and manure (Jumiati & Mulyani, 2014). As a result, average coffee production is low due to the inappropriate use of production facilities (Zen & Budiasih 2018). Efforts to increase land productivity are usually carried out by increasing sludge production facilities' input. The average land area in the Simalungun people's arabica coffee plantation is 0.8 ha, or including narrow land. The addition of land production costs tends to be ineffective on narrow lands (Kyalo et al., 2019) (Bullock et al., 2024). Narrow agricultural land ownership is common among small farmers in rural areas. As a result, efforts to intensify farming income do not have a positive impact on increasing crop yields; on the contrary, they can even increase expenditure costs.

As mentioned above, farmers are basically trying to increase the production of their coffee plantations. However, a variety of obstacles render these expenditures inefficient from a management perspective. Despite maximizing cultivation activities, farmers' limited resources hinder these intensification efforts. Coffee farmers in Simalungun typically use family labor to carry out various management activities in the field. Due to their limited

resources and lack of knowledge, farmers in Simalungun are unable to overcome the issue of low productivity in their coffee gardens. Limited resources are the main cause of low production, so farming becomes inefficient.

Cost factors associated with inefficient farming management can manifest in various types of farming. Costs also increase when there are problems with the land, such as when farmers try to increase inputs to modernize their management with a more intensive approach. However, efforts to intensify management can increase costs, which is actually inefficient (Suwanmaneepong, S., Kerdsriserm et al. 2020) (Byamugisha and Dubosse 2023). Efforts to increase agricultural intensification can basically streamline expenditure, as shown in the case of narrow land on a greenhouse scale (Huber et al. 2023). This shows that the land area plays a significant role in determining costs for farmers.

For generations, traditional farmers find themselves ensnared in the cycle of cultivating land. Farm work generally relies on family labor, which is only able to carry out physical activities rather than making management innovations. The average coffee plant is over 10 years old and rarely undergoes rejuvenation. Despite farmers' efforts to enhance the management system, it fails to significantly boost crop yields.

Reducing the input of production factors easily solves inefficiency cases (Nurhayati, 2020). In simple terms, this strategy is acceptable. This study with DEA analysis also shows that the total cost has a real effect on inefficiency. A negative coefficient (-0.372507) indicates the direction and importance of reducing production costs. If we hold other variables constant, we can observe a decrease in the cost of production, but we cannot isolate this fact from other activities. Reducing direct inputs will reduce income, especially when farmers also lack knowledge and experience. Technology input is actually important in conditions where knowledge and the quality of human resources are lacking. Dualism between land use and productivity is common in almost all agricultural systems models. When agricultural management is not accompanied by a new approach, the extraction of land will always lead to degradation (Khan et al., 2023). All agricultural activities fundamentally impact the environment. When agricultural management does not pay attention to these environmental problems, it encourages land degradation. In connection with inefficient agricultural land use activities, it is necessary to improve the mechanism to manage agricultural land more positively by focusing on sustainable practices (Tokbergenova et al., 2018).

The high production costs for Arabica coffee farmers in Simalungun are also the impact of expensive production input prices, such as fertilizers. This is understandable because farmers have difficulty getting the fertilizer they need at a reasonable price. Consequently, farmers struggle to enhance the efficiency of their coffee plantation management due to the high cost of fertilizer. Therefore, government policy intervention is needed to ensure that the coffee plantation is

sustainable by ensuring the availability of production facilities needed by farmers as a policy target so that farmers get a solution in maintaining their coffee plantations (Tamirat & Tadele, 2023) (Li et al., 2023) (Petrescu-Mag et al., 2024).

The Effect of Total Farmer Income on Efficiency

For the Total Farmer Income variable, the regression coefficient was 0.203723 and the P value was 0.000 (P value <0.05). This means that the Total Farmer Income variable has a positive and significant effect on the efficiency of coffee plantations. If the Farmer Income variable goes up by one unit, the Efficiency variable will go up by the same amount, and if the Total Farmer Income variable goes down by one unit, the Efficiency variable will go down by the same amount. An increase in income by 1 unit will increase the efficiency of Arabica coffee management by 0.203723 and vice versa. Total income is a significant determinant of whether farming is efficient or vice versa. The smallholder coffee plantations in Simalungun district, traditionally managed by the local community (adat), have a system of rules that prevent women, who are the primary workers in the land, from making many decisions regarding their farming management. As a result, there has been a generational dependence on family labor, particularly that of women. Coffee plantation management is dependent on a few resources. Reducing production inputs inevitably leads to a decrease in income.

The issue of inefficiency in smallholder plantation land cannot be avoided to change the profile of smallholder plantations. Income, as a key economic variable, determines the sustainability of farming. Economic activity will serve as a measure of overall household activity. This is how farmers view the management of their resources (Lambrecht et al. 2024). Economic goals in managing sustainable agricultural resources are very decisive as a condition for the sustainability of a farming business. The coefficient of total production, with a negative notation of -0.04347 (Table 4), indicates the low productivity value. This indicates the direction of inefficient management trends, as evidenced by the inefficient use of total costs (Table 4). Farmers typically choose survival strategies to confront losses, particularly when the prices of production facilities rise and crop production remains relatively stable. The strategy of reducing expenditure is inevitable because farmers do not have other means to find alternative solutions to the problem. Furthermore, when there are no government policies or related institutions that support farmers' production facilities (Yusuf et al. 2022) (Martial, Asaad, and Gunawan 2020).

Factors that contribute to inefficient coffee production in the coffee business are inextricably linked to the educational background and knowledge of coffee farmers. The educational background of the majority of junior high school graduates in Simalungun reflects the relatively low level of education and knowledge of coffee farmers, with the existing coffee plantation system in the

region classified as hereditary, leading to a still rudimentary understanding of coffee management (Grossman, 2003)(Daba et al., 2023). Indicators of education level influence a farmer's ability to improve their knowledge (Tamirat & Tadele 2023). The higher a farmer's level of education, the greater his knowledge of agriculture and technology (Hassan et al., 2024). In the Simalungun region, the junior high school level of education, which most coffee farming communities rely on for agricultural management, is not fully optimized. The lack of maximization is due to the lack of access to resources such as training, counseling, and seminars, making the community lack skills and specialized knowledge in the management of coffee plantations, so that people still carry out traditional-based management, which results in not maximizing coffee production and still low farmer income compared to farmer expenses during the process of managing coffee plantations (Maldayo et al., 2024). Age and length of farming also correlate with low knowledge, which ultimately renders the farm management system inefficient (Gusti et al., 2022). Farmers who are older usually have better farming experience and extensive traditional knowledge, but the disadvantage of old age is that it makes them less responsive to new innovations and technologies that can improve efficiency. Conversely, farmers who are younger or have less experience can adopt new technologies more quickly, but they lack in-depth practical knowledge of specific land management (Kehinde et al., 2021).

The inefficiency of the Simalungun coffee farming method is caused by a number of other variables in addition to the ones related to education, age, and length of farming experience. Several factors contribute to the unprofitable management of coffee plantations, including family-owned or leased land ownership, which increases operational costs and requires the landowner to share coffee yields; gender; the use of credit and extension; off-farm activities; and the availability of seeds and varieties (Tamirat & Tadele 2023). In addition, factors such as gender, age, education, access, productivity, land area, and the number of plants contribute to the profit of coffee plantation and the income gains of coffee farmers. However, the age of the plant does not significantly impact the profits of coffee farms (Sari, 2018).

Furthermore to the previously mentioned elements, unstable coffee prices and expensive labour also lead to production inefficiencies (Andrea et al., 2022). When prices are unstable and relatively cheap, coffee farmers cannot cover their operational costs, and profits are relatively small. Other problems in the traditional farm management system that cause inefficiency are determined by outdated agricultural technology, weak management, and a lack of access to markets and information systems (Kenamon et al., 2021); (Herlina et al., 2019); (Zen & Budiasih 2018); (Suprianto & Sarifudin 2020); (Suprianto & Mayasari, 2022). The local community traditionally manages the Simalungun people's coffee plantations, making the adoption of technology challenging. With simple

technology, coffee farmers carry out the cultivation chain from planting to harvest, including making limited fertilizer inputs. Community coffee plants are typically over ten years old, and many even come from their parents' inheritance. In fact, technology input is the right strategy to improve management efficiency on traditional community plantations. This inefficient condition tends to occur when there is no government intervention to direct farmers to efficient cultivation patterns (Tamirat & Tadele 2023).

Enhancing the efficiency of agriculture directly contributes to the sustainability of the agricultural system. Income efficiency is one of the important pillars of sustainable agriculture, in addition to ecological sustainability and social sustainability. These three variables support each other so that the agricultural system can survive in the long run. In situations where farming is not efficient, people tend to shift their focus to alternative forms of livelihood. Farmers will switch from coffee to more profitable crops like oranges and vegetables. Simalungun district, one of the coffee centers in North Sumatra, is currently experiencing many conversions to other agriculture. Respondent farmers tend not to maintain their coffee plantations when they are considered economically disadvantaged. To maintain people's coffee plantations as a leading commodity in Simalungun, it is important to ensure that farmers are guaranteeing their farming income. Traditional farmers face a challenge in adhering to binding local rules, which hinders their ability to modernize their agricultural system, particularly in older and less productive coffee plantations. As a result, the increase in inputs tends to only increase production costs, not improve management efficiency. Based to Chen et al. (2019) specifically, the technology's input must align with the farmer's needs. A certain technology may be suitable for one farmer, but it may also be the other way around, depending on the location and problem. People in Simalungun struggle to enhance their income due to the lack of technological advancements in their Arabica coffee plantations, despite their efforts to boost production, which is a primary goal in plantation management.

The Effect of Total Farmer Production on Efficiency

The regression coefficient and P-value for the variable Total Farmer's Production were, respectively, -0.04347 and 0.3102 (P-value <0.05), so testing can conclude that there is no significant effect of the variable Total Farmer's Production on the efficiency of coffee plantations. This means that if the farmer production variable is increased by 1 unit, the efficiency variable will not be affected.

According to the DEA analysis above, total production does not have a significant impact on the efficiency of coffee farming in Simalungun. However, total production affects farmers' income from coffee plantations. These two factors influence each other in the context of farming activities. The total

production of coffee farmers, although it does not significantly affect efficiency, has a big impact on total income. Farmers obtain their total income by selling their total production at the prevailing price and subtracting all incurred costs.

Encouraging farmers to increase their coffee production can initiate efforts to improve efficiency, thereby boosting income. Therefore, in order to increase the income of coffee farmers and be more efficient, farm management must carry out post-harvest activities that have an impact on the total income of farmers. We can make these efforts by optimizing the marketing function of each marketing institution, which includes branding the product, promoting it, forming partnerships, enhancing post-harvest quality, and selling processed coffee products like sangria coffee (Mosallanezhad et al., 2023) (Carolina & Rosiana, 2022). Since technical variables directly involved in product production essentially determine production efficiency, total production has no effect on efficiency (Jumiati & Mulyani 2014) (Hidayati, 2021) (Tamirat & Tadele, 2023). The relationship between efficiency and total farmer income (per capita income) is significant. The utilization of factors that support production actually determines total production (Ahdiningtyas et al., 2023) (Sudiawan et al., 2022); (Sularso et al., 2019) (Widaningrum et al., 2023).

An increase in coffee yields, both in quality and production, essentially indicates the efficiency of the coffee plantation management system and can increase the value of farmers' income. This depends on the overall management. A good level of crop production indicates a good crop management system anyway, thus increasing management efficiency (Toledo et al., 2013).

Technology adoption is one of the crop management strategies to increase production. Increasing the productivity of resources like information technology can contribute to modernizing traditional management and streamline farming by reducing production costs. The adoption of technology in traditional agriculture is an important part of reducing inefficiency rates, improving supply chain coordination, and ultimately lowering production costs. It also encourages the transformation of traditional agriculture to be more sustainable (El & Allahyari, 2018). Farmers will see an increase in income if they successfully adopt new technology to increase their total agricultural production. Income directly enhances the efficiency of farming management. Arabica coffee farmers in Simalungun do not face this situation. Farmers in Simalungun manage their coffee plantations using improvised technology, relying on minimal technological inputs such as fertilizers and various cultivation techniques. Traditional farmers tend to survive by minimizing inputs in order to be able to maintain their farming. This makes traditional agriculture, including smallholder plantations, sustainable on a medium scale.

The dilemma between increasing yields and reducing production costs is considered to be the opposite. As the definition of sustainable management of natural resources changes, there is a trade-off between several activities. When

we manage and extract natural resources from the land, we ensure their high subtractability, particularly on private or owned land. The land's output necessitates a corresponding input to ensure its sustainability. In other words, to achieve sustainability, there must be a balance of input and output. This implies that if we attempt to preserve resources by lowering the output from the land, we can prevent harm to these resources. However, this is contrary to the interests of farmers, who strive to increase their farming output as a form of output from the land. To be sustainable, efforts to improve farming efficiency start with the motivation of the farmers themselves. As a sustainable approach, efforts to balance input and output necessitate knowledge and motivation to adopt sustainable agriculture models. An intrinsically and extrinsically sourced supportive incentive system will motivate farmers to adopt a sustainable approach. This can reduce farmers' perceptions of the level of risk they face when adoption does not align with their goals (Bopp et al., 2019).

Therefore, farmers need the support of the government and local institutions to access agricultural technology more efficiently according to their needs. Farmers require stable market guarantees to enhance their bargaining power and secure price stability for their coffee products. Policies that directly address their problems, such as ensuring access to fertilizers or high-quality seeds, are necessary. Furthermore, it is imperative to transform local institutions that can guarantee equal rights for women, who are the primary laborers in Simalungun's coffee plantations.

CONCLUSION AND SUGGESTION

Conclusion

Most people classify the efficiency level of Arabica coffee plantation management in Simalaungun as inefficiency, indicating that Arabica coffee farming in Simalaungun has not significantly impacted farmers' household income. 51 percent of respondents exhibited inefficiency, 25 percent demonstrated low efficiency, 13 percent demonstrated medium efficiency, and only 11 percent demonstrated high efficiency. Factors affecting efficiency in the management of coffee plantations in Simalungun are total farmer costs and total farmer income, with a significant value smaller than alpha 0.05, while the variable total farmer production does not affect efficiency. Traditional management with limited resources and narrow land contributes to the inefficiency of the plantation farming system, making it challenging to intensify agriculture to increase crop yields.

Suggestion

Future researchers should consider exploring the efficiency of coffee plantation management by utilizing modernization of technology and the use of superior seeds capable of high productivity. As input for the government to be able to improve skills for farmers by offering training and education so that farmers can adopt modern agricultural techniques that have an impact on increasing the effectiveness of coffee plantation management in North Sumatra.

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