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Analysis Of Profit Efficiency Of Rice Farming In Solok Regency

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Abstract—Profit efficiency is a combination of technical and allocative efficiency which provides more information than other partial efficiency measurements and will determine future farming prospects. This study aims to (1) analyze the profit efficiency of rice farming in Solok Regency and (2) analyze the socio-economic factors of farmers influence the profit efficiency of rice farming in Solok Regency. This study was conducted in X Koto Singkarak District, Solok Regency in June-July 2024 using a survey method of 100 respondents taken by random sampling. Data were analyzed using the Cobb Douglas Stochastic Profit Frontier function using the Maximum Likelihood Estimation (MLE) approach. The results showed at a confidence level of 95%, seed prices and land rental cost have a positive effect on profits. NPK Phonska fertilizer prices, labor wages, and equipment depreciation costs have a negative effect on profits. Profit efficiency of rice farming in Solok Regency is 0.91 means rice farming has reached 91% profit from the maximum profit limit. Rice farming experience and farmer's formal education have a positive effect on profit efficiency of rice farming in Solok Regency. Increasing the profit efficiency of rice farming can be achieved by reducing the cost allocation for NPK Phonska fertilizer, labor wages, and equipment depreciation costs because the increase in the value of these variables leads to a decrease in rice farming profits. Farmer who are members of farmer groups are expected no to overuse fertilizer even though they get subsidized fertilizers in order to reduce production costs, increase profits, and increase the profit efficiency of rice farming.

Keywords— Productivity, Profit Efficiency, Rice Farming, Solok Regency, Stochastic Profit Frontier Cobb Douglas

I. INTRODUCTION

Rice is one of the main food sources for 95% population in Indonesia which is widely cultivated by farming households in Indonesia. The need for rice as food will continue to increase along with population growth, the development of the food industry, and the increase in per capita income. Therefore, production must be increased in order to meet food needs. There are three alternatives to increase production, namely increasing land area, developing and adopting technology, or using production factors more efficiently. Using resources more efficiently is the best and most effective way to increase productivity [1].

Productivity is one of the benchmarks in determining the success of farming. Productivity problems can be overcome by efficient input allocation [2]. One of the government's efforts to encourage an increase in agricultural productivity is by providing subsidized fertilizers, which based on Permentan Number 10 of 2022, the government provides subsidies for urea and NPK Phonska fertilizers for nine main commodities, one of which is rice. However, this has not been fully able to increase rice production. Based on BPS Indonesia data, rice production in Indonesia fluctuates from year to year and in 2023 has decreased by 2.05% than 2022 [3].

Successful agriculture is not only determined by high production and productivity, but how increased production and productivity can increase farm income. The currently problem of rice farming in Indonesia are low production and high input costs

which cause a decrease in profits. From the farmer's side, increasing productivity faces obstacles related to the availability of capital, allocation and price of production inputs, as well as the selling price.

West Sumatra is one of the largest rice-producing areas in Indonesia in 2023, but its productivity has decreased than previous year. In the context of agricultural development, the West Sumatra government has determined agricultural areas based on their commodities. Based on the 2021 Decree of the Governor of West Sumatra concerning the determination of agricultural areas for plantations, food crops, and horticulture Solok Regency is a food crop area for rice plants in three areas, namely Gunung Talang, Bukit Sundi, and X Koto Singkarak. Among the three areas, X Koto Singkarak is the area with the lowest productivity, which is 5.09 tons/ha [4]. Indicates farmers are not efficient in allocating production inputs and there are still opportunities to increase productivity through the efficient use of inputs.

Efficiency is the main factor affecting farmers' income and food security [5]. Efficiency is an important factor in increasing productivity achieved through proper allocation of resources. The right allocation of resources has a major impact on productivity and sustainability of farming [5]. Agricultural efficiency measurement is needed as information material in determining the direction of agricultural development policies in order to support increasing agricultural productivity. Technical efficiency is commonly used and provides answers on how to produce. In achieving technical efficiency it may be contrary to maximizing profits and potentially causing losses. Profit efficiency approach is appropriately used on the assumption farmers operate based on economic optimization and endogenous input level [6].

Profit function approach combines the concepts of technical and allocative efficiency in profit relations and any error in production decisions is assumed to lower profits for farmers. If farmers fail to operate at the profit limit, it is considered inefficient in obtaining profits and vice versa. How feasible a production process is to produce profits is influenced by the variation in the change in inputs to agricultural output [7]. Profit efficiency is able to catch errors in terms of inputs and outputs in the production process [6].

Various studies have been conducted to examine the productive efficiency of farmers focusing on the technical and allocative efficiency of agriculture. However, few have examined the profit efficiency of agriculture even when input and output prices are known when measuring the efficiency of farm allocation. Thus, there is a gap because profit efficiency has not been calculated simultaneously with the three efficiency components. Consideration of physical productivity measured through technical efficiency is important in improving production efficiency, but profit efficiency will bring greater benefits to producer farmers [8]. Profit efficiency is a combination of technical efficiency and allocative efficiency. Thus, for agriculture to be profitable, farmers must generate maximum profits efficiently even at fixed production costs and prices [9]. Profit efficiency provides more information than other partial efficiency measurements. Profit efficiency will determine the future prospects of farming. Profit efficiency has significant implications regarding of development strategy type can be adopted to formulate policies to improve farming efficiency [5].

Profit efficiency studies need to be carried out to find out the level of profit efficiency and the affecting factors in rice farming in Solok Regency to determine policy decisions to increase the profit efficiency.

II. Research Methods

This study was conducted in Regency X Koto Singkarak, Solok Regency which was determined purposively with the consideration (1) rice planting area based on the Decree of the Governor of West Sumatera Number 525-757 of 2021 concerning the Determination of Agricultural Areas for Plantation Crops, Food Crops, and Horticulture of West Sumatra Province and (2) the fifth largest rice-producing areas in Solok Regency with the lowest productivity when compared to other rice areas in Solok Regency [4].

This study was carried out in June-July 2024 using a survey method using questionnaires through interviews. Populations are 2,640 rice farmers in X Koto Singkarak District. The number of samples was determined using the Cochran's formula:

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$$n = \frac{(Z)^2 \, x \, N \, x \, (\sigma)^2}{(N-1) \, x \, (e)^2 + (Z)^2 x \, (\sigma)^2}$$

$$n = \frac{(1{,}96)^2 \, x \, 2.640 \, x \, (1{,}04)^2}{(2.640-1) \, x \, (0{,}2)^2 + (1{,}96)^2 x \, (1{,}04)^2}$$

$$n = 99{,}98$$

n represents sample size, N represents population size, Z represents probability value, σ represents standard deviation, and e represents margin error.

Based on calculations, sample was determined to be 100 rice farmers in X Koto Singkarak Regency which were taken by random sampling. The observed variables were field data during the last planting period at the study site, namely in February-June 2024.

Farm profit measured in term of Gross Margin (GM) equal to the difference between Total Revenue (TR) and Total Variable Costs (TVC), which are expressed by the following equation:

$$\mathbf{GM\ (\pi) = \Sigma\ (TR\text{-}TVC) = (PQ) - (WXi)}$$

Profit efficiency in this study is defined as the profit obtained from operations on profit frontier by considering prices and specific factors of agriculture and considering farming that maximizes profits. The farming profit used in this study is the gross margin. Profit efficiency is expressed as the ratio of actual profit predictions to maximum profits for farmers with best practices, which is expressed as follows:

$$\textbf{Profit Efficiency } (E\pi) = \frac{\pi}{\pi \, max} = \frac{exp\,[\pi\,(p,z)]exp\,(ln\,V)exp\,(-ln\,U) - \theta}{exp\,\,[\pi\,(p,z)]\,exp\,\,(lnV) - \theta}$$

The stochastic frontier function with inefficiency components and to estimate all parameters together is performed by the one-step Maximum Likelihood Estimation (MLE) approach. Therefore, the explicit form of the Cobb Douglass profit function of rice farmers in this study is formulated as follows:

$$\mathbf{Ln\ \pi = Ln\beta 0 + \beta_1 Ln\ P_1 + \beta_2 LnP_2 + \beta_3 LnP_3 + \beta_4 LnP_4 + \beta_5 LnP_5 + \beta_6 LnP_6 + \beta_7 LnZ_1 + \beta_8 LnZ_2\ (V_i - U_i)}$$

Where:

Π : Rice farming profit (Rp/Planting Season)

P_1 : Average price of normalized seeds (Rp/Planting Season)

P_2 : Average price of normalized urea fertilizer (Rp/kg/Planting Season)

P_3 : Average price of normalized NPK Phonska fertilizer (Rp/kg/Planting Season)

P_4 : Average price of normalized insecticides (Rp/package/Planting Season)

P_5 : Average price of normalized herbicides (Rp/package/MT)

P_6 : Average wage of normalized labor wages (Rp/man/day)

Z_1 : Equipment depreciation cost (Rp/Planting Season)

Z_2 : Land rental cost (Rp/Planting Season)

β_0 : Constant

B_i : Regression coefficient

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V_i : Random errors

U_i : Profit inefficiency effects

Inefficiency model of rice farming in this study represented as follows:

$$Ui = \partial 0 + \partial_1 M_1 + \partial_2 M_2 + \partial_3 M_3 + \partial_4 M_4 + \partial_5 M_5 + \partial_6 M_6$$

Where:

U_i : Inefficiency of rice farming

M_1 : Farmer's age (years)

M_2 : Rice farming experience (years)

M_3 : Farmer's formal education (years)

M_4 : Land ownership status (1=owned, 0=rented)

M_5 : Membership of farmer groups (1=yes, 0=no)

M_6 : Ease of access to subsidized fertilizers (1=yes, 0=no)

Estimation of all parameters of Stochastic Profit Frontier Cobb Douglas Function and inefficiency model were obtained simultaneously using STATA 17.0.

III. Results And Discussion

3.1 Affecting Factors the Profit of Rice Farming in Solok Regency

Before analyzing profit function using Cobb Douglas profit function, an agricultural analysis was first carried out to determine production, cost, revenue, and gross margin of rice farming during one planting season. Analysis of rice farming in Solok Regency for the February-June 2024 planting season is presented in table 1.

Table 1. Costs, Revenue, and Gross Margin Of Rice Farming In Solok Regency in February-Juny 2024

	Input	Cost (Rp/Hectare)	% of Contribution
Variable Input	Seed	502,042.86	1.42
	Fertilizer	2,047,344.80	5.79
	Pesticides	203,125.53	0.57
	Labor wages	19,813,504.75	56.01
Fixed Input	Equipment depreciation cost	34,402.50	0.10
	Land rental cost	12,771,556.54	36.11
Total Cost (Rp/Hectare)		**35,371,976.98**	
Production (Kg/Hectare)		**6,026.09**	
Selling Price (Rp/Kg)		**8,187.00**	
Revenue (Rp/Hectare)		**49,318.093.75**	
Gross Margin		**26,752,075.81**	

Maximum Likelihood Estimation (MLE) approach provides an overview of the best performance of sample farmers in the study area. Results of Estimating Stochastic Profit Frontier Cobb Douglas using Maximum Likelihood Estimation (MLE) approach are presented in table 2.

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Table 2. Stochastic Profit Frontier Cobb Douglas Function Estimates

Using Maximum Likelihood Estimation (MLE) Approach

Variable	Coefficient	Z	P>|z|
Seed price (P_1)	**1.740**	**2.13**	**0.033**
Urea fertilizer price (P_2)	0.053	0.21	0.835
NPK Phonska fertilizer price (P_3)	**-0.583**	**-2.85**	**0.004**
Insecticide price (P_4)	-0.045	-1.64	0.100
Herbicide prices (P_5)	-0.031	-1.79	0.073
Labor wages (P_6)	**-0.819**	**-2.44**	**0.015**
Equipment depreciation cost (Z_1)	**-0.211**	**-3.94**	**0.000**
Land rental cost (Z_2)	**0.698**	**2.59**	**0.010**
Constant	6.406	1.70	0.089
Conf. Interval		95%	

Based on Table 2, at a confidence level of 95% seed price (P_1), NPK Phonska fertilizer price (P_3), equipment depreciation cost (Z_1), and land rental cost (Z_2) used in the model have a significant effect on profitability of rice farming in Solok Regency because the P>|z| less than 0.05.

Seed price (P_1) has a coefficient value of 1,740 means every increase in seed prices by one percent will cause an increase in profit by 1,740 percent. The use of seeds in rice farming in the study area was 62.32 kg/hectare, more than the recommendation of 20-25 kg/hectare [10] and the use of seeds in other areas in Solok Regency as much as 52 kg/hectare [11].

Allocating more seeds does not lead to a significant decrease profits because the planting distances applied by farmers are wider than recommended. The planting distance applied by farmers is 30x30 cm the recommendation is 20x20 cm or 25x25 cm [12]. A wide planting distance will produce more saplings and more production. In addition, the number of seedlings per planting hole by farmers is more, which are 3-5 stems per planting hole while the recommendation is only 2-3 stems per planting hole. Both of these things increase production and have a positive effect on increasing agricultural profits. Most farmers in the study area (72%) used seeds sourced from previous crops assuming they would produce more rice, save costs, and avoid dependence on company-produced seeds. Judging from its contribution to total agricultural costs, seed costs contribute only 1.42% (Table 1). Seed cost is a variable cost, the lower seeds cost leads to higher gross margins and profit efficiency.

Urea fertilizer price (P_2) has a coefficient value of 0.5 and P>|z| value > 0,05 means urea fertilizer price has no effect on profits. The allocation of urea fertilizer by farmers varies based on capital and habits. Farmers allocated urea fertilizer of 315.63 kg/hectare, more than the recommendation of 200 kg/hectare [10]. The results are different with [13] and [14] which found urea fertilizer has a positive effect on rice production in measuring technical efficiency. The advantages of farming are related to technical efficiency because they affect the amount of production produced. Thus, the positive effect of urea fertilizer on production has a positive effect on agricultural profits.

NPK Phonska fertilizer price (P_3) has a coefficient value of -0.583 means NPK Phonska fertilizer price has a negative effect on profits. A 1% increase in the price of NPK Phonska fertilizer will decrease profits by 0.583%. Profit decrease occurred due to the excessive use of NPK Phonska. Similar to [15] which found an excess of fertilizer in rice farming. Average amount of use by farmers was 298.62 kg/hectare the recommendation was only 75-100 kg/hectare [10].

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Fertilizer shortages often occur due to supply delays and mismatches in the amount of subsidized fertilizer realization received by farmers with the Definitive Plan for Group Needs (DPGN) causing farmers to buy non-subsidized fertilizers [16]. Judging from its effect on income, in allocative efficiency research, fertilizer costs have a negative effect on agricultural income [17]. Therefore, to reduce costs in order to increase the profitability of rice farming, its use must be reduced.

Insecticide price (P_4) has a coefficient value of -0.045. Herbicide price (P_5) has a coefficient value of -0.031. Insecticide price (P_4) and herbicide price (P_5) have no effect on profit because P>|z| value > 0,05. Same with [17] which found pesticides have no effect on production. Pesticides does not directly increase productivity but play a role in protecting productivity from pests and diseases causes of crop failure. The increased use of insecticides and herbicides led to increased agricultural costs, decreased agricultural profits. Increasing the profitability of rice farming can be achieved by reducing the use of both types of pesticides. The high cost of pesticides in agriculture is caused by the behavior of farmers who are willing to pay high prices for pesticides that are considered effective in controlling pest and disease attacks [18].

Labor wages (P_6) have a coefficient value of -0.819 means labor wages have a negative effect on profitability of rice farming. An increase in workers' wages by 1% will decrease profits by 0.819%. The large use of human labor in rice farming in Solok Regency is due to the use of simple equipment and low of farmer's productivity. Increased profits can be achieved through optimizing the use of human labor and using agricultural technology. Using agricultural technology in the form of agricultural machinery can reduce the amount of labor use and farmers can focus on other activities [19].

Fixed inputs (Z_1 and Z_2) have a P>|z| value < 0.05 means fixed input variables have a significant effect on profitability. Equipment depreciation cost (Z_1) has a coefficient value of -0.211 meaning a 1% increase in equipment depreciation costs led to a 0.211% decrease in profits. Land rental costs (Z_2) has a coefficient value of 0.698 meaning a 1% increase in land rental costs led to an increase in profits of 0.698%. Same with [20] which found rice production on leased land is better than on own land. Land rental cost in Solok Regency is fixed in each planting season and is not affected by the quantity of rice production. Land rental cost varies depending on the type of plant and the location of farming [21]. Farmers who farm on leased land try optimally to increase production and profits.

3.2 Profit Efficiency of Rice Farming in Solok Regency

Profit efficiency is defined as the ability of farmers to achieve maximum profits by considering prices and levels of fixed factors. Estimates are made using farm-specific prices and fixed input rates as arguments in the analysis. In this study, the measurement of profit efficiency level uses the Cobb Douglas stochastic border advantage function model. Stochastic border approach can generate the conjecture coefficients affect profits, determine the profit efficiency level of each sample, and identify the factors affecting profit efficiency. Farming efficient if the efficiency score ≥ 0.7 and inefficient if efficiency score < 0.7 (Coelli, 2005). The efficiency of rice farming profits in Solok Regency is presented in table 3.

Table 3. Distribution of Profit Efficiencies of Rice Farming in Solok Regency

Efficiencies	Frequency	Percentage (%)
<0,7	8	8
0.7-0.8	7	7
0.8-0.9	11	11
0.9-1.0	74	74
Average	0.91	
Minimum	0.36	
Maximum	1.00	

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Based on Table 3, the efficiency of rice farming profits in Solok Regency ranges from 0.36-1.00. Farmers in a "best practice" with an efficiency value of 1.00 and in a "least practice" with an efficiency value of 0.36. Although technically the implementation of agriculture and the use of inputs are not in accordance with the recommendations, agriculture can achieve profit efficiency due to its high production.

Based on efficiency values agriculture is classified into 2 groups, efficient agriculture with an efficiency value of ≥0.7 and inefficient agriculture with an efficiency value of <0.7 [6]. Thus, 92% of rice farming in Solok Regency is efficient and 8% is inefficient. Most rice farms (74%) in Solok Regency have a profit efficiency value of 0.9-1.0. This value is higher than rice farming in Nigeria by 0.61 (Kolawole, 2006), in Brunei 0.81 [22], in Vietnam 0.67 [23], and in Uganda 0.59 [24].

Average of profit efficiency is 0.91 means 91% of maximum profit has been derived from production efficiency. Rice farming in Solok Regency has reached 91% of the maximum profit limit assuming the cost structure is well allocated and there is an opportunity to increase profit efficiency by 9% through improved technical efficiency, allocation, and scale. Thus, in general, rice farming in Solok Regency has achieved profit efficiency.

3.3 Factors Affecting the Profit Efficiency of Rice Farming in Solok Regency

Socio-economic factors used as variables in this study include farmer age (M_1), farming experience (M_2), farmer formal education (M_3), land ownership status (M_4), farmer group membership (M_5), and ease of access to subsidized fertilizer (M_6). Estimates of factors affecting rice farming inefficiency in Solok Regency are presented in Table 4.

Table 4. Factors Affecting the Profit Inefficiency of Rice Farming Solok Regency

Using Cobb Douglas Stochastic Profit Frontier Function

Variable	Coefficient	z	P>|z|
Farmer's age (M_1)	0.113	0.94	0.345
Rice farming experience (M_2)	**-0.174**	**-2.01**	**0.045**
Farmer's formal education (M_3)	**-0.706**	**-1.97**	**0.049**
Land ownership status (M_4)	7.765	1.77	0.076
Membership of farmer groups (M_5)	5.111	1.69	0.092
Ease of access to subsidized fertilizers (M_6)	-4.981	-1.63	0.104
Constant	-9.318	-1.07	0.284
Conf. interval	95%		

Based on Table 4, on the confidence level of 95% farmers' socio-economic variables affecting the inefficiency of rice farming profits in Solok Regency are farming experience (M_2) and formal education (M_3).

Farmer's age (M_1) has a coefficient value 0.113 and P>|z| value > 0.05 means farmer's age does not have a significant effect on profit efficiency, same with [27] study on the technical inefficiency of rice farming. The older the farmer's physical ability decreases, therefore it requires labor in farming [25]

Rice farming experience (M_2) has a coefficient value -0.174 means the longer farming experience the lower level of profit inefficiency of rice farming. The longer farming experience, the more efficient in managing farming and the better ability to increase productivity and profits [26]. This results same with [28] which found farming experience has a significant effect on farming income.

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Farmer's formal education (M_3) has a coefficient value of -0.706 means farmer's education has a negative effect on profit inefficiency. An increase of 1 year of farmer education will increase profit efficiency by 70.6%. This is in line with the increase in income due to the increase in farmer's education [26]. The higher the level of farmer's education, the better at adopting technological innovations and more rational in making decisions in farms. This can certainly increase productivity and farm profits.

Land ownership status (M_4) in this study is a dummy variable, valued at 1 farming on one's own land and 0 if farming on leased land. Land ownership status (M_4) has a coefficient value of 7,765 and P>|z| value (0.076) > 0.05 means land ownership status does not have a significant effect on inefficiency of rice farming profits. These results are same as the technical efficiency of rice farming [27]. There is no guarantee agriculture on its own land is more efficient and rented land is inefficient [29]

Membership of farmer group (M_5) in this study is a dummy variable, valued at 1 if the farmer is a member of farmer group and a value 0 if the farmer is not a member of farmer group. Farmer group membership doesn't have a significant effect on profit inefficiency of rice farming because the value of P>|z| > 0.05. Farmer group membership has no significant effect on the inefficiency of rice farming profits because the P>|z| > 0.05. Farmer group membership does not determine the level of efficiency of rice farming profits because the implementation of agriculture and the allocation of agricultural inputs by farmers are not determined by their membership status as a farmer group but are determined by the farmer's mindset, farming experience, and availability of agricultural capital.

Ease of access to subsidized fertilizers (M_6) is a dummy variable with a value of 1 if farmers easily access subsidized fertilizers and 0 if farmers have difficulty accessing subsidized fertilizers. Ease of access to subsidized fertilizers (M_6) has no significant effect on profit inefficiency because the value of P>|z| >0.05. The results of this study are different with [30] which found the use of subsidized fertilizers is effective in increasing agricultural profits. The allocation of fertilizers by farmers is not based on the ease of access to subsidized fertilizers but based on the experience and availability of capital. Farmers who are members of farmer groups tend to be extravagant in using fertilizers by increasing use of subsidized fertilizers with non-subsidized fertilizers. As a result, agricultural costs are high and profit efficiency of rice farming is decreasing.

IV. Conclusion

Profit of rice farming in Solok Regency is influenced by seed price, NPK Phonska fertilizer price, labor wages, equipment depreciation cost, and land rental costs. NPK Phonska fertilizer price, labor wages, and equipment depreciation cost have a negative effect on profits. Seed price and land rental cost have a positive effect on rice farming profits. Average value of profit efficiency of rice farming in Solok Regency is 0.91, means rice farming has reached 91% profit from the maximum profit limit. Rice farming experience and farmer's formal education have a positive effect on profit efficiency of rice farming in Solok Regency. Farmers' age, land ownership status, farmer group membership, and ease of access to subsidized fertilizers have no effect on profit efficiency of rice farming in Solok Regency.

V. Suggestion

Increasing profit efficiency of rice farming can be achieved by reducing the cost allocation for NPK Phonska fertilizer, labor wages, and equipment depreciation costs because the increase in value causes a decrease in rice farming profits in Solok Regency. To reduce production cost and increase profit efficiency of rice farming in Solok Regency, farmers who are members of farmer groups are expected no to overuse fertilizer even though they get subsidized fertilizers. For further research, differentiating wage variable between human labor and machine labor is recommended because the payment systems are different in rice farming activities.

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