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Environmental efficiency of semi-organic rice farming in Bantul Regency

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Abstract. The problems faced in organic rice farming is decreasing quality and fertility of land caused by the use of non-organic fertilizers or pesticides and also by climate change. This study aims to determine the environmental efficiency of semi-organic rice farming. The sampling method was purposively carried out consisting of 115 farmers from four farmer groups in Bantul Regency and had implemented semi-organic rice farming. The technical analysis used was Stochastic Frontier Translog Analysis with one input variable namely N fertilizer which was thought to be an input that could decrease environmental quality (detrimental environment input). The results showed that the coefficient value used to analyze the environmental efficiency from the Stochastic Frontier Analysis Translog is the coefficient value that interacts with N fertilizer. The environmental efficiency of semi-organic rice farming is still very low, ranging from 0.1434 to 0.6541 with an average of 0.40. This efficiency value shows that semi-organic rice production will survive or even increase by reducing 60% from the use of N fertilizer. Environmental efficiency is influenced by the use of factors of production which are detrimental to the environment, climate change (temperature changes) and water resources management.

1. Introduction

Efforts to increase rice production nationally by the government are faced various technical and non-technical challenges such as decreasing soil fertility, availability of technological facilities, and shifting the function of paddy fields. Besides paddy field production is impacted by the climate and water resources, which is driven by environmental condition and also water management [1]. The impact of global climate change can be seen from the fluctuation of main crops production yield in tropical countries, this has affected the food price fluctuations especially rice [2]. People believe that meeting the needs of national rice can be overcome by organic rice farming, both through SRI (System of Rice Intensification) and other ways of organic farming. Farmers who fully used organic material as input believed they were able to provide products that were safer for health and environment and produced higher than conventional methods [3].

Recently, there is a big change in tastes and preferences for different foods due to the globalization of food trade, increased levels of economic dependence, and cultural exchanges between the east and west world [4]. In addition, increasing income and increasing public awareness of health and healthy food are also important factors [5]. Even some consumers have a concern for the production process on agricultural land, how to care for plants and animals so that groups appear to care about the process of agricultural production and personal health [6]. In agribusiness, the development of consumption must be anticipated by producing food that meets the security standards and is environmentally friendly, namely organic food.

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Organic farming is an effort that can affect farmers both individually and collectively, to reduce the level of health and environmental risks [7]. Indonesia has established organic food standards stated in Indonesian National Standard SNI 01-6729-2002, which states that organic food is food produced by organic farming which implementing management practices aimed to maintain ecosystems and achieve sustainable productivity [8]

In 2009, around three percent of 58,000 hectares of rice fields in Yogyakarta implemented an organic system. In Bantul Regency, from 16,000 hectares of rice land, only five percent of them were organic certified [9]. Based on the area that has been cultivated, it showed that only a small portion of the potential land can be developed in capturing the opportunities of organic rice market demand. However, after experiencing success in organic rice farming, recently many farmers have not been able to survive for organic rice farming.

Economic growth and welfare of farm households depends on the level of farm income and the resulting surplus. Thus, the level of production and farm income, besides being a major determinant of the welfare of farmers' households, also emerged as one of the important factors that conditioned economic growth. The level of farm income is largely determined by the efficiency of farmers in allocating their resources into various alternative production activities. If farmers do not use these resources efficiently, there will be potential that is not / has not yet been exploited to increase farm income and create a surplus. Conversely, if farmers act efficiently in allocating their resources, then additional contribution of agricultural sector can be obtained through growth-oriented development efforts from the sector concerned.

In terms of environmental security, natural resources in Indonesia have decreased from time to time, and some have experienced damage due to uncontrolled use of resources. Such conditions have an impact on agricultural sector so that this sector is no longer able to meet food demand. The subsequent impact is the import of various food needs from other countries. Semi-organic rice farming in Bantul Regency has not fully used organic inputs (factors of production), however still uses inorganic fertilizers, although in relatively small amounts, there are still inorganic inputs that cause a decrease in environmental quality.

Environmental efficiency is defined as the ratio of the feasibility of a minimum input that is detrimental to the environment against conventional inputs at the level of observed outputs and certain technologies [10]. Environmental efficiency is the ratio of the smallest nutrient balance to the observed nutrient balance [11]. Several studies on environmental efficiency have been studied using the method of analyzing the production function model of the stochastic frontier trans-log on commodities that use inorganic production factors that can damage the environment [10][12]. This study uses stochastic frontier trans-log production function, but for semi-organic rice commodities which are actually relatively safe for the environment, this study therefore proves whether this organic rice has been efficiently seen from its environmental safety. The purpose of this study is to analyze the environmental efficiency of semi-organic rice farming in Bantul regency.

This research is expected to be taken as consideration in formulating agricultural development policies through environmental efficiency. The results of this study are expected to be a sustainable development of semi-organic rice farming by taking into account the environmental potential of local resources owned.

2. Methods

This research was carried out in Bantul Regency with the consideration that the district had been a pilot project for the organic rice farming system and several farmer groups that produced certified organic rice. Respondents were semi-organic rice farmers, namely farmers who practice organic rice farming but use inorganic fertilizers to a minimum and do not use chemical pesticides. Sampling uses a purposive sampling method, namely in the districts of Imogri, Pandak and Sewon with 93 respondents.

Technical analysis of environmental efficiency starts from the Stochastic frontier Analysis translog, the estimation results of the production function are used to find out the interaction of 2 variables, one of which is the N fertilizer variable which is the input that is thought to cause environmental degradation.

Environmental efficiency is used to see multiple variables that result in a decrease in environmental quality. The translog stochastic frontier production function model is as follows:

$$\text{Ln } Y_{it} = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + ... + \beta_7 \ln Z_7 + 0,5\beta_{11}\ln^2 X_1 + 0,5\beta_{22}\ln^2 X_2 + 0,5\beta_{33}\ln^2 X_3 + ... + 0,5\beta_{77}\ln^2 Z_7 + \beta_{12}\ln X_1 \ln X_2 + \beta_{13}\ln X_1 \ln X_3 + ... + \beta_{17}\ln X_1 \ln Z_7 + \beta_{23}\ln X_2 \ln X_3 + \beta_{24}\ln X_2 \ln X_4 + ... + \beta_{27}\ln X_2 \ln Z_7 + \beta_{34}\ln X_3 \ln X_4 + \beta_{35}\ln X_3 \ln X_5 + ... + \beta_{37}\ln X_3 \ln Z_7 + \beta_{45}\ln X_4 \ln X_5 + \beta_{46}\ln X_4 \ln Z_6 + ... + \beta_{47}\ln X_4 \ln Z_7 + \beta_{56}\ln X_5 \ln X_6 + \beta_{57}\ln X_5 \ln Z_7 + \beta_{67}\ln X_6 \ln Z_7 + (u - v) \text{ ....} \quad (1)$$

It means:
Y = Semi-organic rice production (kg) X1 = Land area (hectare)
X_2 = Seed (kg)
X_3 = Organic Fertilizer (kg)
X_4 = anorganic Fertilizer (Rp)
X_5 = Labor (hko)
X_6 = Organic Pesticide value (Rp)
Z_7 = Fertillizer N (kg)
(u – v) = *error term*
v = External variable
u = inefficienci

Based on translog forntier production function in equation 1, the environmental efficiency analysis can be performed using the Maximum Likelihood method. The use of detrimental input in production function in equation 2, namely Z, can be replaced with ΦZ such that the technical inefficiency of rice farming approaches zero (u = 0). The notation Φ is called the environmental efficiency index. Thus the new translog production function is:

$$\text{Ln } Y_{it} = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + ... + \beta_7 \ln \Phi Z_7 + 0,5\beta_{11}\ln^2 X_1 + 0,5\beta_{22}\ln^2 X_2 + 0,5\beta_{33}\ln^2 X_3 + ... + 0,5\beta_{77}\ln^2 \Phi Z_7 + \beta_{12}\ln X_1 \ln X_2 + \beta_{13}\ln X_1 \ln X_3 + ... + \beta_{17}\ln X_1 \ln \Phi Z_7 + \beta_{23}\ln X_2 \ln X_3 + \beta_{24}\ln X_2 \ln X_4 + ... + \beta_{27}\ln X_2 \ln \Phi Z_7 + \beta_{34}\ln X_3 \ln X_4 + \beta_{35}\ln X_3 \ln X_5 + ... + \beta_{37}\ln X_3 \ln \Phi Z_7 + \beta_{45}\ln X_4 \ln X_5 + \beta_{46}\ln X_4 \ln X_6 + ... + \beta_{47}\ln X_4 \ln \Phi Z_7 + \beta_{56}\ln X_5 \ln X_6 + \beta_{57}\ln X_5 \ln \Phi Z_7 + \beta_{67}\ln X_6 \ln \Phi Z_7 + \beta_{67}\ln \Phi X_6 \ln \Phi Z_7 + (u-v) \text{.....} \quad (2)$$

This study only examined one input of environmental detrimental variables (inputs that lead to environmental degradation), namely N fertilizer (Z7). By subtracting equation 1 from equation 2 we get the following equation:

$$0,5\beta_{77}[\ln \Phi Z - \ln Z]^2 + [\beta_7 + \beta_{17}\ln X_1 + \beta_{27}\ln X_2 + \beta_{37}\ln X_3 + \beta_{47}\ln X_4 + \beta_{57}\ln X_5 + \beta_{67}\ln X_6 + \beta_{77}\ln Z_7][\ln \Phi Z - \ln Z] + u = 0 \text{ .....} \quad (3)$$

Since $\ln EL = \ln \Phi Z - \ln Z = \ln(\Phi Z/Z) = \ln \Phi$, then equation 3 is modified as follows:

$$0,5\beta_{77}[\ln EL]^2 + [\beta_7 + \beta_{17}\ln X_1 + \beta_{27}\ln X_2 + \beta_{37}\ln X_3 + \beta_{47}\ln X_4 + \beta_{57}\ln X_5 + \beta_{67}\ln X_6 + \beta_{77}\ln Z_7][\ln EL] + u = 0 \text{.....} \quad (4)$$

Equation 4 can be solved as LnEL using the following quadratic equation:

$$\text{Ln } EL = [-[\beta_7 + \beta_{17}\ln X_1 + \beta_{27}\ln X_2 + \beta_{37}\ln X_3 + \beta_{47}\ln X_4 + \beta_{57}\ln X_5 + \beta_{67}\ln X_6 + \beta_{77}\ln Z] + \{[\beta_7 + \beta_{17}\ln X_1 + \beta_{27}\ln X_2 + \beta_{37}\ln X_3 + \beta_{47}\ln X_4 + \beta_{57}\ln X_5 + \beta_{67}\ln X_6 + \beta_{77}\ln Z_7]^2 - 2\beta_{77}U_i\}^{0,5}] / \beta_{77} \text{ ....} \quad (5)$$

The value of environmental efficiency (EL) can be estimated from the exponential value of equation 5 above.

$$EL = \exp(\ln EL) = \Phi = (\Phi Z / Z) \text{ .....} \quad (6)$$

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3. Results and discussion

3.1. Production function stochastic frontier analysis translog

Stochastic frontier analysis (SFA) translog production function is one of the methods used to analyze environmental efficiency. This translog production function calculates the relationship or interaction between factors of production. Analysis of translog production function is used since this function has advantages [13] among others. The translog production function can be used for second- order approach of homogeneous linear production so that in order to estimate substitution elasticity and estimate frontier production.

The estimation results of the production function of the stochastic frontier analysis Translog of semi-organic rice production in table 1 shows that based on the parameter σ2 is valued at 0.0280 and significant at 1% error means that the variation of semi-organic rice production originating from the inefficiency effect (ui) and external effects (vi) of 0.0295 or 2.95%. Estimating the second parameter is the gamma value (γ) which is the ratio of the deviation of the inefficiency effect to the deviation that might be caused by an external effect. The gamma value (γ) in semi-organic rice farming is 0.9888 and significant at 1% error means that 98% of the errors in the semi-organic rice production function are caused by inefficiency effects and the rest or 2% is caused by external effects.

Table 1. The estimation results of the production function of the stochastic frontier analysis Translog of semi-organic rice production

Variable	Coefficien	t-ratio	Variable	Coefficien	t-ratio
Konstanta	44,785***	3,9803	x_1- x_5	-0,0281	-0,1935
Land area (x_1)	0,2672	0,2918	x_1-x_6	-0,0082	-0,5042
Seed (x_2)	- 1,2025	1,2472	x_1-z_7	-0,4726*	-1,6502
Organic Fertilizer (x_3)	1,5172***	2,6833	x_2- x_3	-0,5142	-1,1830
Anorganic Fertilizer (x_4)	-0,1393*	-1,7158	x_2-x_4	-0,0034	-0,1356
Labor (x_5)	0,6621	0,5144	x_2-x_5	0,0503	0,1278
Organic Pesticide (x_6)	0,0529	0,2066	x_2-x_6	0,0266	0,6627
N Fertilizer (z_7)	-2,8046***	-4,1443	x_2-z_7	0,2076**	2,1529
x_1- x_1	0,0145	1,2514	x_3-x_4	0,0229	0,7297
x_2- x_2	0,3136	0,9616	x_3-x_5	-0,1008	-0,2890
x_3-x_3	0,0570	0,4396	x_3-x_6	-0,0216	-1,1052
x_4- x_4	-0,0126	-1,3584	x_3-z_7	0,0959	0,2351
x_5- x_5	0,0011	0,0119	x_4-x_5	-0,0116	-0,6358
x_6- x_6	0,0051*	1,6610	x_4-x_6	-0,0007	-0,1183
z_7- z_7	0,1375	0,1465	x_4-z_7	-0,0029	-0,0611
x_1 -x_2	-0,4394	-0,5075	x_5-x_6	-0,0012	-0,0720
x_1- x_3	0,5988***	3,4561	x_5-z_7	0,0736*	1,6660
x_1- x_4	-0,0377	-0,7723	x_6-z_7	0,0066	0,2023
σ^2	0,0280***	6,3404			
γ	0,9788***	6,1180			

Based on Table 1 it is known that there are 8 factors of production that significantly influence to the production of semi-organic rice as indicated by the value of t arithmetic greater than t table at an error rate of 1% (2.6188), 5% (1.9806) and 10 % (1.6580). Organic fertilizer production factors, N fertilizer and anorganic fertilizer. Besides semi-organic rice production is influenced by the main production factors, semi-organic rice production is also influenced by land interactions with organic fertilizers, seed interactions with organic fertilizers, interactions of organic pesticides with organic pesticides, land interactions with N fertilizers and labor interactions with N fertilizers.

The regression coefficient value in the translog production function is not an input elasticity value whose magnitude can be known directly as in the Cobb-Douglas production function [14]. The results

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of the estimation of the translog production function can only determine the increase or decrease in production factors for semi-organic rice production.

The constant results of the estimation of the translog production function in Table 1 have a positive and significant effect on an error rate of 1%, this shows that if all semi-organic rice production factors are in a ceteris paribus state, semi-organic rice production is 44.7852 kg per 0.17 hectare of land.

The most important production factor in semi-organic rice farming is organic fertilizer. Organic fertilizer coefficient showed positive and significant effect on an error rate of 1%, meaning that the addition of organic fertilizer will increase semi-organic rice production. Inorganic fertilizer production factors have coefficient values that negatively affect semi-organic rice production at an error rate of 10%. Increasing the use of inorganic fertilizer production factors will reduce the production of semi-organic rice. Fertilizer N which is considered as one of the detrimental environment inputs has a negative effect and significantly at an error rate of 1%. The effect of N fertilizer on semi-organic rice production has a negative effect, namely the addition of N fertilizer production factors will reduce semi-organic rice production and reduce environmental quality.

The interaction of organic pesticides with organic pesticides has a positive and significant coefficient at an error rate of 10%, meaning that the addition of organic pesticides in large quantities will further increase semi-organic rice production. The coefficient of land interaction with organic fertilizer has a positive and significant value at an error rate of 1%, meaning that an increase in land area can increase production, if there is an interaction in the addition of organic fertilizer production factors, then semi-organic rice production will increase. The interaction of land and N fertilizer has a regression coefficient marked negative. The interaction value of the factor of production is significant at an error rate of 10%, meaning that the addition of land area increases the production of semi-organic rice, but the addition of N fertilizer will reduce the production of semi-organic rice. Similar to the interaction of seed production factors with significant N fertilizer at a 5% error rate of land, the addition of seed production factors will increase semi-organic rice production but with the addition of N fertilizer, semi- organic rice production will decrease. Labor interaction with N fertilizer has a positive effect on semi- organic rice at an error rate of 10%. The effect of labor interaction with N fertilizer is not as expected. Actually, the interaction with N fertilizer will reduce the production of semi-organic rice but the results of this study increase the production of semi-organic

3.2. Environmental efficiency of semi-organic rice farming

The environmental efficiency of semi-organic rice farming in Bantul Regency, accordance to other study regarding the use of Nitrogen fertilizer input variable which is considered to potentially pollute and damage the environment (detrimental environment input)[10]. The calculation of environmental efficiency uses the β coefficient values obtained from the stochastic frontier translog production function in Table 1. The β coefficient value used is the β value that only interacts with nitrogen fertilizer (z), namely βz (N fertilizer), β1z (land-N fertilizer), β2z (N-fertilizer seeds), β3z (organic fertilizer-N fertilizer), β4z (inorganic fertilizer-N fertilizer), β5z (labor-fertilizer N), β6z (organic pesticide-N fertilizer) and βzz (N fertilizer -P fertilizers N).

Based on Table 2, environmental efficiency values of semi-organic rice farming range from 0.07 to 0.89. The largest distribution of efficiency values or 35% of farmers who have environmental efficiency is 0.07 to 0.25 and 62.37% of farmers have environmental efficiency less than 0.45 or below the average (0.40). This condition shows that semi-organic rice farmers still use a lot of fertilizer and do not understand the importance of being environmentally friendly by trying to minimize the use of N fertilizers and optimizing the use of organic fertilizers and organic pesticides to get the expected semi-organic rice production.

Table 2. Distribution of Environmental Efficiency of Semi-organic Rice Farming in Bantul Regency Environmental

Efficiency	Amount	Percent (%)	Cumulative percent (%)
0,07-0,25	33	35,48	35,48
0,26-0,44	25	26,88	62,37
0,45-0,63	14	15,05	77,42
0,64-0,82	14	15,05	92,47
>0,83	7	7,53	100
Total	93	**100**	
Mean	**0.40**		

Average environmental efficiency was 0.40. This value indicates that semi-organic rice production will be able to survive or even increase if the use of N fertilizer which is considered as an input that can damage the environment must be reduced by 60%. Reducing the use of N fertilizer is expected to contribute significantly to improvement and development of semi-organic rice farming in term of rice production and costs reduction.

The use of N-fertilizer is a step to provide fertilizer in accordance with crop needs, since rice could absorb nutrients optimally and reduce the level of N loss due to accumulation of N in the soil layer [15]. The value of environmental efficiency in this study is still higher than other research concerning shallots in Nganjuk Regency which showed average level of environmental efficiency of shallot farmers is 0.2765 [16].

The low value of environmental efficiency is not only influenced by the use of factors of production that are safe for the environment or can reduce environmental quality, it is also influenced by climate change (the temperature changes) and water resource management. The climate changes (the temperature changes) would affect negatively the paddy production in Indonesia both in the shortrun and long run. However, the temperature changes would positively influence the rice price fluctuation in Indonesia [2]. The good water management on flood impact is required to mitigate the negative impact of the future climate and secure the future paddy field production [1].

4. Conclusion

N Fertilizer is an input that could reduce environmental quality. Inputs that interact with N fertilizer and could reduce semi-organic rice production were seeds and fertilizers. The environmental efficiency value of organic rice farming is 0.40, in order to increase semi-organic rice production, the use of N fertilizer must be reduced by 60%. The reduction in the use of N fertilizer is expected to contribute significantly to semi-organic rice farming which not only increasing semi-organic rice production, but also improve soil fertility and the environment. Environmental efficiency is influenced by the use of factors of production which are detrimental to the environment, climate change (temperature changes) and water resources management.

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